Public Health Assessment for

CORPUS CHRISTI REFINERIES (SITE WIDE ACTIVITIES)
(A/K/A CORPUS CHRISTI REFINERY ROW)
CORPUS CHRISTI, NUECES COUNTY, TEXAS

AUGUST 29, 2016

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

Comment Period Ends:

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THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment-Public Comment Release was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate. This document represents the agency's best efforts, based on currently available information, to fulfill the statutory criteria set out in CERCLA section 104 (i)(6) within a limited time frame. To the extent possible, it presents an assessment of potential risks to human health. Actions authorized by CERCLA section 104 (i)(11), or otherwise authorized by CERCLA, may be undertaken to prevent or mitigate human exposure or risks to human health. In addition, ATSDR will utilize this document to determine if follow-up health actions are appropriate at this time.

This document has previously been provided to EPA and the affected state in an initial release, as required by CERCLA section 104 (i) (6) (H) for their information and review. Where necessary, it has been revised in response to comments or additional relevant information provided by them to ATSDR. This revised document has now been released for a 60-day public comment period. Subsequent to the public comment period, ATSDR will address all public comments and revise or append the document as appropriate. The public health assessment will then be reissued. This will conclude the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

Agency for Toxic Substances & Disease Registry..Thomas R. Frieden, M.D., M.P.H., Administrator
Patrick N. Breysse, Ph.D., CIH, Director

Division of Community Health Investigations…..Ileana Arias Ph.D., Director
Tina Forrester, Ph.D., Deputy Director

Central Branch.………………………………………………………………………………...Richard E. Gillig, M.C.P., Chief

Eastern Branch ……………………………………………………………………...Sharon Williams-Fleetwood, Ph.D., Chief

Western Branch ………………. .... Cassandra Smith, B.S., M.S., Chief

Science Support Branch ………. ....Susan Moore, M.S., Chief

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Please address comments regarding this report to:

Agency for Toxic Substances and Disease Registry
Attn: Records Center
1600 Clifton Road, N.E., MS F-09
Atlanta, Georgia 30333

You May Contact ATSDR Toll Free at
1-800-CDC-INFO
or
Visit our Home Page at: http://www.atsdr.cdc.gov

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Prepared by:

U.S. Department of Health and Human Services
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Division of Toxicology and Human Health Sciences
Atlanta, Georgia 30333

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Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
ACS	American Cancer Society
ADHD	Attention-deficit/hyperactivity disorder
AIHA	American Industrial Hygiene Association
AMCV	air monitoring comparison value
API	Advanced Pollution Instrumentation
AQG	air quality guideline
AQI	Air Quality Index
AQP	Corpus Christi Air Quality Project
ASARCO	American Smelting and Refining Company
ATSDR	Agency for Toxic Substances and Disease Registry
Auto GC	automated gas chromatograph
BE	biomonitoring equivalent
BLL	blood lead level
BMCL	benchmark concentration lower confidence limit
BMD	benchmark dose
BMDL	benchmark dose level
BRFSS	Behavioral Risk Factor Surveillance System
Cal. EPA	California Environmental Protection Agency
CAR	Community Activity Report
CBAI	Coastal Bend Asthma Initiative
CCRR	Corpus Christi Refinery Row
CDC	Centers for Disease Control and Prevention
CEL	cancer effect level
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended
CFR	Code of Federal Regulations
CI	confidence interval
CL	confidence limit
CMSA	consolidated metropolitan statistical area
CNS	central nervous system
COPD	chronic obstructive pulmonary disease
CPF	conditional probability function
CREG	cancer risk evaluation guide
CSF	cancer slope factor

CV	health-based comparison value
DCHP	Driscoll Children's Health Plan
DHHS	U.S. Department of Health and Human Services
DL	detection limit
DPNA	Dona Park Neighborhood Assessment
DSHS	Texas Department of State Health Services
ECHO	Enforcement and Compliance History Online
EJ IWG	Environmental Justice Interagency Working Group
EMEG	environmental media evaluation guide
$^{acute}ESL_{odor}$	acute odor-based effects screening level
EI	exposure investigation
ESL	effects screening level
FDA	Food and Drug Administration
FID	flame ionization detector
GC/MS	gas chromatography with mass spectrometry
GIS	Geographic Information System
GM	geometric mean
GRAS	generally recognized as safe
GRASP	Geospatial Research, Analysis & Services Program
G/U	genitourinary
HCEI	Hillcrest Community Environmental Investigation
HEAST	Health Effects Assessment Summary Tables
HEC	human equivalent concentration
HF	hydrogen fluoride
HI	hazard index
HPV	high production volume
HQ	hazard quotient
hr	hour
H_2S	hydrogen sulfide
IARC	International Agency for Research on Cancer
IRIS	Integrated Risk Information System
IUR	inhalation unit risk
Kg	kilogram
KM	Kaplan-Meier
lb	pound
LCL	lower confidence limit
LEPC	Local Emergency Planning Committee

LOAEL	lowest-observed-adverse-effect-level
m^3/day	cubic meters per day
µg/dL	micrograms per deciliter
µg/m^3	micrograms per cubic meter of air
MGD	million gallons of wastewater per day
mg/L	milligrams per liter
mg/kg	milligrams per kilogram
MMT	Mobile Monitoring Team
MRL	minimal risk level
MW	molecular weight
N	total number
NA	not available
NAAQS	National Ambient Air Quality Standards
NATA	National-Scale Air Toxics Assessment
NCEA	National Center for Environmental Assessment
NCEH	National Center for Environmental Health
NCI	National Cancer Institute
ND	not detected
NEI	National Emissions Inventory
NGLs	natural gas liquids
ng/m^3	nanograms per cubic meter
ng/mL	nanograms per milliliter
NHANES	National Health and Nutrition Examination Survey
NIOSH	National Institute for Occupational Safety and Health
NOAEL	no-observed-adverse-effect-level
NR	not ranked
NTD	neural tube defect
NTP	National Toxicology Program
OEHHA	Office of Environmental Health Hazard Assessment
OEJTA	Office of Environmental Justice and Tribal Affairs
OSHA	Occupational Safety and Health Administration
OSRTI	Office of Superfund Remediation and Technology Innovation
PAH	polycyclic aromatic hydrocarbon
PBPK	physiologically-based pharmacokinetic
PCL	protective concentration level
PEL	permissible exposure limit
PM	particulate matter

$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
PM_{10}	particulate matter less than 10 microns in diameter
POD	point of departure
ppb	parts per billion
ppm	parts per million
PPRTV	Provisional Peer Reviewed Toxicity Values
PVC	polyvinyl chloride
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RDA	recommended daily allowance
REL	reference exposure level
ReV	reference value
RfC	reference concentration
RfC – H	reference concentration – Health Effects Assessment Summary Tables
RfC – I	reference concentration – Integrated Risk Information System
RfC – P	reference concentration – Provisional Peer Reviewed Toxicity Values electronic library
RfD	reference dose
RHAB	Regional Health Awareness Board
ROS	regression on order statistics
RTGC	real-time gas chromatography
SARA	Superfund Amendment and Reauthorization Act
sd	standard deviation
SID	sudden infant death syndrome
SL	target risk screening level
SL – C	target risk screening level – California Environmental Protection Agency
SL – I	target risk screening level – Integrated Risk Information System
SL – P	target risk screening level – Provisional Peer Reviewed Toxicity Values electronic library
SMR	steam methane reformer
SO_2	sulfur dioxide
SOP	standard operating procedure
STEL	short-term exposure limit
STP	standard temperature and pressure
SVI	Social Vulnerability Index
SVOC	semi-volatile organic compound
TACB	Texas Air Control Board

TACP	Texas Asthma Control Program
TAMIS	Texas Air Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TCR	Texas Cancer Registry
TDH	Texas Department of Health
TLV	threshold limit value
TNMHC	total non-methane hydrocarbons
TNRCC	Texas Natural Resources Conservation Commission
TPH	total petroleum hydrocarbons
TR	target risk level
TRI	Toxics Release Inventory
TSP	total suspended particulates
TWA	time weighted average
UCL	upper confidence limit
UF	uncertainty factor
URF	unit risk factor
U.S. EPA	U.S. Environmental Protection Agency
UT	The University of Texas
VCCEP	Voluntary Childrens Chemical Evaluation Program
VOC	volatile organic compound
WHO	World Health Organization
WWTP	Waste Water Treatment Plant
XRF	x-ray fluorescence

1. Executive Summary

Introduction

The Agency for Toxic Substances and Disease Registry (ATSDR), a federal public health agency, is involved in public health activities in Corpus Christi, Nueces County, Texas. This Corpus Christi report determines whether chemicals detected in outdoor air along "Refinery Row" — an area near Corpus Christi's north end — are or have been at levels potentially high enough to cause harm to the health of area residents.

Refineries and petrochemical facilities in Northern Corpus Christi release chemicals into the outdoor air through stack emissions, general maintenance, startups and shutdowns, and accidental releases. Other sources in the area, such as cars, trucks, trains, barges, gas stations, and dry cleaners, also release chemicals to the outdoor air. Because air is not contained, people living, working, and visiting in the Refinery Row area come in contact with chemicals when breathing the air.

Refinery Row consists of about 10 miles of petrochemical facilities, bordered by residential neighborhoods. Because air pollution can be harmful to human health when it accumulates in the air in high enough levels, area residents have long been concerned about the potential dangers of breathing chemicals released from industrial activities at Refinery Row. In 2003, ATSDR agreed to evaluate the residents' concerns about pollutants in the outdoor air.

To accurately define the air quality of Refinery Row, ATSDR compiled several years of air monitoring data. ATSDR gathered available air pollution data from the following Refinery Row stationary air monitoring programs:

- Corpus Christi Air Quality Project (AQP) network from 2005–2010,
- Industry network from 1996–2010, and
- Texas Commission on Environmental Quality (TCEQ) network from 1980–2010.

ATSDR also reviewed air data from 24 Refinery Row-area mobile monitoring events that occurred between July 1993 and March 2008. In this report, "air data" refer to ambient (i.e., outdoor) air data.

ATSDR's report focused on the stationary and mobile air data, but the agency completed several additional activities as part of the public health evaluation process. For example, the agency compared concurrent data from the three networks, which used different measurement devices and analytical methods, to evaluate data quality. ATSDR's trend analyses allowed the agency to describe the temporal, seasonal, and geographic trends that influence chemical air levels along Refinery Row.

Conclusions

After reviewing more than 150 chemicals detected in Refinery Row outdoor air, ATSDR reached two health-based conclusions.

Conclusion 1

Short-term exposure risk: Benzene, hydrogen sulfide, particulate matter, and sulfur dioxide in Refinery Row outdoor air rarely reached levels associated with harmful acute health effects. On those rare occasions, ATSDR concludes that breathing the maximum levels measured of these compounds in the past and present in air could potentially harm people's health, especially sensitive populations such as children, older adults, and those with preexisting health conditions.

Basis for Decision 1

- **Benzene**: The ATSDR acute benzene health-based comparion value (CV)[1] was exceeded in 2.7% of the samples from stationary air monitors and in 35% of the samples from mobile monitors. One stationery monitor (Huisache) and several mobile monitors found that maximum benzene levels rarely approach and exceed health effect levels. At the highest levels detected, benzene could potentially cause respiratory irritation and a decrease in various types of blood cells.

  ATSDR notes that the Huisache stationary air monitor is in a sparsely populated area, and the mobile monitors recording the highest levels were on or near facility boundaries. Therefore, workers and people walking, running, and biking near the facilities and the ship channel are more likely to be the ones who might, on rare occasions, be exposed to these higher levels of benzene.

- **Hydrogen Sulfide**: Twenty-five out of 349,528 (0.007%) stationary air monitoring samples exceeded the ATSDR acute hydrogen sulfide CV. Hydrogen sulfide exceeded its acute CV in 16% of the mobile monitoring samples.

  Two stationery monitors (Huisache and JI Hailey) and several mobile monitors found maximum hydrogen sulfide levels that are at and approaching health effect levels. These maximum levels of hydrogen sulfide in Refinery Row air, although rare, indicate levels that could potentially cause respiratory effects in people with asthma. The Huisache monitor is in a sparsely populated area,

[1] Health-based comparison values (CVs) are estimates of daily human exposure to a chemical that is not likely to result in harmful health effects over a specified exposure duration, which are acute (1-14 days), intermediate (15-364 days), and chronic (365 days and longer). Although concentrations at or below a CV represent low or no risk, concentrations above a CV are not necessarily harmful.

whereas JI Hailey is to the north of Refinery Row and not near any homes. Workers and people walking, running, and biking near the facilities and the ship channel are more likely to be the ones who might, on rare occasions, be exposed to these higher levels of hydrogen sulfide.

ATSDR also found that the community concern about recurring odors throughout Refinery Row may be associated with hydrogen sulfide in the air. All stationary air monitors and mobile monitors found hydrogen sulfide regularly above its lowest odor threshold, which can lead to odor-related health symptoms, such as eye irritation, headaches, cough, difficulties in breathing, negative mood states, and stress or annoyance.

- **Particulate Matter**: Air samples were tested for two types of particulate matter (PM)
    - PM_{10} – particles smaller than 10 microns in diameter
    - $PM_{2.5}$ – particles smaller than 2.5 microns in diameter

ATSDR found that PM_{10} 24-hour concentrations are below U.S. Environmental Protection Agency's (U.S. EPA) National Ambient Air Quality Standards (NAAQS) and therefore are not expected to harm people's health.

Only two $PM_{2.5}$ 24-hour concentrations in Refinery Row air (specifically, pre-2005 maximum concentrations found at the Huisache and Navigation air monitoring sites) were above U.S. EPA's NAAQS[2]. The Huisache monitor currently operates in a sparsely populated area, whereas the Navigation monitor operated in the past in a residential neighborhood.

The U.S. EPA has an Air Quality Index (AQI) online tool known as "AIRNow AQI Calculator," which can be used to estimate potential health effects from known 24-hour levels of $PM_{2.5}$. Using this online AQI calculator, ATSDR found that the maximum $PM_{2.5}$ air concentrations along Refinery Row in the past, although rare, are numerically above NAAQS and represent an increased likelihood of respiratory and cardiopulmonary symptoms in sensitive people, especially those with heart or lung diseases, children, and older adults. Although current $PM_{2.5}$ levels are below NAAQS, the data are limited because only two stationary air monitors along Refinery Row currently monitor $PM_{2.5}$ levels.

[2] ATSDR evaluated whether the measured levels of particulate matter were numerically above the NAAQS and did not evaluate the data using the statistical approach used by U.S. EPA under its regulatory authority.

- **Sulfur Dioxide**: This chemical exceeded the ATSDR acute CV in 1.5% of the stationary air monitoring samples and 44% of the mobile monitoring samples. From 1996–2010, maximum sulfur dioxide concentrations from the 5-minute and 1-hour averaged stationary air data, as well as from the mobile monitors, infrequently approached and exceeded health effect levels. Therefore, short-term exposures to the highest concentrations of sufur dioxide measured in Refinery Row air, although rare, indicate levels that could potentially cause harmful respiratory health effects in people with asthma or other related preexisting conditions, children, and older adults during times of elevated inhalation rates (e.g., breathing harder during exercise).

  Before 1996, maximum sulfur dioxide concentrations—although detected rarely during mobile monitoring events—suggested the potential to cause harmful health effects in the general population (including healthy persons without asthma or other conditions that might increase sulfur dioxide exposure susceptibility). Such effects are temporary and would have gone away when not breathing those former maximum sulfur dioxide levels (i.e., after the exposure ended.)

- **Chemical Mixtures**: Although the science of evaluating chemical mixtures is still evolving and many uncertainties exist in any chemical mixtures evaluation, ATSDR assumes that pollutants with similar effects will have an additive dose. Thus, short-term simultaneous exposure to the maximum levels of benzene, hydrogen sulfide, particulate matter, and sulfur dioxide in Refinery Row air could potentially lead to a combined acute respiratory health effect greater than that of the individual compounds. Exposure to mixtures of these compounds could lead to temporary respiratory effects such as nose and throat irritation and shortness of breath; and neurological effects such as headaches and other effects related to odors in the community. Note that simultaneous exposure to the maximum levels of these compounds was not observed in the available air monitoring data.

- **Limitations**: ATSDR notes limitations in its evaluation of short-term exposures, such as that some chemicals only had experimental (animal) health effects studies available and not epidemiological (human) studies. The agency also notes that the stationary monitoring data may not capture all of the releases the community experiences because these data are not available for all pollutants, over all time frames, and across all locations of interest. However, ATSDR believes the locations of the current

	monitors provide good coverage, especially when combined with the mobile monitoring data.
Conclusion 2	**Long-term exposure cancer risk:** ATSDR concludes long-term exposure to the average levels of benzene, cadmium, chromium, 1,2-dibromoethane, and naphthalene results in a low additional risk of cancer (i.e., the chance of getting cancer from breathing each chemical alone is low). ATSDR estimates that breathing a mixture of chemicals found in Refinery Row outdoor air for many years increases the risk of cancer. **Long-term exposure noncancer risk**: ATSDR concludes that long-term exposure to the average levels of chemicals detected in Refinery Row air is not expected to cause harmful noncancer health effects.
Basis for Decision 2	• **Individual Pollutants Cancer Risk**: ATSDR estimated the proportion of a population that may be affected by a carcinogen during a lifetime of exposure. The cancer risk estimates benzene, cadmium, chromium, 1,2-dibromoethane, and naphthalene were each at least 1 additional case of cancer per 100,000 persons. These estimates are within U.S. EPA's target risk range[3] and exposure to each chemical alone results in a low additional risk of cancer. Long-term benzene exposure had the highest calculated cancer risk of these carcinogens. ATSDR notes that benzene concentrations are influenced by wind conditions and time of day, and increase with proximity to the Huisache stationary air monitor. Therefore, neighborhoods such as Oak Park, Dona Park, and Hillcrest may have higher concentrations of benzene, depending on wind direction. Overall trends show benzene levels have dropped over the years. • **Chemical Mixtures Cancer Risk:** Assuming additive effects, the cumulative cancer risk estimate for Refinery Row is the sum of the individual chemical risk estimates. The main contributors to cumulative cancer risk in Refinery Row air are benzene (31%), 1,2-dibromoethane (26%), and chromium (11%). The cumulative cancer risk for a mixture of Refinery Row chemicals is 1.8×10^{-4} (or about 2 additional cancer cases per 10,000 people). Thus, breathing a mixture of chemicals found in outdoor air for many years results in an increased risk of cancer. • **Individual Pollutants Noncancer Risk:** Long-term exposures to the average concentrations of chemicals detected in Refinery Row outdoor air were and are below levels known to cause noncancer

[3] For carcinogens, U.S. EPA's target risk range is between 10^{-4} (1 in 10,000) and 10^{-6} (1 in 1,000,000).

health effects in humans or animals. Therefore, breathing air over the long-term containing these chemicals is not expected to cause harmful noncancer health effects.

- **Limitations**: ATSDR notes limitations in its estimates that likely overestimate the cancer risk for some chemicals, such as that 1) cadmium and 1,2-dibromoethane were detected in less than 20% of the samples so an average concentration could not be used in the calculations[4], and 2) only total chromium levels were available (not the more harmful hexavalent chromium levels) for the cancer estimates[5]. The chemical mixtures estimate assuming additive effects likely overestimates cancer risk because different contaminants may cause cancers to different areas of the body via different mechanisms. Other limitations could lead to an underestimation of cancer risk, such as the lack of routine monitoring of polycyclic aromatic hydrocarbons (PAHs) that are carcinogens and could have increased the cumulative cancer risk estimate if data had been available.

Other Findings

ATSDR evaluated health outcome data for the Corpus Christi Refinery Row area, including asthma hospitalization and birth defect rates. The Texas Department of State Health Services (DSHS)[6] evaluated several types of cancers in the Corpus Christi Refinery Row area.

- **Asthma Hospitalizations**: ATSDR found that Nueces County has a higher rate of asthma hospitalizations among children than Texas as a whole. ATSDR's air evaluation found that exposure to benzene, hydrogen sulfide, particulate matter, and sulfur dioxide detected in Refinery Row air indicated levels which, although infrequent, could potentially result in respiratory health effects in susceptible populations, like people with asthma or other related respiratory illnesses.
- **Birth Defects**: ATSDR looked at 63 birth defects to see whether these defects were more common in children of mothers living within 2 miles of Refinery Row compared with children of mothers living 10 or more miles away[7]. Although these types of comparisons cannot be used to directly link birth defects to

[4] The highest 95th percentile, which is generally a more conservative (health protective) value than the average, was used to estimate chronic exposure risk.

[5] Although hexavalent chromium is believed to be a fraction of the total chromium measured, to arrive at the most conservative risk estimates, ATSDR treated the total chromium measured in Refinery Row air as hexavalent chromium.

[6] Referred to throughout this public health assessment as "Department of State Health Services" (DSHS).

[7] Refers to children of mothers living more than 10 miles from Refinery Row but still within the tri-county (Nueces, San Patricio, and Kleberg) Corpus Christi area.

chemicals found in the air, they can help health agencies focus on prevention efforts. Overall, ATSDR found that 2 heart defects (ventricular septal defect and “other anomalies of the aorta”) were slightly more common in children who lived near Refinery Row. These birth defect increases could be by chance or caused by other risk factors unavailable for review in this analysis.

- **Cancer**: Comparisons based on statewide cancer rates show the number of male colon and rectum, bladder, kidney, and liver cancer cases reported for the Corpus Christi Refinery Row area[8] was statistically greater than expected. Although benzene is associated with one of the elevated types of cancer (i.e., liver cancer), ATSDR cannot determine if these increases are due to air pollution from industries along Refinery Row. No increase in cancer rates was observed in women.
- **Limitations**: ATSDR’s air data evaluation and health outcome data evaluation cannot determine whether air pollutants in the Corpus Christi Refinery Row area caused any observed increases in health problems. The available data do not include a measure of an individual’s actual exposure to Refinery Row pollutants.

Next Steps

Based on its review of available information, ATSDR recommends that

1. Stationary and mobile monitoring efforts by industry, The University of Texas (UT), and TCEQ continue to track chemical levels in Refinery Row ambient air.
2. Routine stationary monitoring programs consider adding PAHs to the chemicals tracked in Refinery Row ambient air.
3. Refinery Row area facilities consider using the best available pollution control technology to reduce point-source chemical releases into the air, as well as promote innovative ideas to further reduce fugitive air emissions, especially for pollutants identified as posing an increased noncancer or cancer risk to area residents.
4. Local organizations and government agencies continue to develop and promote asthma education and distribute asthma information to area residents.

[8] The Corpus Christi Refinery Row area for the cancer rate analyses is defined by ZIP codes 78401, 78402, 78404, 78405, 78406, 78407, 78408, 78409, 78410, 78411, 78416, 78417 and 78370, which approximates a 5-mile buffer surrounding Refinery Row.

	5. DSHS continue plans to monitor Corpus Christi area birth defects and to work with local organizations to develop community intervention strategies. 6. DSHS continue plans to update its cancer investigation as more recent data become available. 7. U.S. EPA continue conducting research on environmental exposures and birth defects.
For More Information	Call ATSDR at 1-800-CDC-INFO and ask for information on the Corpus Christi Refinery Row site, or visit the agency's site-specific webpage at http://www.atsdr.cdc.gov/sites/corpuschristi/.

2. Statement of Issues

The Agency for Toxic Substances and Disease Registry (ATSDR) has been involved in public health activities in and near the southeastern Texas City of Corpus Christi.

Near Corpus Christi's north end is an area most often referred to as "Refinery Row"—approximately 10 miles of petrochemical facilities bordered by residential neighborhoods. In 2003, ATSDR agreed to evaluate community health concerns about air emissions from the Refinery Row area petrochemical facilities. ATSDR has included its evaluations in this report, referred to here as the "Corpus Christi report."

This Corpus Christi report determines whether pollutants detected in ambient (i.e., outdoor) air along Refinery Row are or have been at levels potentially high enough to affect the health of residents in nearby neighborhoods.

3. Background Information

The City of Corpus Christi is a coastal community located in southeastern Texas (see Figure 1A, Appendix A). The Refinery Row area is toward the north end of the city and consists of approximately 10 miles of petrochemical facilities. These facilities are bordered by residential neighborhoods.

3.1. Demographic and Other Statistics

Using 2010 Census of Population and Housing data and an area-proportion spatial analysis technique, ATSDR calculated that 21,684 persons reside within 1 mile of the Refinery Row industrial corridor [US Census Bureau 2010]. Of these, about 74% were white and about 10% black. Approximately 68% identified themselves as Hispanic or Latino. Within the 1-mile boundary, the demographic statistics identify residents' ages as approximately 13% being 65 and older and 10% being children 6 years or younger. Using the same area-proportion spatial analysis technique, ATSDR calculated that 53,085 persons reside within 2 miles of the Refinery Row industrial corridor. Additional demographic data are contained in

- Figure 2A, Appendix A. Additional demographic data regarding persons who live within the ATSDR-defined industrial corridor 1-mile and 2-mile boundaries.
- Figure 3A, Appendix A. Population density by census block for the Refinery Row area. Sparsely populated areas are south of Interstate 37 (I-37) along some sections of the industrial corridor. Densely populated areas, shown as darker green on this figure, are mostly to the west and southeast of the main industrial corridor. Overall, this figure highlights those areas along the industrial corridor where a high concentration of people live in close proximity to Refinery Row facilities.
- Figure 4A, Appendix A. The percent of Hispanic/Latino people by census block for the Refinery Row area. Of note, people who identify their origin as Hispanic or Latino may be of any race. This figure highlights that many areas throughout the Refinery Row industrial corridor have a large Hispanic/Latino population (i.e., over 50%).
- Figure 5A, Appendix A. General location of public and private schools within a 1-mile and 2-mile boundary of the facilities. Over 20 schools exist within the 2-mile boundary. In addition to

schools, over 25 child care centers are within the 2-mile industrial corridor boundary (see Figure 6A, Appendix A.)

- Figure 7A, Appendix A. General location of elder care centers. There are six elder care centers within the 2-mile industrial corridor boundary.

Overall, these figures highlight that many institutions with sensitive populations, like children and the elderly, are in the Refinery Row area.

3.2. Refinery Row Facilities

In this section, ATSDR mentions some of the facilities along Refinery Row that emit chemicals into the ambient air. Attributing airborne exposures to specific sources on individual facilities is often extremely difficult, especially in areas such as Refinery Row with many different environmental contaminant sources.

In general, Corpus Christi refineries use physical, thermal, and chemical separation techniques to separate crude oil. The refineries separate the crude oil into several products such as gasoline, kerosene, diesel, petroleum coke, and asphalt. In addition to the refineries' routine operating emissions, process upsets, startups, and shutdowns all result in emission events. Other refinery emission sources are fugitive emissions from truck and barge loading operations and equipment leaks, such as from valves, storage tanks, and other industrial equipment. Other industries, such as asphalt plants, oil and gas gathering facilities, and wastewater treatment operations, also emit pollutants to the ambient air. In addition to these sources in the Refinery Row area, mobile emissions exist from car and bus traffic and barge navigation in the ship channel. Other regional sources exist in close proximity to the Refinery Row area, such as the Corpus Christi International Airport.

ATSDR first used the U.S. Environmental Protection Agency's (U.S. EPA's) Toxics Release Inventory (TRI) database to help determine the types of industries and potential chemicals of interest in the Refinery Row area. According to the TRI database, nine industries in the Refinery Row area are classified as "petroleum" or "petroleum bulk terminals" [USEPA 2013a].

- BTB Refining
- CITGO Deep Sea Terminal
- CITGO East
- CITGO West
- Flint Hills East
- Flint Hills West
- Martin Operating LP
- Valero East
- Valero West

ATSDR also searched the TRI database for the primary chemicals of interest discussed in this public health evaluation (e.g., benzene and chromium) and determined that two facilities not related to the petroleum industry within the Refinery Row area also emit these chemicals into the air. According to

TRI, these two industries are American Chrome & Chemicals LP (hereafter referred to as Elementis Chromium) and Equistar Chemicals LP [USEPA 2012a].

However, only certain industries are required to disclose to the TRI database releases for specific hazardous chemicals. Thus the TRI database does not cover all industries or all chemicals of concern. See "Reporting Criteria" at http://www2.epa.gov/toxics-release-inventory-tri-program/basics-tri-reporting for more information about TRI. While TRI data typically capture large and stationary emission-release sources, smaller stationary sources are not captured. Thus, the TRI database might not capture some additional facilities, but these facilities nonetheless emit chemicals of interest into Refinery Row ambient air.

The Texas Commission on Environmental Quality's (TCEQ's) Mobile Monitoring Team (MMT) conducts ambient air monitoring in Texas. ATSDR reviewed TCEQ's 2007 and 2008 MMT reports for the Refinery Row area that noted a variety of sources for air emissions and odors, including both large and small facilities [TCEQ 2007, 2008]. These MMT reports indicate TCEQ has monitored an additional 14 facilities in the Refinery Row area that were not captured during ATSDR's TRI database searches, including the Broadway Waste Water Treatment Plant (WWTP) and Javelina Gas Co.

ATSDR also included in its facility list Encycle Texas Inc., which was a subsidiary of American Smelting and Refining Company (ASARCO) LLC. Although this facility ceased operation in 2003, community members have expressed concern about it. Figure 8A, Appendix A, shows the location of the 11 industries identified by the TRI database, the additional 14 facilities monitored by TCEQ as part of its mobile monitoring projects, and the former Encycle/ASARCO facility.

To provide further information and perspective regarding these industries, ATSDR created short summary profiles of these 26 facilities (see Appendix O). ATSDR gathered information in the facility profiles during a file review at TCEQ's Houston office. ATSDR also compiled information from online sources such as U.S. EPA's Enforcement and Compliance History Online (ECHO) database (http://www.epa-echo.gov/echo/) and TCEQ's emission event database (http://www11.tceq.state.tx.us/oce/eer/index.cfm).

3.3. ATSDR Activities

ATSDR and its cooperative agreement state partner, the Texas Department of State Health Services (DSHS)[9], have been responding to health concerns expressed by Corpus Christi community members for many years. Between 1995 and 2008, ATSDR received seven petitions related to Corpus Christi. The petitions focused on concerns about

- Pollutants released to soil from a former smelter.
- Pollutants released to the air, soil, and water from two landfills.
- Pollutants released to the air from refineries and petrochemical companies.
- Elevated birth defect rates.

As stated previously, this public health evaluation focuses on chemicals released to the air from refineries and petrochemical companies. In addition to this report, numerous actions have occurred over the years that are not all noted in this document, such as monthly conference calls with concerned

[9] Referred to throughout this public health assessment as "Department of State Health Services" (DSHS).

residents and industry representatives. Appendix C summarizes some of the major events that ATSDR and DSHS engaged in while working in the Corpus Christi area. Appendix C also provides additional background information, such as the history of Corpus Christi, information on land use in the area, and the results of ATSDR's Social Vulnerability Index (SVI) analysis for the Refinery Row area.

4. Air Monitoring and Data Screening

4.1. Stationary Air Monitoring Networks and Mobile Monitoring Events

To accurately characterize Refinery Row air quality for past and current exposure evaluation, ATSDR compiled many years of air monitoring data. For this report, ATSDR compiled available ambient (i.e., outdoor) air data from the following Refinery Row stationary air monitoring programs:

- Corpus Christi Air Quality Project (AQP) network from 2005–2010,
- Industry network from 1996–2010, and
- Texas Commission on Environmental Quality (TCEQ) network from 1980–2010.

Table 1 lists the station names and chemicals ATSDR evaluated for each network. Figure 8A, Appendix A, shows the stationary air monitor locations relative to the Refinery Row facilities. Table 1B, Appendix B, provides additional details about each specific monitor.

Table 1. Stationary Air Monitoring Networks, Station Names, and Chemicals Evaluated (2 pages)

Air Monitoring Network	*Station Names*	*Chemicals Evaluated**
AQP	Dona Park J.I. Hailey Oak Park Off Up River Road Port Grain Elevator Solar Estates West End Inner Harbor	Hydrogen Sulfide Sulfur Dioxide Volatile Organic Compounds
Industry	Crossley Elementary School Huisache Oak Park Elementary School Tuloso Midway Elementary School Tuloso Midway Middle School Up River Road	Volatile Organic Compounds

TCEQ	Dona Park Fire Station #5 Hillcrest Huisache Navigation Navigation Boulevard Old Galveston Road Poth Lane Tuloso Midway Middle School West Guth Park	Hydrogen Sulfide Metals Particulate Matter Sulfur Dioxide Volatile Organic Compounds

* chemicals evaluated vary for each monitoring station

AQP Corpus Christi Air Quality Project
TCEQ Texas Commission on Environmental Quality

In addition to chemical-specific air data collected at the stationary monitors, ATSDR compiled data on meteorological conditions (e.g., wind speed and wind direction) from TCEQ's online database. ATSDR also compiled ambient air data from 24 Refinery Row-area mobile monitoring events that occurred between July 1993 and March 2008. The following text provides further information about the monitoring locations and chemicals monitored. Appendix D provides information about the monitoring methods, monitoring schedules, and data quality.

4.1.1. *Corpus Christi Air Quality Project Monitoring*

Researchers from The University of Texas (UT) at Austin's Center for Energy and Environmental Resources designed the Corpus Christi Air Quality Project (AQP), with input from multiple parties. The AQP network includes seven air monitoring stations. Of the seven locations, three are near neighborhoods (Dona Park, Oak Park, and Solar Estates). The remaining four are closer to currently operating Refinery Row facilities. ATSDR notes both AQP and TCEQ have a monitor at the Dona Park site. For the period 2005–2010, ATSDR compiled hydrogen sulfide, sulfur dioxide, and volatile organic compound (VOC) data from the AQP network monitors [TCEQ 2010, 2013c; UT 2011a, 2011b, 2013a].

4.1.2. *Industry-Sponsored Monitoring*

Several northern Corpus Christi facilities collaborate to monitor ambient air quality along the Refinery Row corridor. The industry network includes six air monitoring stations. Air monitors are located near operating schools (Oak Park Elementary and Tuloso Midway Middle) and former schools (Crossley Elementary and Tuloso Midway Elementary) allowing ATSDR to evaluate past and current air exposures of both children and adults in the community. One location is near a neighborhood (Up River Road monitor) and one is located near the Refinery Row complex (Huisache monitor). In the past, the area surrounding the Huisache air monitor included many homes; however, the majority of homes near this monitor were bought out in the late 1990s. ATSDR notes both industry and TCEQ have monitors at the Huisache and Tuloso Midway Middle School sites. ATSDR evaluated VOC data from the industry network monitors for data collected from 1996 to 2010 [ToxStrategies 2011].

4.1.3. *Texas Commission on Environmental Quality Monitoring*

Over the years, Texas environmental agencies—the Texas Air Control Board (TACB), the Texas Natural Resources Conservation Commission (TNRCC), and now TCEQ—have managed the state's ambient air monitoring network. ATSDR compiled 1980s through 2010 air data from 10 TCEQ monitoring stations along Refinery Row. Four of these stations are currently in operation[10]. Of these four stations, two operate near neighborhoods (Dona Park and Hillcrest), one near a school (Tuloso Midway Middle), and one (Huisache) near the industrial area. In the past, five stations (Fire Station #5, Navigation, Old Galveston Road, Poth Lane, and West Guth Park) operated near neighborhoods. The Poth Lane location is in the same area as Huisache, which is currently industrial without many homes. One station (Navigation Boulevard) operated on the northern section of Refinery Row, along the ship channel. ATSDR evaluated hydrogen sulfide, sulfur dioxide, metals, particulate matter, and VOC data from the TCEQ network monitors for data collected from 1980–2010 [TCEQ 2013a, 2013b, 2013c, 2014]. Meteorological data (e.g., wind direction and wind speed) were also compiled from the Dona Park, Hillcrest, Huisache, and Tuloso Midway Middle School monitors.

4.1.4. Mobile Monitoring Events

ATSDR compiled ambient air data from 24 mobile sampling events that occurred in the vicinity of Corpus Christi Refinery Row between July 1993 and March 2008 [TCEQ 2002, 2003a, 2003b, 2004, 2006, 2007, 2008; TNRCC 1994, 1995, 1996a, 1996b, 1997, 1998a, 1998b, 1998c, 1999, 2000a, 2000b, 2000c, 2000d, 2001]. TCEQ deploys the mobile monitors to collect measurements of carbonyl compounds, sulfur compounds, semi-volatile organic compounds (SVOCs), and VOCs. The short-term mobile monitoring events allow TCEQ to monitor emission sources throughout the Refinery Row area.

4.1.5. Air Monitoring Data Limitations

Although TCEQ analyzed samples for metals in the 1980s, the equipment and methods used during that time frame resulted in data of unknown quality and could underestimate actual ambient air concentrations (see Section 1D.3.2 in Appendix D). These data will be discussed, but ATSDR will not use them to draw definitive health conclusions. ATSDR also notes that only one stationary air monitor (i.e., a TCEQ monitor at the Dona Park site) currently collects routine measurements for metals analysis; data from this one monitor were evaluated for public health significance in this document.

Routinely collected ambient air monitoring data are not available for polycyclic aromatic hydrocarbons (PAHs)—an SVOC subset. PAHs can be released from a variety of refinery sources, including atmospheric distillation, catalytic cracking, residual fuel oil, lubricant oil processing, bitumen processing and loading, coking, and waste-water treatment [IARC 1989].

4.2. Data Organization and Focus

Given the various locations of air emission sources and ambient air monitors, the various monitoring methodologies and monitoring intervals, and the various chemicals monitored, ambient air monitoring at the Corpus Christi Refinery Row site is a complex operation. To help with its evaluation, ATSDR organized the air data into seven groups:

1. Automated gas chromatograph (Auto GC),

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[10] There are five currently operating monitors. TCEQ installed the Palm Auto GC, which was activated on August 8, 2010. ATSDR's evaluation of air data for Corpus Christi Refinery Row includes most available air data from the 1980s through 2010. Because, however, this Palm monitor was not operating before 2010 and because other monitors (Hillcrest and Crossley Elementary School) have been operating for years near the Palm station, in this public health assessment ATSDR choose not to evaluate the 2010 partial year Palm Auto GC data.

2. TCEQ canisters,
3. Industry canisters,
4. AQP triggered canisters,
5. Mobile monitoring,
6. Metals and particulate matter, and
7. Sulfur compounds.

These categories allowed ATSDR to group data collected during similar time frames and for similar chemicals. Also, by grouping chemicals with similar monitoring intervals, ATSDR could perform various statistical analyses for some of the datasets. The following text provides the agency's data organization structure.

Auto GC. Automated gas chromatograph (Auto GC) data are collected continuously for 24 hours every day from three stationary air monitors. VOCs are measured at AQP's Oak Park and Solar Estates monitors, and benzene is measured at industry's Huisache monitor. Auto GC data provide information about the chemical levels in air that people breathe every day, all year long. These data can help ATSDR evaluate both short-term and long-term exposures.

TCEQ Canisters. Canister air data from five TCEQ stationary air monitors measure over 90 VOCs. For the most part, the VOC measurements are routinely collected once every six days for 24 hours per day. These data can help ATSDR evaluate both short-term and long-term exposures.

Industry Canisters. Canister air data from five industry stationary air monitors measure between 17 and 26 VOCs. The VOC measurements are collected two to six times per month, depending on the season, for 24 hours per day. These data can help ATSDR evaluate both short-term and long-term exposures.

AQP Triggered Canisters. Canister air data from seven AQP stationary air monitors measure VOCs when triggered by high hydrocarbon levels. Collected episodically (i.e., occasionally), these data capture chemicals during high concentration events and can help ATSDR evaluate short-term exposures.

Mobile Monitoring. Air data from 24 sampling events from a variety of locations along Refinery Row include measurements of VOCs, SVOCs, hydrogen sulfide, sulfur dioxide, and carbonyl compounds. These data were collected using a variety of instruments and varying averaging times. Together, these data capture chemicals during high concentration events and can help ATSDR evaluate short-term exposures.

Metals and Particulate Matter. TCEQ stationary air monitors collect airborne measurements of particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) and particulate matter less than 10 microns in diameter (PM_{10}) once every 6 days for 24 hours per day. At one of these monitors (Dona Park), samples are also analyzed for metals. These data can help ATSDR evaluate both short-term and long-term exposures.

In the 1980s, four TCEQ stationary air monitors collected airborne total suspended particulates (TSP) about once every 6 days for 24 hours per day and analyzed for metals. Because of the equipment and methods used during that time frame, ATSDR finds that the 1980s metals data are of unknown quality and therefore will be used for screening purposes only.

<u>Sulfur Compounds.</u> At seven stationary air monitors, both hydrogen sulfide and sulfur dioxide measurements are collected continuously every day for 24 hours per day. In addition, continuous monitoring of sulfur dioxide has occurred at another monitor (Tuloso Midway Middle School) beginning in 1984. These data provide information about hydrogen sulfide and sulfur dioxide in air that people breathe every day, all year. These data can help ATSDR evaluate both short-term and long-term exposures.

4.3. Data Screening

During the public health evaluation process, ATSDR reviews environmental data and evaluates these data in the context of the site-specific exposure pathway evaluation. This screening analysis process enables ATSDR to sort through data in a consistent manner and identify chemicals that might need closer evaluation. This screening process compares measured air concentrations with health-based comparison values (CVs) [ATSDR 2005a].

Health-based CVs are estimates of daily human exposure to a chemical that is not likely to result in harmful health effects over a specified exposure duration. ATSDR has developed CVs for specific media (e.g., air, water, and soil). ATSDR CVs are generally available for three specified exposure periods: acute (1–14 days), intermediate (15–364 days), and chronic (365 days and longer) [ATSDR 2005a].

Some of the CVs and health guidelines ATSDR scientists use include ATSDR's cancer risk evaluation guides (CREGs), environmental media evaluation guides (EMEGs), and minimal risk levels (MRLs). If an ATSDR CV is not available for a particular chemical, ATSDR screens those environmental data with CVs developed by other sources, such as U.S. EPA's reference concentrations (RfCs).

Health-based CVs and health guidelines, as well as all other health-based screening criteria, are conservative levels of protection—they are not thresholds of toxicity. Although concentrations at or below a CV represent low or no risk, concentrations above a CV are not necessarily harmful. To ensure that they will protect even the most sensitive populations (e.g., children or the elderly), CVs are designed intentionally to be much lower, usually by two or three orders of magnitude,[11] than the corresponding no-observed-adverse-effect-levels (NOAELs) or lowest-observed-adverse-effect-levels (LOAELs) on which the CVs are based. Most NOAELs and LOAELs are established in laboratory animals; relatively few are derived from epidemiologic (i.e., chiefly worker) studies. All ATSDR health-based CVs are nonenforceable—they are for screening purposes only.

ATSDR regularly updates its environmental and health guidelines. ATSDR's Toxicological Profiles provide detailed information about ATSDR's substance-specific health guidelines (MRLs). When determining what environmental guideline value to use, ATSDR follows a general hierarchy [ATSDR 2005a]:

- Hierarchy 1 includes ATSDR environmental guidelines such as CREGs and chronic EMEG/MRLs.

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[11] "Order of magnitude" refers to an estimate of size or magnitude expressed as a power of ten. An increase of one order of magnitude is the same as multiplying a quantity by 10, an increase of two orders of magnitude equals multiplication by 100, an increase of three orders of magnitude is equivalent of multiplying by 1000, and so on. Likewise, a decrease of one order of magnitude is the same as multiplying a quantity by 0.1 (or dividing by 10), a decrease of two orders of magnitude is the equivalent of multiplying by 0.01 (or dividing by 100), and so on.

- In the absence of these Hierarchy 1 values, ATSDR might select Hierarchy 2 values (including ATSDR intermediate EMEG/MRLs and U.S. EPA RfCs.

When environmental guidelines are unavailable from the hierarchy, ATSDR considers values from other sources[12].

ATSDR screened the Corpus Christi Refinery Row air data with its CVs, as well as those from California EPA (Cal. EPA), U.S. EPA, and TCEQ [ATSDR 2013; Cal EPA 2014; USEPA 2012c, 2013b; TCEQ 2013d]. Selecting the environmental guidelines most appropriate and applicable to site-specific conditions is of critical importance in conducting public health evaluations. Exposures identified at a site should closely approximate the exposure assumptions used to derive the environmental guidelines [ATSDR 2005a]. For example, including an air contaminant for further evaluation based on a few maximum detections that exceed a long-term CV might be inappropriate if the maximum concentrations are below short-term CVs, and the mean concentration is below long-term CVs.

Table 2B, Appendix B, provides the lowest, readily available CV for each chemical. See Appendix E for information on the derivation and intended use of the comparison values used in this public health evaluation.

For its Refinery Row evaluation, ATSDR completed two screening steps—initial screening and refined screening. Figure 1 provides a basic diagram of the Refinery Row screening process.

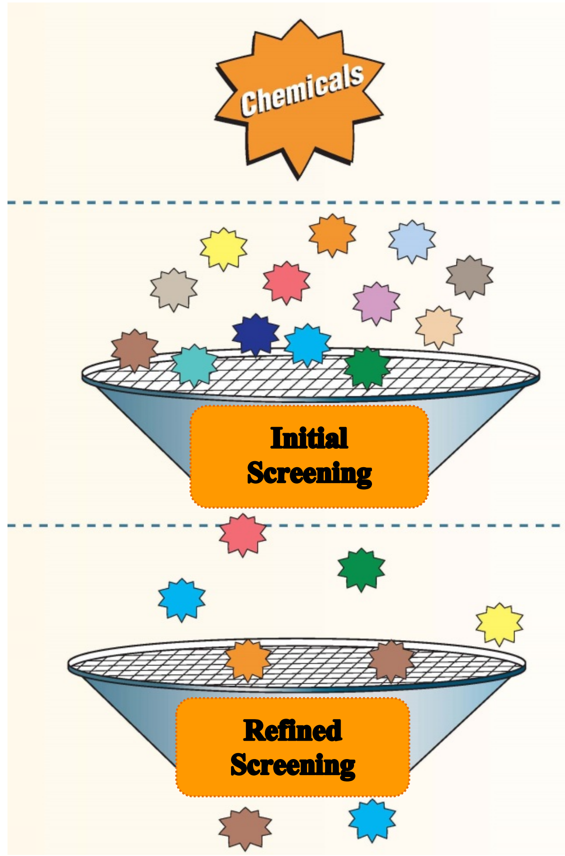
[12] ATSDR has not officially reviewed the bases of comparison values from other sources.

Figure 1. Refinery Row Basic Screening Approach Diagram

Chemicals: Gather data on air chemical levels →

Initial Screening: Determine whether maximum chemical levels exceed the lowest, relevant health-based comparison values (CVs) →

Refined Screening: Determine whether maximum chemical levels exceed short-term CVs and mean chemical levels exceed long-term CVs →



4.3.1. Initial Screening Approach

ATSDR screened the available Corpus Christi Refinery Row air data with the CVs listed in Table 2B, Appendix B.

Initial Screening Step 1: For episodic air measurements (i.e., those occurring occasionally), ATSDR determined whether the *maximum* detected chemical concentrations exceeded *short-term CVs* as well as noted those chemicals with no short-term CVs. ATSDR retained for public health evaluation those chemicals from these two groups:

- AQP triggered canisters, and
- Mobile monitoring.

The data from these two groups capture chemicals during high concentration events and can help ATSDR evaluate short-term exposures. Thus, ATSDR screened the datasets with only short-term CVs.

Initial Screening Step 2: For continuous monitoring (24 hours every day) and semi-continuous monitoring (24-hour averaging periods, once every 2–6 days) at stationary air monitors, ATSDR determined whether the *maximum* detected chemical concentrations exceeded available *long-*

term CVs as well as noted those chemicals with no long-term CVs. ATSDR retained for the refined screening process those chemicals from these five groups:

- o Auto GC,
- o TCEQ canisters,
- o Industry canisters,
- o Metals and particulate matter, and
- o Sulfur compounds.

The datasets from these five groups can help ATSDR evaluate both short-term and long-term exposures. Because short-term CVs typically exceed long-term CVs by at least an order of magnitude, ATSDR's first step was to conservatively screen these datasets with the lower, long-term CVs.

4.3.2. Refined Screening Approach

For chemicals retained based on Initial Screening Step 2, ATSDR calculated mean chemical concentrations for each stationary air monitor in each of the five groups (Auto GC, TCEQ canisters, industry canisters, metals and particulate matter, and sulfur compounds). Mean chemical concentrations were calculated by following the steps outlined in Appendix G. Then,

Refined Screening Step 1: ATSDR determined whether the chemical's *maximum* concentration was above its *short-term CV* or *mean* concentration was above its *long-term CV*, or both. ATSDR selected these chemicals for public health evaluation, as well as those chemicals with no CVs.

Refined Screening Step 2: For a chemical with a detection rate ≤ 20% at a stationary air monitor, ATSDR could not calculate the chemical's mean concentration for that monitoring station. ATSDR selected these infrequently detected chemicals for public health evaluation if 1) ATSDR could not calculate the chemical's mean concentration at any of stationary air monitors in the group, and 2) the chemical's method reporting limit (TCEQ data) or detection limit (industry data) was above the lowest, available long-term CV. ATSDR selected chemicals meeting these criteria because the agency does not know whether the chemical was consistently present in air above the long-term CV but below the method reporting limit or detection limit.

Of note, although concentrations at or below CVs are considered low or no risk, concentrations above these values will not necessarily pose a human health risk.

4.3.3. Screening Results

ATSDR presents the results of its initial screening of Refinery Row air data for each group in Tables 3B–10B, Appendix B, and its refined screening results[13] in Tables 11B–22B, Appendix B. Appendix F provides a detailed description of the screening process for each group. Table 2 summarizes the 39 compounds chosen for public health evaluation based on ATSDR's Refinery Row screening process.

[13] In general, two time periods were used to group data for calculations—chemical data available before 2005 and those from 2005–2010. Because the AQP network did not begin sampling activities until 2005, ATSDR chose to separate the industry and TCEQ data into two time periods (pre-2005 and 2005–2010).

Table 2. Refinery Row Data Screening Results

Compounds of Potential Concern				
Maximum Level above Short-term* CV	***Mean Level above Long-term* CV***	***Other Long-term Considerations†***	***No Short-term CV***	***No Long-term CV***
Barium‡	Arsenic	Cadmium	1-Butanol	1-Butanol
Benzene	Barium‡	Chloroprene	Chlorine	1-Butene
Cadmium	Benzene	Cobalt	Chloroprene	c-2-Butene
Carbon Tetrachloride	1,3-Butadiene	1,2-Dibromoethane	Dodecane	t-2-Butene
Chloroform	Carbon Tetrachloride	1,2-Dichloropropane	Furfural	Chlorine
Chromium‡	Chloroform	1,1,2,2-Tetrachloroethane	Ethane	Ethane
1,2-Dibromoethane	Chromium	1,1,2-Trichloroethane	Propane	Lead
Hydrogen Sulfide	1,2-Dichloroethane	Vinyl Chloride	Propylene	2-Methyl-2-Butene
Isoprene	Hydrogen Sulfide			1-Pentene
Lead	Naphthalene			c-2-Pentene
$PM_{2.5}$	Trichloroethylene			t-2-Pentene
Sulfur Dioxide				Propane
Toluene				Sulfur Dioxide

* Short-term exposures refer to chemical exposures that may last only a few minutes or a few hours, to those that may last for days, weeks, or even a few months. Long-term exposures refer to chemical exposures lasting a year or more.

† Chemical retained because 1) ATSDR could not calculate the chemical's mean concentration for any group at any monitor, and 2) the chemical's method reporting limit (TCEQ data) or detection limit (industry data) was above the lowest, available long-term CV.

‡ Chemical levels exceeded CVs for the 1980s metals dataset only.

CV health-based comparison value

$PM_{2.5}$ particulate matter less than 2.5 microns in diameter

5. Exposure Pathway Evaluation

To determine whether people are 1) now exposed to contaminants, 2) were exposed in the past, or 3) could be exposed in the future, ATSDR examines the path between a contaminant and a person or group of people who could be exposed. Completed exposure pathways have five required elements. ATSDR evaluates a pathway to determine whether all five factors are present. Each of these five factors or elements must be present for a person to be exposed to a contaminant:

1. A contamination source,
2. Transport through an environmental medium,

3. An exposure point,

4. A route to human exposure, and

5. People.

In the Refinery Row area, ATSDR considers exposure to ambient air a completed exposure pathway (see Table 3).

Table 3. Completed Exposure Pathway Elements

Pathway Name	***Exposure Pathway Elements***					***Time Frame***
	Sources	*Fate and Transport*	*Point of Exposure*	*Route of Exposure*	*Exposed Population*	
Ambient Air	Refineries, petrochemical facilities, mobile sources (cars, trucks, etc.)	Stack and fugitive emissions, general maintenance and process upsets, mobile sources, and other sources emit volatile chemicals into the air	Outdoors in Northern Corpus Christi	Inhalation	Community members, workers, and visitors to the Refinery Row area	Past, Present, Future

Refineries and petrochemical facilities in Northern Corpus Christi release chemicals into the ambient air through stack and fugitive emissions, general maintenance, and process upsets. Pollutants are also released from mobile sources, such as cars, trucks, trains, ships, barges, and airplanes. Other sources in the area, such as gas stations and dry cleaners, also release chemicals to the ambient air. Because ambient air is a continuous medium (i.e., air is not contained), people living, working, and visiting in the Refinery Row area are exposed to the ambient air though inhalation; that is, during their daily activities they breathe in chemicals from the outdoor air.

For the Refinery Row area, ATSDR obtained air monitoring data from three stationary networks (i.e., AQP, industry, and TCEQ). Combined, these networks placed air monitors throughout the community and the Refinery Row area (see Figure 8A, Appendix A). The stationary monitors are where people might be exposed, such as outdoors near schools, parks and homes, as well as at locations in close proximity to refinery operations and the ship channel. For each of the stationary air monitors, Table 1B, Appendix B, includes the monitor name, a general description of the area where the monitor is located, and other information about the monitor. For the current area descriptions, ATSDR uses these designations:

- Neighborhood—when mostly homes, parks, and schools are near the air monitor,
- Industry—when mostly facilities are located near the air monitor, and
- Industry, Ship Channel—when the air monitor is located close to both facilities and to the ship channel.

ATSDR notes the area descriptors that identify stationary monitor locations have changed over time. Past conditions for some areas are different. For example, the Huisache and Poth Lane air monitoring stations are currently described as “Industry.” About 15 years ago, however, these stations were in an area ATSDR would designate as “Neighborhood,” and which the local community commonly refers to as the Oak Park Triangle. The majority of homes in the Oak Park Triangle were bought out in the late 1990s.

In addition to the stationary air monitors, 24 mobile monitoring events occurred in the Corpus Christi Refinery Row area. These monitoring events captured air chemical levels at a variety of locations, including facility fence lines and neighborhoods. These short-term, mobile events provided additional insight into the levels of chemicals found throughout the Refinery Row area.

Exposure duration will be greatest in areas people frequent more often, such as their homes where they might engage in outdoor activities (e.g., gardening, lawn mowing, and playing). People are also exposed at schools and parks, and when they walk, run, and bike near the facilities and near the ship channel. People who work in the area, at the refineries as well as in other neighborhood businesses, are also exposed to the ambient air during their daily work activities.

6. Data Analyses and Trends

6.1. Analysis Approach

In Section 4.1, ATSDR provides information on the three currently operating stationary networks operated by AQP, industry, and TCEQ. For its stationary air monitor data analyses, ATSDR used R[14] version 3.1.1 [R Core Team 2014], along with various R packages. These analyses allowed ATSDR to

- Estimate a mean concentration for comparison with long-term CVs in its refined screening analysis (see Section 4.3.2).
- Perform cross-network comparisons of one monitoring network to the others to provide further insight into data quality (see Section 6.2).
- Describe the temporal, seasonal, and geographic trends that influence chemical air levels along Refinery Row (see section 6.4).

In general, two periods were used to group data for calculations—chemical data available before 2005 and chemical data from 2005–2010. Because the AQP network did not begin sampling activities until 2005, ATSDR chose to separate the industry and TCEQ data into two time periods (pre-2005 and 2005–2010) to facilitate comparison between networks and time periods. ATSDR estimated chemical means and approximate 95% confidence intervals for the two time periods. Two-sided confidence intervals (i.e., upper and lower confidence intervals) were calculated and used to facilitate comparison between stations and between time periods.

ATSDR notes that the bias and precision of the mean estimates can be influenced by unique features in the datasets such as

- Censoring—Chemical concentrations either reported or not reported below a given detection or reporting limit.
- Sampling design—The frequency and duration of sample collection over time.
- Correlation structure—Chemical concentration measurements can be related to each other in time or space.

[14] R is a free software programming language and software environment for statistical computing and graphics.

- Seasonality—Chemical concentrations can display consistent changes day-to-day and season-to-season.

Each of the three stationary air monitoring networks presented unique features that influenced bias and precision of the estimated means. They each required different approaches to calculating the mean and estimating the confidence intervals. Appendix G provides further information specific to ATSDR's data analyses methods.

6.2. Cross-network Comparisons

The three stationary air monitoring networks measure air quality throughout Refinery Row, and some monitoring stations are in close proximity to each other. ATSDR compared the measurements made by one network with measurements made by another. These "cross-network comparisons" provide further insight into data quality—despite the fact that each network used different measurement devices and analytical methods, the expected results should show reasonably comparable concurrent measurements in the nearby locations. Stations farther removed from each other should have less of a relationship, potentially moderated by wind directions from nearby chemical emission sources that favor one monitor location over another.

ATSDR selected benzene for its cross-network comparisons. This chemical is of concern to the community and is often detected above its chronic comparison values. All three networks also frequently measured benzene at levels above reporting and detection limits. To illustrate its findings, benzene comparisons between network sites are shown on figures with a "line of equality" to indicate a relationship that would exist if both compared monitors produced identical data. Data points from sites that have similar data will fall roughly equally on either side of the line. Data predominantly to the right or left of this line of equality indicate that one of the monitoring sites had higher concentrations than the other site.

As part of its analysis, ATSDR also determined whether the relationships of the monitoring sites were statistically significant, meaning the different measurement devices and analytical methods used by the networks showed similar benzene levels for concurrent time periods. Appendix G provides the detailed results of ATSDR's cross-network comparisons. The following text provides a short summary of these findings.

6.2.1. Canister Benzene Data Comparisons

ATSDR merged data from three pairs of geographically comparable industry and TCEQ canister sites by date. Figure 9A, Appendix A, shows the three pairs of canister sites that were cross-compared, which are

- Dona Park (TCEQ) and Up River Road (industry),
- Huisache (TCEQ) and Oak Park Elementary School (industry), and
- Hillcrest (TCEQ) and Crossley Elementary School (industry).

Overall, the benzene levels at one site were correlated with the benzene levels at the other site (i.e., the sites showed similar benzene levels for concurrent time periods – see Section 2G.1 in Appendix G). Additionally, the relationships were clearly affected by some sites' proximity to Refinery Row and by wind direction.

6.2.2. Auto GC Benzene Data Comparisons

ATSDR compared AQP's Oak Park and industry's Huisache Auto GC benzene data. Figure 10A, Appendix A, shows wind direction strongly influenced the relationship of benzene measured at one Auto GC station relative to the other Auto GC station. Although the strength of the relationship varied by wind direction, ATSDR notes the two Auto GC's benzene data were correlated regardless of wind direction (see Section 2G.2 in Appendix G). ATSDR also notes that when winds were from the east-northeast, the concentrations were consistently higher at the Huisache Auto GC station (as indicated by the data points being to the left of the line of equality). When the winds were from another direction (i.e., south-southwest), the relationship between the two benzene measurements was close to one-to-one.

6.2.3. Auto GC and Canister Benzene Data Comparisons

For its cross-network comparisons of benzene data, ATSDR also compared the 24-hour canister data available from each of the three stationary networks to the Auto GC data available from AQP and industry for concurrent time periods. Figures 11A–16A, Appendix A, show the sites that were cross-compared. Overall, ATSDR found positive correlations between the networks, each of which showed similar benzene measurements on concurrent days despite the use of different devices and analytical methods. In general, the most significant and strongest data correlations existed between sites that were geographically closest to each other, such as industry's Huisache Auto GC and TCEQ's Huisache canister benzene data.

6.3. Meteorological Trends

TCEQ operates four stations in the Refinery Row area that collect meteorological data. ATSDR looked at long-term, seasonal, and daily trends that influence chemical air levels along Refinery Row.

6.3.1. Long-term Trends

ATSDR plotted meteorological data from 2000 to 2010 for three stations (Tuloso Midway Middle School, Huisache, and Hillcrest) and from 2003 to 2010 for the Dona Park station using wind roses to show long-term trends. These wind roses[15] reveal similar patterns from the coast, from Corpus Christi Bay, and up to 10 miles inland from the bay (see Figure 17A, Appendix A). In general, the predominant wind direction was from the southeast. Winds were least likely to come from the west and southwest. These long-term patterns are consistent across all four stations.

6.3.2. Seasonal Trends

In the Corpus Christi Refinery Row area, the winds are similar through the seasons at all monitoring sites, with the predominant wind direction from the southeast. However, meteorology is subject to apparent seasonal variation. At all sites, spring and summer have winds predominantly out of the southeast. In the autumn and winter months, there is still a predominance of winds from the southeast, but there is also a greater variability in the wind direction, with a greater percent of winds coming from the north, northwest, and northeast (see Figure 18A, Appendix A).

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[15] A wind rose is a way of showing average wind direction and speed. These pictures gives a summary of how often wind comes from a direction towards the weather station (wind from), as well as the wind speed during that time. The weather station is at the center of a wind rose, so an arrow to the east of the center indicates wind from the east. The arrows are labeled with a percent, which indicates the percent of time the wind was coming from that direction at that speed. Relative wind speeds are shown by the color of the arrow.

The decreased frequency of southeasterly winds during the autumn and winter resulted in more days with winds blowing towards the monitors located south of Refinery Row. This autumn and winter wind pattern could result in higher measured chemical concentrations at these monitors during these seasons. In the winter months, decreased solar radiation and temperature would likely result in less vertical mixing of chemicals in the air and potentially higher chemical concentrations as well.

During the summer, winds were consistently from the southeast, which would result in Refinery Row area emissions blowing away from the more populated areas of Corpus Christi. Consequently, lower chemical concentrations would be expected at the monitors located south of Refinery Row. Higher temperatures and increased solar radiation would likely increase mixing of chemicals in the air, thereby diluting chemical concentrations. Wind speeds, which will effect mixing, also exhibited seasonal patterns—with higher wind speeds during the winter, spring, and late autumn months, and slightly slower speeds, overall, during the summer and early autumn.

6.3.3. Daily Trends

Regardless of season, wind directions did not appear to vary greatly between day and night. Overall, average wind speeds were lower at night and showed a slightly more clockwise rotation in spring, summer and autumn—in other words, the wind direction rotated clockwise slightly at night. Figure 19A, Appendix A, shows an example of wind roses by day and night for Hillcrest.

6.4. Chemical Trends

ATSDR looked at chemical concentration trends: 1) by wind speed and direction, and 2) according to location (spatial) and time (temporal). This review looked at trends for several compounds of interest (i.e., benzene, hydrogen sulfide, particulate matter, and sulfur dioxide). In general, these four compounds were chosen because of data completeness, potential health impact, and correlation to other compounds.

ATSDR used bivariate polar plots to analyze how concentrations of a given chemical vary by wind speed and wind direction. The statistic plotted was the conditional probability function (CPF), which is used to show the probability that the chemical concentration is within a given interval when the winds are from a given direction and speed [Uria-Tellaetxe and Carslaw 2014]. In other words, these plots can give clues on the direction of the sources of a given pollutant in relation to the location of the monitor. Appendix G provides further information about ATSDR's use of polar plots.

ATSDR notes that because of the uncertainty in determining the extent to which an individual source at a specific facility contributes to general air pollution, this public health evaluation does not provide quantitative estimates of each source's impact on levels of air pollution. This document does, however, analyze wind direction and speed in relation to chemical concentrations at the monitoring sites. This analysis can provide further information on chemical sources, such as how wind direction and speed impact when Refinery Row-related sources are likely to lead to concentrations in the top quantile[16] at the monitors. CPF plots can also provide some indication whether nearby areas, which may not have monitors, are likely to be impacted by similar sources.

[16] In this section, ATSDR groups concentration data into various equal proportions (called quantiles), including by quartiles (25%), quintiles (20%), and deciles (10%).

6.4.1. Benzene

Wind direction and speed trends: ATSDR developed CPF plots for the Auto GC benzene data at Huisache, Oak Park, and Solar Estates that divided the benzene concentrations into quartile ranges (0-25%, 25-50%, 50-75%, and 75-100%). This means the agency looked at the relationship of benzene concentrations and wind direction at lower concentrations (0-25% of the concentration range), at lower-to-mid concentrations (25-50% of the concentration range), at mid-to-higher concentrations (50-75% of the concentration range), and at higher concentrations (75-100% of the concentration range). One would generally expect the higher concentrations (75-100% of the concentration range) to come from the most significant sources of benzene. To keep the data comparable, 2005–2010 data were used to develop the polar plots because only Huisache had data prior to 2005.

The polar plots illustrate a strong relationship between the Auto GC measurements and Refinery Row-related benzene emission sources (see Figures 20A–22A, Appendix A). The patterns of Refinery Row benzene air emissions shown in these Auto GC figures are consistent with modeling performed by the University of Texas [UT 2010]. ATSDR also developed CPF polar plots at the TCEQ and industry canister sites that had benzene data after 2005. For the highest concentration range (75-100%), these canister sites showed similar benzene concentration patterns with regard to Refinery Row air emissions (see Figures 23A and 24A, Appendix A).

Spatial and temporal trends: Figure 25A, Appendix A, and Table 11B, Appendix B, show benzene concentrations at the three Auto GC stations from 2003 through 2010. The Huisache Auto GC station had the highest levels of benzene and exceeded the acute EMEG/MRL some of the time. The Oak Park Auto GC showed fewer exceedences of the acute EMEG/MRL than Huisache. The Solar Estates Auto GC site rarely exceeded the acute EMEG/MRL for benzene. Figures 26A and 27A, Appendix A, show benzene data scatter plots for the TCEQ and industry canister sampling monitors. Like the Auto GC benzene data, these canister benzene data plots show the Huisache monitor exceeded the acute EMEG/MRL more than the other monitors. Appendix G provides additional spatial trends for the TCEQ and industry canister sites.

Although the Huisache Auto GC recorded the highest average and peak benzene concentrations of the three Auto GC stations, monthly average concentrations have decreased over the years at Huisache compared to the other two Auto GC stations (see Figure 28A, Appendix A). These averages are higher than ATSDR's CREG of 0.04 ppb, but well below the chronic EMEG/MRL of 9 ppb (which is based on noncancer effects of benzene). The data for all three stations in this figure show strong seasonality, with higher concentrations occurring during the winter and autumn months. This is expected, given the seasonal meteorology in the region and the relative position of the monitors to Refinery Row.

The Huisache and Oak Park Auto GC monitors show a strong diurnal pattern (e.g., concentrations of benzene increased overnight through the morning and then decreased during the afternoon), but this pattern was less pronounced at Solar Estates (see Figure 29A, Appendix A). The diurnal pattern is consistent with the breakdown of benzene through interactions with hydroxyl radicals in sunlight [ATSDR 2007]. This process could also contribute to the seasonal cycle of benzene concentrations. Regardless of the day of the week, the diurnal pattern remained consistent.

Benzene average concentrations in the spring and summer months are much less than the average concentrations during the autumn and winter months. The higher concentrations during the autumn and winter months were consistent with the finding that there were more days in autumn and winter with winds blowing toward the monitors located south of Refinery Row.

6.4.2. *Hydrogen Sulfide*

Wind direction and speed trends: For the seven Refinery Row monitors, ATSDR used bivariate CPF polar plots for the top quintile (20%) of hydrogen sulfide concentrations (see Figure 30A, Appendix A). ATSDR used the top quintile CPF because the lower quintiles did not reveal meaningful trends. To make the data comparable to each other, the period used to develop these polar plots was 2006 through 2010 (only the latter part of 2005 had data available for hydrogen sulfide at the AQP stations). The polar plot analysis found only a slight increase in probability of concentrations being in the top quintile range near the Solar Estates monitor, which is furthest from the ship channel. All other monitors showed varying levels of increased probabilities of top quintile concentrations when winds were blowing from the direction of Refinery Row emission sources and the ship channel (see Figure 30A, Appendix A).

Spatial and temporal trends: Trends in hourly hydrogen sulfide levels at the seven monitoring sites showed sporadically high levels (e.g., above ATSDR's acute EMEG/MRL) at Huisache and JI Hailey until 2008 (see Figure 31A, Appendix A, and Table 21B, Appendix B). After 2008, the levels at these two stations became more comparable to other sites. Solar Estates had the lowest average concentrations, and, relative to the other sites, also had the lowest peak levels of hydrogen sulfide.

Monthly hydrogen sulfide concentrations (see Figure 32A, Appendix A) were never above ATSDR's intermediate EMEG/MRL of 20 ppb[17]. Monthly average levels over time remained just below the U.S. EPA's RfC of 1.4 ppb. Huisache's monthly average hydrogen sulfide concentrations dropped after 2008 to levels more consistent with the other sites in the area.

Hourly concentrations at every site except Dona Park showed a bimodal pattern in hydrogen sulfide measurements, that is, concentrations were high in the morning and evening hours (see Figure 33A, Appendix A). The concentrations were consistent regardless of day of the week.

6.4.3. *Particulate Matter*

Wind direction and speed trends: ATSDR developed polar plots for $PM_{2.5}$ at Dona Park and Huisache (see Figure 34A, Appendix A). Both sites had higher probabilities of a top quartile $PM_{2.5}$ concentrations when the winds were from the southeast. At Huisache, a smaller increase in probability of a top quartile concentration occurred when the winds were from the east-northeast as well.

Using $PM_{2.5}$ speciation data from Dona Park, Karnae and John (2011) conducted a study to try to identify the sources of $PM_{2.5}$ at this monitor. They found that secondary sulfates (i.e., sulfur particulates formed in the atmosphere) account for 30.4% of the $PM_{2.5}$. Aged sea salt accounts for 18.5%, biomass burns in South and Central America account for 12.7%, crustal dust (some from Africa) accounts for 10.1%, traffic accounts for 9.7%, fresh sea salt accounts for 8.1%, industrial sources account for 6%, and oil and combustion accounts for 4.6%. ATSDR notes that the pattern in its $PM_{2.5}$ polar plots would be consistent with long-range transport of the crustal dust and sea salt. Possible $PM_{2.5}$ industrial sources to the northeast could be associated with a higher probability of top quartile $PM_{2.5}$ concentrations at Huisache. But using these data alone, other distant sources cannot be ruled out.

Spatial and temporal trends: Daily measurements of $PM_{2.5}$ were taken at Huisache, Dona Park, and Navigation (see Figure 35A, Appendix A). Only two measurements of $PM_{2.5}$ were higher than the 24-

[17] ATSDR defines "intermediate" as a duration of 14–365 days.

hour[18] National Ambient Air Quality Standard (NAAQS) of 35 µg/m^3. The yearly 98th percentile of yearly data (averaged over 3 years) did not exceed the 35 µg/m^3 NAAQS standard. Average levels of $PM_{2.5}$ were relatively unchanged, with the three-year rolling mean below the NAAQS $PM_{2.5}$ standard of 12 µg/m^3. Annual average levels were, in some years, higher than the World Health Organization guidance value of 10 µg/m^3. Overall, Huisache measurements were slightly higher than Dona Park. Three-year rolling statistics were not calculated for Navigation as only three years of data were available.

6.4.4. Sulfur Dioxide

Wind direction and speed trends: ATSDR developed bivariate CPF polar plots for the top decile (10%) of sulfur dioxide concentrations along Refinery Row. Because sulfur dioxide is primarily an acute inhalation hazard, ATSDR used the top decile of concentrations for these plots; also, the data at some sites were too highly censored to allow for lower deciles to be used. To make the data comparable to each other, the period used to develop these polar plots was 2006 through 2010—only the later part of 2005 had data available for sulfur dioxide at the AQP stations. The polar plot analysis found that, with the exception of West End Inner Harbor, the monitors showed increased probabilities of top decile concentrations when winds were blowing from the direction of Refinery Row emission sources (see Figure 36A, Appendix A).

Spatial and temporal trends: Although all stations exceeded the acute EMEG/MRL, ATSDR found that peak sulfur dioxide concentrations from 2000–2010 were several times higher at the Huisache and JI Hailey monitoring sites than the other monitoring sites along Refinery Row (see Figure 37A, Appendix A). However, Table 21B, Appendix B, shows the highest concentration was found in the past prior to 2000 at the Tuloso Midway Middle School. ATSDR also notes increased sulfur dioxide concentrations occurred at Solar Estates from October 2006 until March 2007, when the winds were from the southeast (see Section 3G.3 in Appendix G for further information).

Overall, monthly average concentrations for sulfur dioxide have declined from 2003 through 2007, and then have remained relatively unchanged through 2010 (see Figure 38A, Appendix A). Figure 39A, Appendix A, shows a general diurnal trend of higher sulfur dioxide levels, with higher levels occurring during the daytime and generally peaking in the afternoon. Huisache and JI Hailey stations both had elevated concentrations the morning and evening hours. UT [2013b] observed that vessels in the Corpus Christi Ship Channel influenced sulfur dioxide levels at JI Hailey and possibly at other sites, with the main sulfur dioxide source likely from auxiliary engines burning high sulfur fuel. More recently, sulfur dioxide concentrations have declined at JI Hailey, possibly due to new regulations that went into effect in 2012 on sulfur content in marine vessel diesel fuel [UT 2013b].

6.5. Toxics Release Inventory Emission Observations

In addition to reviewing the site-specific air monitoring data collected in the Refinery Row area, ATSDR also provides general observations about reported air emissions by the Refinery Row facilities. These observations are from information in U.S. EPA's Toxics Release Inventory (TRI) database. TRI provides estimates of the annual air emissions of many chemicals (see http://www.epa.gov/triexplorer/). TRI data provide ATSDR staff with a general overview of the potential chemicals in an area. For comparison

[18] According to NAAQS, the 98th percentile of 24-hour average $PM_{2.5}$ concentrations in 1 year, averaged over 3 consecutive calendar years, must not exceed 35 µg/m^3.

purposes, ATSDR downloaded data from the TRI system for the years 2000, 2005, and 2010 [USEPA 2012a].

As stated in Section 3.2, 11 facilities in the Refinery Row area are listed in TRI. After gathering the available point source (i.e., stack) and fugitive air emission release[19] data, ATSDR decided to focus its TRI review on releases of benzene, 1,3-butadiene, chlorine, and chromium compounds. Appendix H contains ATSDR's TRI observations about these four compounds as well as notes the TRI dataset's limitations. With regard to benzene, some of these observations include

- Eight facilities in the Refinery Row area reported benzene emissions to TRI (see Table 24B, Appendix B).
- Benzene total air emissions for Nueces County ranked in the top 10 in the United States, steadily increasing from 9th to 4th from 2000 to 2010 (see Table 25B, Appendix B).
- For 2000, 2005, and 2010, Flint Hills West and Valero East together contributed more than 50% of the Nueces County total benzene air emissions reported to TRI (see Figure 40A, Appendix A).
- Except for 2 years, Nueces County fugitive benzene emissions have exceeded point source benzene emissions (see Figure 41A, Appendix A).

Over the years, awareness has increased of the potential health effects of chemicals released into the environment. Accordingly, through environmental regulation and advances in air emissions control technology, releases of chemicals into the environment have greatly reduced.

7. Public Health Evaluation

ATSDR addresses the question of whether exposure to the levels of chemicals detected in and around Refinery Row could result in harmful health effects. While the relative toxicity of a chemical is important, the human body's response to a chemical exposure is determined by several additional factors, including the

- Concentration (how much) of the chemical the person was exposed to,
- Amount of time (how long) the person was exposed, and
- Route by which the person was exposed (e.g., breathing the chemical).

Lifestyle factors (e.g., occupation and personal habits) strongly affect the likelihood, magnitude, and duration of exposure. Individual characteristics such as age, gender, nutritional status, overall health, and genetic constitution affect how the human body absorbs, distributes, uses, and gets rid of a contaminant. A unique combination of all these factors will determine a person's physiologic response to a chemical contaminant and any harmful health effects that person could suffer because of the chemical exposure.

ATSDR notes that in sensitive persons, low levels of some chemicals in the air might exacerbate respiratory symptoms. Sensitive persons includes those with preexisting respiratory conditions that

[19] Fugitive air emissions are all releases to air that are not released through a confined air stream like a stack. Fugitive emissions include equipment leaks, evaporative losses from surface impoundments and spills, and releases from building ventilation systems.

could lead to any kind of compromised lung function, including asthma, emphysema, influenza, and chronic bronchitis. Sensitive persons include those with allergic reactions to certain chemicals. Still, allergic reactions do not exhibit the same relatively predictable dose-response behavior as do nonallergic reactions. And other factors might affect respiratory health such as cold air and warm, humid air, which are known to aggravate respiratory ailments in sensitive persons. Increased air pollution levels in urban areas such as Corpus Christi are known to affect sensitive persons adversely. In general, whenever air pollution is worse than usual, ATSDR advises sensitive persons to stay indoors as a protective public health measure. For information on air quality, the AIRNow Web site at http://airnow.gov/ provides the public with easy access to national air quality information, daily air quality forecasts, and real-time air quality conditions for over 300 cities across the United States, including Corpus Christi, Texas. The URL also provides links to more detailed state and local air quality Web sites.

Corpus Christi residents are exposed to ambient, urban air pollution. Inhalation is the main exposure route. ATSDR evaluated Refinery Row air data for both short-term and long-term exposures. Short-term exposures refer to chemical exposures that may last only a few minutes or a few hours, to those that may last for days, weeks, or even a few months. Long-term exposures refer to chemical exposures lasting a year or more.

As stated previously, ATSDR compared a chemical's maximum and mean concentrations with relevant health guidelines. If a health guideline was exceeded or unavailable, ATSDR conducted a review of the supporting toxicological research to evaluate the potential for site exposures to cause harm. Reviewing the basis for an MRL or other health guideline as part of a site-specific analysis in no way diminishes the importance of the health guideline; rather, it serves as a means of gaining perspective on how strongly the supporting toxicologic data suggest that *harmful* exposures have occurred or might occur under site-specific exposure conditions [ATSDR 2005a].

Two key steps in this analysis are 1) comparing site exposure levels with observed effect levels reported in critical studies, and 2) considering study parameters in the context of site exposures [ATSDR 2005a]. This analysis requires the examination and interpretation of reliable, substance-specific health effects data and a review of epidemiologic (human) and experimental (animal) studies. In general, a study based on human data holds the greatest weight in describing relationships between a particular exposure and a human health effect. Fewer uncertainties arise regarding potential outcomes documented in well-designed epidemiologic (i.e., human-based) studies. Therefore, understanding the strengths and weaknesses of epidemiologic studies helps determine the suitability of a particular study in supporting and in drawing public health conclusions [ATSDR 2005a].

Insofar as animal data are concerned, ATSDR scientists evaluate their relevance to humans on a case-by-case basis. Numerous considerations affect the quality of experimental data and their relevance to site-specific exposures. As a general guide, scientists consider the following factors, as well as many others not mentioned here:

- How the test animal received its dose (e.g., gavage/water, gavage/oil, water, food, or vapor) influences the relevance of the findings. Often, the exposure route in experimental studies is different from the route by which people living near a site could be exposed. These differences can influence the likelihood of human adverse health effects.

- The dosing regimen can influence the absorption and ultimately the observed effects. For example, were animals dosed continuously or intermittently? Were animals dosed over the short-term or long-term?
- Understanding the biologic changes that ultimately lead to clinical disease in a test animal can aid in determining how well animal data might predict the same type of adverse effect in humans. For example, ATSDR might note whether the animal mode of action is plausible in humans. Metabolic data, if available, could provide insight into whether observed effects might be unique to, or different from, the study animal compared with humans. In the absence of such data, ATSDR assumes that similar effects would occur in humans.

Overall, assessing the relevance of available human and animal studies with respect to site-specific exposures requires both technical expertise and professional judgment. Because of uncertainties regarding exposure conditions and the adverse effects associated with environmental exposure levels, definitive answers about whether health effects actually will or will not occur are not always possible. Nevertheless, providing a framework that puts site-specific exposures and the potential for harm in perspective is possible, and it is one of the primary goals of ATSDR's public health evaluation process [ATSDR 2005a].

In this public health report, ATSDR describes the key points of its site-specific analysis for each of the chemicals chosen for further evaluation (see Table 2 of Section 4.3.3). For these chemicals, ATSDR evaluates short-term exposure, long-term noncancer exposure, and cancer risk, as appropriate. In reality, exposure occurs to multiple chemicals at the same time. Therefore, ATSDR also describes its approach and assesses the potential health risks from exposure to chemical mixtures (see Section 7.9).

Overall, ATSDR found the air levels of eight compounds (benzene, cadmium, chromium, 1,2-dibromoethane, hydrogen sulfide, naphthalene, particulate matter, and sulfur dioxide) to be of potential health concern and describes here its evaluation of these eight compounds. Appendix I contains ATSDR's evaluation of the remaining chemicals chosen for public health evaluation as determined by the screening process (see Section 4.3.3).

7.1. Benzene

Benzene is a colorless and highly flammable gas component of crude oil, gasoline, and smoke (e.g., from forest fires, tobacco, and engine exhaust). While benzene commonly enters the environment from both industrial and natural sources, the majority of U.S. exposures are from tobacco smoke (45%), automobile exhaust and industry (20%), and other home sources (16%). Home sources include paints and gasoline stored in the home (e.g., in basements or attached garages) [Wallace 1995; Ott and Roberts 1998]. Benzene evaporates very quickly into air, where it can react with other chemicals and break down within a few days [ATSDR 2007].

The most sensitive health endpoint that indicates benzene is harming the body is blood cell changes—particularly the suppression of the body's production of white blood cells (acute and chronic exposure). White blood cells fight off assault from infectious diseases and other substances foreign to the body. Without this protection, significant long-term exposure to benzene can increase a person's chance of infection and of developing cancer. ATSDR has a CREG (0.04 parts per billion (ppb)), an acute EMEG/MRL (9 ppb), and a chronic EMEG/MRL (3 ppb) for benzene. The U.S. EPA carcinogenic target risk screening level (SL) is 0.097 ppb and the RfC is 9.4 ppb. TCEQ has a short-term air monitoring comparison value (AMCV) of 180 ppb, a noncancer-based long-term AMCV of 86 ppb, and a carcinogenic-based long-term AMCV of 1.4 ppb for benzene in air.

Short-term exposure: Acute exposure to benzene concentrations as low as 60 parts per million (ppm) (or 60,000 ppb) have caused neurological effects such as headaches, dizziness, and nausea. In most cases, these symptoms are reversible with the cessation of exposure [ATSDR 2007]. The ATSDR acute EMEG/MRL is based on an acute study in mice that found a lowest-observed-adverse-effect level (LOAEL) of 10.2 ppm (or 10,200 ppb) for a decrease in the production of white blood cells (lymphocytes) [ATSDR 2007; Rozen et al. 1984]. Adjusting this LOAEL to a human equivalent concentration (HEC) yielded an adjusted human LOAEL of 2.55 ppm (or 2,550 ppb). After dividing this value by an uncertainty factor of 300 (10 for using a LOAEL instead of a no-observed-adverse-effect level (NOAEL), 3 for extrapolating from a mouse study to humans, and 10 for human variability), ATSDR derived an acute CV of 0.009 ppm (or 9 ppb) [ATSDR 2007].

Benzene is the only VOC to exceed its acute screening CV of 9 ppb in routinely collected samples (i.e., continuous and semi-continuous sampling strategy) from stationary air monitors (Auto GC, TCEQ canisters, and industry canisters groups). The Huisache stationary air monitor recorded benzene exceedence rates greater than the other stationary air monitors, with the highest rate (6.9%) at Huisache in the pre-2005 dataset and a maximum level (1,014.02 ppb) in the 2005–2010 dataset[20]. Overall, the ATSDR acute benzene CV was exceeded in 2.7% of the routinely collected samples from these stationary air monitors. For episodically collected samples, the benzene acute CV was exceeded in 15% of the samples from AQP triggered canisters and in 35% of the samples from mobile monitoring. The maximum concentrations for these two datasets were 407.25 ppb and 370,000 ppb, respectively.

The highest concentration recorded (370,000 ppb) was not in a neighborhood location—it was a 30-minute canister grab sample[21] collected in July 2000 downwind of an air intake on a tank's nonoperational thermal oxidizer. The next highest mobile monitoring benzene concentrations of 18,000[22] ppb in May 2000 and 3,300 ppb in March 2000 were also not near neighborhood locations. These benzene concentrations measured in Refinery Row air could potentially cause harmful health effects related to respiratory irritation and a decrease in various types of blood cells. At the highest concentration measured, exposure for as little as 30 minutes has caused dizziness, drowsiness, nausea, headaches, and fatigue [Flury 1928; Midzenski et al. 1992; ATSDR 2007]. These effects are generally reversible and will lessen with fresh air. All of the samples with benzene concentrations above the human equivalent LOAEL (2,550 ppb) were collected during mobile monitoring events on facility properties located outside of any neighborhood. The highest benzene value measured in continuously collected samples from a stationary air monitor was 1,014.02 ppb. Although this 1,014.02 ppb value is below the human equivalent LOAEL of 2,550 ppb from animal studies, the studies did not document a

[20] In general, two time periods were used to group data for calculations—chemical data available before 2005 and those from 2005–2010. Because the AQP network did not begin sampling activities until 2005, ATSDR chose to separate the industry and TCEQ data into two time periods (pre-2005 and 2005–2010) to facilitate comparison between networks and time periods.

[21] The report indicated that some data did not meet the data quality objectives for the project; therefore the data have been qualified. For example, the 370,000 ppb value was qualified with a note that "not all data met precision specifications; on average, data may vary by 180%" [TNRCC 2000d].

[22] The data qualifier for the 18,000 ppb concentration indicated blank samples did not meet specifications and data could be biased by +0.11 ppb.

NOAEL, and it is possible for health effects to occur at lower concentrations than the LOAEL [ATSDR 2007].

Overall, one stationery monitor (Huisache) and several mobile monitors found maximum benzene levels infrequently approach and exceed health effect levels. Short-term exposure to the highest concentrations of benzene measured in Refinery Row air indicates a potential for harmful health effects during episodic release events from facilities. ATSDR notes that the Huisache stationary air monitor is in a sparsely populated area, and the mobile monitors recording the highest levels were on or near facility boundaries. Workers and people walking, running, and biking near the facilities and the ship channel are the ones who might be exposed to these higher levels of benzene on rare occasions.

Long-term noncancer exposure: The mean concentrations from stationary air monitors in the Auto GC, TCEQ canisters, and industry canisters groups ranged from 0.21–2.21 ppb. None of the mean values exceeded noncancer long-term CVs. Thus ATSDR does not expect that long-term exposure to benzene concentrations in Refinery Row air would cause harmful noncancer health effects.

Cancer risk: Benzene is widely recognized as carcinogenic to humans. Leukemia is the cancer generally observed in people exposed to benzene. Leukemia is a cancer of the blood or blood forming tissue in the body. Many studies indicate that leukemia risk rises with increased concentrations of benzene in ambient air [USEPA 2003a; ATSDR 2007]. The lowest human cancer effect level (CEL) for leukemia reported in ATSDR's Toxicological Profile for Benzene [ATSDR 2007] is 300 ppb [Ott et al. 1978]. And several studies support the U.S. EPA inhalation unit risk (IUR) of 7.8×10^{-6} micrograms per cubic meter of air $(\mu g/m^3)^{-1}$ [USEPA 2003a; Rinsky et al. 1981, 1987].

As part of its evaluation, ATSDR calculated cancer risk estimates for chemical carcinogens selected for further consideration based on the screening process. To calculate cancer risk estimates, each chemical's mean concentration[23] is multiplied by its U.S. EPA IUR. These cancer risk estimates are expressed as a probability; that is, the proportion of a population that might be affected by a carcinogen during a lifetime of exposure (24 hours/day, 365 days/year, for 70 years). The cancer risks associated with various concentrations of benzene, based on the benzene IUR, are in Table 27B, Appendix B.

For the Auto GC, TCEQ canisters, and industry canisters groups, benzene was detected above the reporting limit in 99% of the pre-2005 samples and in 97% of the 2005–2010 samples. While the ATSDR CREG was exceeded in 88% of the samples, it is not uncommon for benzene concentrations to exceed this screening value. According to U.S. EPA's 2005 National-Scale Air Toxics Assessment (NATA) [USEPA 2011], the CREG (0.04 ppb) is about an order of magnitude lower than the estimated average benzene concentrations for the United States (0.332 ppb), for Texas (0.293 ppb), and for Nueces County (0.293 ppb) (see Table 1J, Appendix J). NATA, which models ambient air concentrations from information in the U.S. EPA National Emissions Inventory (NEI), is U.S. EPA's ongoing comprehensive evaluation of air toxics in the United States. For several chemicals, ATSDR cites these NATA values, as well as typical levels found in rural and urban area air in the United States,[24] to put site-specific concentrations into perspective for the reader—not to imply the acceptability of the levels from a public health perspective.

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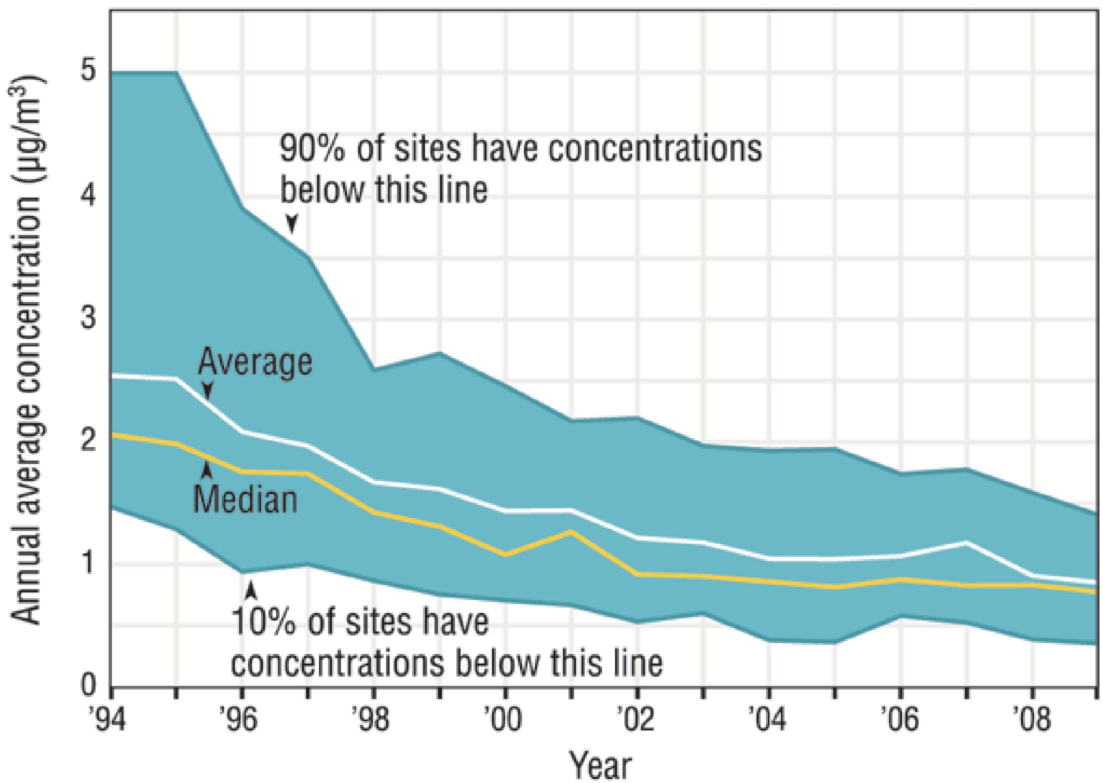
[23] For a chemical with a detection rate ≤ 20%, ATSDR could not calculate the chemical's mean concentration and instead used the chemical's 95th percentile value.

[24] As reported in ATSDR's toxicological profiles.

A recent U.S. EPA assessment of air toxics in the United States also found that annual average benzene concentrations exceeded the CREG in more than 90% of trend sites used to characterize long-term benzene changes in outdoor air quality [USEPA 2010b]. Trend sites met specific criteria for data completeness over the period of record (1994–2009). In all, 22 sites met the criteria for the U.S. EPA analysis. Spatially, these sites are distributed across the nation, although they tend to be more heavily representative of larger urban areas, where monitoring is generally more extensive. Figure 2 shows that the average benzene concentrations for the 22 trend sites decreased from 2.52 µg/m^3 (or 0.79 ppb) in 1994 to 0.85 µg/m^3 (or 0.28 ppb) in 2009.

Figure 2. Ambient air benzene concentrations in the U.S. (1994-2009)*



Source: This figure is adapted from US Environmental Protection Agency. 2010. Report on the environment. Ambient concentrations of benzene. Last updated 14 Dec 2010. Available at: http://cfpub.epa.gov/eroe/index.cfm?fuseaction=detail.viewInd&lv=list.listbyalpha&r=231333&subtop=341.

* Coverage is from 22 monitoring sites nationwide (out of a total of 339 site measuring benzene in 2009) that have sufficient data to assess benzene trends since 1994.

µg/m^3 micrograms per cubic meter

Mean concentrations from stationary air monitors in the Auto GC, TCEQ canisters, and industry canisters groups ranged from 0.21–2.21 ppb (or 0.67–7.1 µg/m^3) along Refinery Row. Although average benzene concentrations from the 2005 NATA assessment and the 22 trend sites assessment indicate the CREG value is normally exceeded throughout the United States, mean benzene concentrations at some locations along Refinery Row are higher than the average benzene levels found in these assessments.

The highest Refinery Row mean, which is 2.21 ppb for pre-2005 data, results in an additional cancer risk of 5.5 in 100,000 for people living in Refinery Row. ATSDR considers 5.5 in 100,000 a low additional cancer risk (see Table 28B, Appendix B).

ATSDR notes a high level of community concern regarding benzene. ATSDR performed physiologically-based pharmacokinetic (PBPK) modeling to develop a more complete picture of benzene exposures at this site. Specifically, ATSDR performed PBPK modeling to compare different exposure scenarios with benzene blood levels and ambient air levels through dose construction and reconstruction (see Appendix K). PBPK modeling supports the conclusions ATSDR reaches in this toxicological evaluation regarding noncancer health effects due to benzene exposures in the Refinery Row area.

7.2. Cadmium

Cadmium is a soft, silver-white metal that occurs naturally in the earth's crust. Cadmium is not usually found in the environment as a pure metal, but as a mineral combined with other elements. It is most often found as complex oxides, sulfides, and carbonates in zinc, lead, and copper ores. Cadmium is used primarily for the production of nickel-cadmium batteries, in metal plating, and for the production of pigments, plastics, synthetics and metallic alloys [ATSDR 2012a].

Cadmium enters soil, water, and air by nonferrous metal mining and refining, manufacture and application of phosphate fertilizers, fossil fuel combustion, and waste incineration and disposal. Cadmium in air can be transported long distances in the atmosphere. Deficiencies in dietary iron, calcium, and proteins can influence cadmium absorption into the body. For example, persons with low iron levels experience higher cadmium absorption [ATSDR 2012a].

Studies of occupational inhalation exposure and accidental ingestion of cadmium-contaminated food have shown that cadmium can be toxic to humans [ATSDR 2012a]. ATSDR has an acute (0.03 $\mu g/m^3$) and chronic (0.01 $\mu g/m^3$) EMEG/MRL and CREG (0.00056 $\mu g/m^3$) for cadmium inhalation. U.S. EPA has a cadmium carcinogenic SL of 0.0014 $\mu g/m^3$. TCEQ has a short-term (0.1 $\mu g/m^3$) and long-term (0.01 $\mu g/m^3$) AMCV. The U.S. Department of Health and Human Services (DHHS) and the International Agency for Research on Cancer (IARC) classify cadmium as a known human carcinogen, and U.S. EPA classifies cadmium as a probable human carcinogen.

Short-term exposure: In various animal studies, acute inhalation of cadmium caused respiratory effects [ATSDR 2012a; NTP 1995]. The acute EMEG/MRL is based on a rat study that found a LOAEL of 88 $\mu g/m^3$ for respiratory effects (alveolar histiocytic infiltrate and inflammation in alveolar septa) [NTP 1995]. To achieve the acute EMEG/MRL, this 88-$\mu g/m^3$ concentration was adjusted for intermittent exposure (6.2 hours/day and 5 days/week) and divided by an uncertainty factor of 300 (10 for use of a LOAEL, 3 for extrapolation from animals to humans with dosimetric adjustment, and 10 for human variability).

In the 1980s metals dataset, cadmium exceeded short-term CVs in 2 of 184 samples, and the maximum level was 0.175 $\mu g/m^3$. As stated in Section 4.1.5, these 1980s data are of unknown quality, and ATSDR therefore cannot draw definitive health conclusions from them. But to put these levels in perspective, ATSDR notes that the maximum cadmium level detected was greater than two orders of magnitude below the animal LOAEL that resulted in respiratory effects.

For the Dona Park datasets, cadmium was detected above the detection limit in 5.6% of the samples, with a maximum concentration of 0.06 µg/m^3. Only 1 of 572 samples exceeded the ATSDR acute EMEG/MRL of 0.03 µg/m^3, and no samples exceeded the 0.1 µg/m^3 TCEQ short-term AMCV. This maximum cadmium concentration is close to the acute EMEG/MRL value and is more than three orders of magnitude below the level documented to cause acute respiratory effects in animals. Thus ATSDR does not expect that short-term exposure to cadmium concentrations in Refinery Row air would cause harmful health effects.

Long-term noncancer exposure: Because cadmium was detected in less than 20% of the samples, mean values could not be calculated following the procedures outlined in Appendix G. The highest 95th percentile (0.0059 µg/m^3), which is generally a more conservative value than the mean, was used to estimate long-term noncancer exposure risk. Because the 95th percentile of the cadmium concentrations is below the chronic EMEG/MRL and TCEQ long-term AMCV, ATSDR does not expect that long-term exposure to cadmium concentrations in Refinery Row air would cause harmful noncancer health effects.

Cancer risk: Cadmium caused tumors when administered to experimental animals by inhalation, orally, or by injection [NTP 2011]. Lung cancers have been documented in both occupationally exposed persons and experimentally exposed rats [ATSDR 2012a; NTP 2011]. The U.S. EPA IUR of 1.8×10^{-3} µg/m^3 is based on a study that observed increases in tumors of the lung and trachea[25], as well as bronchus[26] cancer deaths, in workers at a cadmium smelter [USEPA 1991; Thun et al. 1985]. The cancer risks associated with various concentrations of cadmium are in Table 27B, Appendix B. Using the cadmium 95th percentile (0.0059 µg/m^3) at Refinery Row and the U.S. EPA IUR results in an additional cancer risk of 1.1 in 100,000, which ATSDR considers low (see Table 28B, Appendix B).

7.3. Chromium

Elemental chromium occurs naturally in rocks, animals, plants, and soil and has various oxidation states. The most common oxidation states are trivalent chromium (III) and hexavalent chromium (VI) [ATSDR 2012b]. Chromium (III) is an essential nutrient required for normal energy metabolism. Low levels of chromium (III) occur naturally in a variety of foods such as fruits, vegetables, nuts, fish, and meats (0.01 to 1.3 milligrams per kilogram (mg/kg)). The U.S. Food and Drug Administration (FDA), however, has not established a recommended daily allowance (RDA) for chromium [ATSDR 2012b].

Chromium (VI), combined with copper and arsenic, is used as a wood preservative. Chromium is a component of crude oil and occurs in petroleum refining [IARC 1989]. Ingestion of chromium (VI) can cause anemia and irritation of the stomach and intestines. Chromium (III), however, is much less toxic and does not appear to cause these problems [ATSDR 2012b]. Chromium (VI) is a known human carcinogen by the inhalation route of exposure. Little evidence supports any hypothesis that chromium (III) is carcinogenic [ATSDR 2012b].

Chromium (III) has an ATSDR intermediate EMEG/MRL of 0.1 µg/m^3. ATSDR has chronic and intermediate EMEG/MRLs for chromium (VI), which are both set at 0.005 µg/m^3, and a CREG value of 8.3×10^{-5} µg/m^3. U.S. EPA has developed an RfC for particulate chromium (VI) (0.1 µg/m^3), an RfC for

[25] The trachea (or windpipe) is a wide, hollow tube that connects the larynx (or voice box) to the bronchi of the lungs.

[26] The bronchi (singularly known as bronchus) are the air tubes from the trachea that branch into the left and right lung.

dissolved chromium (VI) aerosols (0.008 μg/m^3), and a carcinogenic SL of 1.1 × 10^{-5} μg/m^3 for chromium (VI). TCEQ has a chromium (VI) short-term (0.1 μg/m^3) and long-term (0.01 μg/m^3) AMCV. IARC has designated chromium (III) as not classifiable as a human carcinogen, and U.S. EPA holds that its potential to cause cancer cannot be determined. DHHS, IARC, and U.S. EPA have all designated chromium (VI) as a human carcinogen.

Although chromium (VI) is believed to be a fraction of the total chromium measured, to arrive at the most conservative risk estimate, ATSDR treats the total chromium measured in Refinery Row air as chromium (VI). Note that assuming the measured chromium is all chromium (VI) will likely overestimate the chromium exposure risk; the actual risk will be lower.

Short-term exposure: Studies of acute exposure to chromium (VI) have shown respiratory system effects, decreased lung function, and asthma. Respiratory effects have been documented in workers exposed to concentrations as low as 2 μg/m^3 [Lindberg and Hedenstierna 1983]. These workers, however, were exposed for a range of years (average 2.5 years), which is much longer than the "up to 14 days" that ATSDR considers in the derivation of its acute duration comparison values. Occupational exposures to 25 μg/m^3 have been documented to cause respiratory effects in fewer than 90 days. Dermal effects in the form of rashes (dermatitis) can also occur both with ingestion and inhalation of high concentrations of chromium; but these concentrations have only occurred in occupational settings [ATSDR 2012b].

Regarding the 1980s metals data, total chromium exceeded the chromium (VI) short-term AMCV about 15% of the time, and the maximum level was 0.731 μg/m^3. As stated in Section 4.1.5, these 1980s data are of unknown quality. Thus ATSDR cannot draw definitive health conclusions from them. To put these levels into perspective, however, ATSDR notes only that the maximum total chromium level detected was below the chromium (VI) levels documented to cause respiratory effects.

In the Refinery Row area, the maximum detected chromium level for the Dona Park datasets of 0.024 μg/m^3 is below the chromium (VI) short-term AMCV of 0.1 μg/m^3 and two or more orders of magnitude below effect levels. Also, as stated previously, chromium (VI) is believed to be a fraction of the total chromium measured so the actual risk will be lower. Thus ATSDR does not expect that short-term exposure to chromium levels measured in Refinery Row air would cause harmful health effects.

Long-term noncancer exposure: The U. S. EPA particulate RfC is most likely representative of the chromium samples collected from Refinery Row air. With regard to the 1980s data, total chromium means ranged from 0.069–0.12 μg/m^3. As stated previously, these 1980s data are of unknown quality and ATSDR cannot draw definitive health conclusions from them. To put these levels into perspective, however, ATSDR notes only that highest mean chromium level (0.12 μg/m^3) is about equal to U.S. EPA's particulate chromium (VI) RfC (0.1 μg/m^3).

The highest mean total chromium concentration (0.0017 μg/m^3) for the Dona Park datasets is below the chromium (VI) ATSDR chronic EMEG/MRL, and the U.S. EPA RfC for particulates and dissolved aerosols. Also, as stated previously, chromium (VI) is believed to be a fraction of the total chromium measured so the actual risk will be lower. Thus ATSDR does not expect that long-term exposure to the total chromium concentrations measured in Refinery Row air would cause harmful noncancer health effects.

Cancer risk: Studies have shown chromium (VI) causes lung cancer in animals and humans [ATSDR 2012b]. The U.S. EPA IUR of 1.2 × 10^{-2} (μg/m^3)$^{-1}$ is based on a study on chromate workers that found an increased incidence of lung cancer with increased chromium exposure [Mancuso 1975]. The cancer risks associated with various concentrations of chromium can be found in Table 27B, Appendix B. Using highest mean concentration of total chromium from the Dona Park datasets and the chromium (VI) U.S. EPA IUR results in an additional cancer risk of 2.0 in 100,000, which ATSDR considers low (see Table 28B, Appendix B). ATSDR notes limitations in its estimate that likely overestimate the cancer risk because only total chromium levels were available , not the more toxic hexavalent chromium (VI) levels, for the cancer estimate.

7.4. 1,2-Dibromoethane

1,2-Dibromoethane is a colorless liquid with a mild, sweet odor. It evaporates easily. Once released into the environment, 1,2-dibromoethane breaks down quickly in air [ATSDR 1992]. Although 1,2-dibromoethane is mostly manufactured, the U.S. EPA stopped most uses in 1984. This chemical was used before that date as a pesticide in soils and on fruits and vegetables to kill insects, worms and fruit flies. It was also used as an additive in leaded gasoline to produce better fuel efficiency.

Background levels in the environment are very low. The air most people breathe contains between 0.01–0.06 ppb of 1,2-dibromoethane [ATSDR 1992]. For the air pathway, TCEQ has a 1,2-dibromoethane short-term (0.5 ppb) and long-term (0.05 ppb) AMCV, ATSDR has a CREG of 0.00022 ppb, and U.S. EPA has an RfC of 1.2 ppb and a carcinogenic SL of 0.00053 ppb.

Short-term exposure: Although the effects of people breathing high levels are unknown, animal studies with short-term exposures to high 1,2-dibromoethane levels showed depression and collapse, indicating effects on the brain [ATSDR 1992]. 1,2-Dibromoethane was measured in routinely collected TCEQ canister samples, as well as in episodically collected AQP triggered canister and mobile monitoring samples. The short-term CV was not exceeded in any TCEQ canisters samples. AQP triggered canister samples showed 1,2-dibromoethane exceedences in 10 of 13 samples at the Port Grain Elevator stationary air monitor in an industry-ship channel area, with a maximum concentration of 4.78 ppb. Mobile monitoring along Refinery Row showed 1,2-dibromoethane levels exceeded the short-term CV in 2 of 292 samples (0.68%), with a maximum of 0.87 ppb.

TCEQ based its short-term CV of 0.5 ppb on the 1,2-dibromoethane National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit and applied a safety factor of 100 [TCEQ 2013e]. The 1,2-dibromoethane NIOSH value limits workers' exposure in air to an average of 0.045 ppm (or 45 ppb) for up to a 10-hour workday over a 40-hour workweek. In 1977, NIOSH recommended limiting worker exposure to this chemical to a ceiling concentration of 0.13 ppm (or 130 ppb), as determined over any 15-minute sampling period. ATSDR notes that the recommended exposure limit and ceiling limit concentrations should be considered protective of healthy workers but not necessarily protective of the general population, which includes sensitive groups (e.g., the elderly and children).

Overall, the maximum detected concentrations of 1,2-dibromoethane along Refinery Row are one to two orders of magnitude below the NIOSH value of 45 ppb and two orders of magnitude below the 130-ppb worker ceiling. This chemical was detected at only one monitor in the AQP triggered canisters group and the location was not residential. For mobile monitoring, 1,2-dibromoethane was detected above the short-term CV less than 1% of the time. As such, ATSDR does not expect infrequent exposures to 1,2-dibromoethane would harm people's health, including sensitive groups.

Long-term noncancer exposure: Because 1,2-dibromoethane was detected in less than 20% of the TCEQ canister samples, mean values could not be calculated following the procedures outlined in Appendix G. The highest 1,2-dibromoethane 95th percentile value from stationary air monitors is 0.01 ppb—generally a more conservative value than the mean. The 1,2-dibromoethane 95th percentile value of 0.01 ppb is more than two orders of magnitude below the RfC of 1.2 ppb and just below the TCEQ long-term AMCV of 0.05 ppb. Thus ATSDR does not expect harmful noncancer health effects from long-term exposures to 1,2-dibromoethane in Refinery Row air.

Cancer risk: DHHS has determined that 1,2-dibromoethane may reasonably be anticipated to be a carcinogen. The U.S. EPA IUR of 6×10^{-4} $(\mu g/m^3)^{-1}$ is based on the same study as the U.S. EPA RfC [NTP 1982]. While cancer has not been reported in workers or other people exposed to 1,2-dibromoethane for several years, rats and mice that repeatedly breathed, swallowed, or had skin contact with 1,2-dibromoethane for long periods developed cancer in several organs at concentrations as low as 10 ppm (or 10,000 ppb) [NTP 1982]. The cancer risk associated with various concentrations of 1,2-dibromoethane is in Table 27B, Appendix B. As stated previously, ATSDR is using the highest 95th percentile value from TCEQ canister sampling (0.01 ppb) to evaluate chronic exposures. Using this value and the U.S. EPA IUR, ATSDR calculated a cancer risk of an additional 4.6 cases per 100,000 persons, which the agency considers low risk (see Table 28B, Appendix B).

7.5. Hydrogen Sulfide

Hydrogen sulfide is a gas released from both natural and manufactured sources and is known for its rotten egg odor. Some industrial sources include sewage treatment facilities, manure-handling operations, pulp and paper mills, petroleum refineries, and food processing plants [ATSDR 2006]. Steel mills and cement manufacturing facilities can have operations (e.g., wastewater treatment) known to release hydrogen sulfide gases. Ambient air concentrations of hydrogen sulfide from natural sources are estimated in the range of 0.11–0.33 ppb, while concentrations in urban areas are often greater than 1 ppb [ATSDR 2006]. These ambient concentrations have no documented health effects. ATSDR has an acute EMEG/MRL of 70 ppb and an intermediate EMEG/MRL of 20 ppb. The U.S. EPA RfC for hydrogen sulfide is 1.4 ppb. Hydrogen sulfide has not been shown to cause cancer in humans and is not currently classified as a carcinogen [ATSDR 2006]. The U.S. EPA, in its most recent cancer assessment, determined that available data are inadequate to assess the carcinogenic potential of hydrogen sulfide [USEPA 2003b].

Short-term exposure: Brief exposures to hydrogen sulfide concentrations greater than 500 ppm (or 500,000 ppb) can cause a loss of consciousness [Bhambhani and Singh 1991; Bhambhani et al. 1994]. In most cases, if removed from the exposure, the person regains consciousness without any other effects. Nevertheless, some persons might suffer permanent or long-term effects such as headaches, poor attention span, poor memory, and poor motor function. Metabolic effects have also been observed in humans following inhalation of hydrogen sulfide at concentrations as low as 5 ppm (or 5,000 ppb) [Bhambhani and Singh 1991; ATSDR 2006].

ATSDR bases its acute hydrogen sulfide EMEG/MRL on health effects (i.e., headache and changes in respiratory tests suggesting bronchial obstruction) reported in some persons with asthma exposed to 2,000 ppb for 30 minutes [Jappinen et al. 1990]. ATSDR treated this LOAEL with an uncertainty factor of 27 (3 for use of a less serious LOAEL, 3 for human variability, and 3 for database inadequacies). ATSDR based its intermediate CV on a separate, subchronic study on rats that found a NOAEL of 10 ppm (or 10,000 ppb) for cellular changes in the nasal factory epithelium (or the skin lining the nasal passages) [Brenneman et al. 2000]. ATSDR converted this NOAEL into a human equivalent dose and treated it with an uncertainty factor of 30 (3 for use of an animal study and 10 for human variability) to achieve the intermediate EMEG/MRL.

In the Refinery Row area, a total of 25 out of 349,528 (0.007%) stationary 1-hour samples exceeded the ATSDR acute EMEG/MRL. These exceedences were limited to two continuous stationary air monitoring locations, Huisache and JI Hailey. The maximum hydrogen sulfide concentration measured at Huisache was 365 ppb, and the maximum concentration at JI Hailey was 342 ppb. The JI Hailey exceedences occurred over the course of two days in 2007, whereas the Huisache exceedences were spread out over several years. Although neither monitoring location is a "neighborhood" location comprised mostly of homes, a few homes remain within ¼ mile of the Huisache location. People who walk, run, and bike near these facilities and near the ship channel might be exposed to these levels of hydrogen sulfide on rare occasions. Continuous monitoring of hydrogen sulfide at the other stationary air monitor locations showed levels below the acute EMEG/MRL.

In all, hydrogen sulfide exceeded the acute EMEG/MRL in 16% of mobile monitoring samples. ATSDR notes that these samples were collected using various methods and averaging times, in which the acute EMEG/MRL was exceeded in anywhere from 5–68% of the samples. The maximum hydrogen sulfide level was 2,000 ppb. Although one study observed a LOAEL of 2,000 ppb in persons with asthma, this study did not find a NOAEL, and health effects could potentially occur at lower concentrations. Overall, because maximum levels are at and are approaching the LOAEL, and because health effects could potentially occur at concentrations lower than the LOAEL, ATSDR concludes that, on rare occasions, hydrogen sulfide air concentrations along Refinery Row indicate levels that could potentially cause harmful health effects in sensitive groups (e.g., persons with asthma).

ATSDR also notes that when hydrogen sulfide exceeds its odor threshold, people who live and work along Refinery Row may experience odor-related health symptoms (see odor discussion in Section N1 of Appendix N). All stationary air monitors and mobile monitors found hydrogen sulfide above odor thresholds. Community concern about recurring odors throughout Refinery Row may be associated with hydrogen sulfide in the ambient air.

Long-term noncancer exposure: The U.S. EPA based its RfC on the same study as the ATSDR intermediate CV [Brenneman et al. 2000]. For the RfC, U.S. EPA converted the NOAEL into a human equivalent dose and treated with an uncertainty factor of 300 (3 for use of an animal study, 10 for use of a subchronic study, and 10 for human variability) to achieve the 1.4-ppb RfC.

Overall, hydrogen sulfide was detected in 63% of the samples. The highest mean at any location (1.44 ppb) is similar to the U.S. EPA RfC, which is considered protective against health effects from chronic exposure. No other mean concentrations exceeded the RfC. Because the highest mean is very close to the RfC and about three orders of magnitude below the lowest documented health effect levels, ATSDR does not expect that long-term exposure to hydrogen sulfide concentrations in Refinery Row air would cause harmful noncancer health effects.

7.6. Naphthalene

Naphthalene is a white, easily evaporating solid. Naphthalene is a product of burned tobacco and coal and a natural component of fossil fuels, such as petroleum and coal. Naphthalene's major commercial use is as a precursor constituent for the production of polyvinyl chloride (PVC) plastics. The major consumer products made from naphthalene are moth repellents, in the form of mothballs or crystals, and toilet deodorant blocks. It is also used for making dyes, resins, leather tanning agents, and the insecticide carbaryl [ATSDR 2005b].]. Naphthalene is a component of crude oil and is a byproduct of petroleum refining [IARC 1989]. Naphthalene enters the environment mostly from burned wood and burned fossil fuels in the home, followed by the use of moth repellents. Only about 10% of the naphthalene entering the environment is from coal production and distillation. Monitoring studies of outdoor ambient air levels of naphthalene have reported concentrations in the range of about 0.08–32.4 ppb, with a median naphthalene concentration of 0.2 ppb reported for urban/suburban air samples collected from 11 U.S. cities [ATSDR 2005b]. The highest outdoor air concentrations have been found in the immediate vicinity of certain industrial sources and hazardous waste sites. ATSDR has a chronic EMEG/MRL of 0.7 ppb, U.S. EPA has an RfC of 0.57 ppb, and Cal. EPA has a carcinogenic SL of 0.014 ppb. TCEQ has a naphthalene short-term (95 ppb) and long-term (9.5 ppb) AMCV.

Short-term exposure: Naphthalene concentrations did not exceed the TCEQ short-term AMCV. Thus ATSDR does not expect that short-term exposures to naphthalene concentrations along Refinery Row would result in harmful health effects.

Long-term noncancer exposure: Only one location detected naphthalene over 20% of the time, allowing a mean calculation by the methods described in Appendix G. This mean was 0.058 ppb (pre-2005 sampling data), which is an order of magnitude below the ATSDR EMEG/MRL and U.S. EPA RfC. As such, ATSDR does not expect long-term exposures to the naphthalene levels detected in Refinery Row air to result in harmful noncancer health effects.

Cancer risk: NTP has classified naphthalene as a reasonably anticipated human carcinogen [NTP 2011]. Although IARC has listed naphthalene as a possible human carcinogen, the U.S. EPA has deemed that its carcinogenic potential could not be determined. Thus far, only Cal. EPA has developed an IUR for naphthalene: 3.4×10^{-5} $(\mu g/m^3)^{-1}$ based on the same studies as the chronic noncancer CVs. These studies found increased incidences of cancers of the nasal passages at a CEL of 10 ppm (or 10,000 ppb) [Cal EPA 2008; ATSDR 2005b; Abdo et al. 2001; NTP 2000, 1992]. As stated previously, only one location yielded enough data to calculate the mean, which, at 0.058 ppb exceeds the Cal. EPA 0.014-ppb carcinogenic SL. The cancer risks associated with various concentrations of naphthalene, based on the Cal. EPA IUR, are in Table 27B, Appendix B. Using the Cal. EPA IUR, the 0.058-ppb mean corresponds to 1.0 additional case of cancer per 100,000 persons, a risk that ATSDR considers low (see Table 28B, Appendix B).

7.7. Particulate Matter

The following description of particulate matter (PM) is from the U.S. EPA Integrated Science Assessment for Particulate Matter [USEPA 2009]:

> PM is the generic term for a broad class of chemically and physically diverse substances that exist as discrete particles (liquid droplets or solids) over a wide range of sizes. Particles originate from a variety of anthropogenic stationary and mobile sources, as well as from natural sources. Particles may be emitted directly or formed in the atmosphere by transformations of gaseous emissions such as sulfur oxides (SO_X), nitrogen oxides (NO_X), and volatile organic compounds (VOC). The chemical and physical properties of PM vary greatly with time, region, meteorology, and source category.

Particulate matter has been associated with a range of respiratory and cardiovascular health problems. Health effects linked to exposure to ambient particulate matter include the following: premature mortality (or death), aggravation of respiratory and cardiovascular disease, aggravated asthma, acute respiratory symptoms, chronic bronchitis, decreased lung function, and increased risk of heart attack [USEPA 2009]. There is no specific PM concentration that is a threshold of health effects.

The size of the PM is directly linked to its potential for causing health problems. U.S. EPA groups PM into two categories [USEPA 2009]:

- Inhalable coarse particles (PM_{10}), which are between 10 and 2.5 microns in diameter and can pass through the throat and nose to enter the lungs, and
- Fine particles ($PM_{2.5}$), which are less than 2.5 microns in diameter and can lead to deeper penetration of the lungs and higher toxicity.

PM_{10} is primarily produced by mechanical processes such as construction activities, road dust re-suspension and wind. $PM_{2.5}$ originates primarily from combustion sources—like wood smoke, motor vehicle exhaust, and emissions from power plants—and certain industrial processes [USEPA 2009]. Although both can mobilize with wind, PM_{10} is more rapidly deposited and travels shorter distances than $PM_{2.5}$ [Hiranuma et al. 2011]. The risk for various health effects has been shown to increase with exposure to PM. The lowest concentrations at which adverse health effects have been demonstrated is not greatly above $PM_{2.5}$ background concentrations, which have been estimated to be 3–5 µg/m^3 in both the United States and western Europe [WHO 2005].

U.S. EPA's regulation of PM has evolved over the years with the increasing knowledge of health effects associated with exposure to PM. In 1971, U.S. EPA first regulated total suspended particulate (TSP). In 1987, U.S. EPA began to regulate PM_{10} instead of TSP, and $PM_{2.5}$ was first regulated in 1997. The most recent research suggests that $PM_{2.5}$ and PM_{10} are better indicators of exposure to particles than TSP. By definition, PM_{10} is a subset of TSP, and $PM_{2.5}$ is a subset of both TSP and PM_{10}. The current primary National Ambient Air Quality Standards (NAAQS) for PM are as follows [USEPA 2012c]:

- **PM_{10}**: The 24-hour average must not exceed 150 µg/m^3 more than once per year on average over three consecutive calendar years.
- **$PM_{2.5}$**: The annual average concentrations of $PM_{2.5}$, averaged over three consecutive calendar years, should not exceed 12 µg/m^3. Further, the 98th percentile of 24-hour average $PM_{2.5}$ concentrations in one year, averaged over three consecutive calendar years, must not exceed 35 µg/m^3.

ATSDR notes the World Health Organization's (WHO's) air quality guidelines (AQGs) for PM_{10} and $PM_{2.5}$ are lower than the U.S. EPA's NAAQS [WHO 2005]:

- **PM_{10}**: The WHO annual average AQG is 20 µg/m^3 and the 24-hour AQG is 50 µg/m^3.
- **$PM_{2.5}$**: The WHO annual average AQG is 10 µg/m^3 and the 24-hour AQG is 25 µg/m^3.

But the WHO AQGs are health-based guidelines, not regulatory standards. Unlike the WHO guidelines, NAAQS for PM are regulatory standards based on technological feasibility and economic considerations in addition to public health priorities. U.S. EPA study evaluated air quality trends from 2005–2007 at more than 2,000 ambient air monitoring stations in metropolitan areas around the U.S. and found that more than half of these stations had $PM_{2.5}$ and PM_{10} annual average concentrations greater than the WHO AQGs. This same study found that $PM_{2.5}$ and PM_{10} 24-hour averages exceeded the WHO AQGs in more than 5% of the samples [USEPA 2009]. ATSDR notes that trend site data are mentioned to put background concentrations into perspective for the reader—not to imply the acceptability of the levels from a public health perspective.

Short-term noncancer exposure: In 2012, U.S. EPA completed a review and assessment of numerous studies relevant to assessing the health effects of PM that were published too recently to be included in their 2009 PM Integrated Science Assessment [USEPA 2012d]. A limited number of studies conducted in the U.S. and Canada show associations between short-term $PM_{2.5}$ exposure and mortality at mean 24-hour average concentrations greater than 12.8 µg/m^3 [USEPA 2012d]. U.S. EPA's recent survey and provisional assessment of studies found new multi-city and single-city studies that demonstrate consistent, positive associations for respiratory effects with mean 24-hour average $PM_{2.5}$ concentrations ranging from 6.7–22.0 µg/m^3 [USEPA 2012d]. U.S. EPA also found new studies that demonstrate consistent positive associations for cardiovascular effects with mean 24-hour average $PM_{2.5}$ concentrations ranging from 6.7–15.3 µg/m^3 [USEPA 2012d]. For these short-term $PM_{2.5}$ studies, ATSDR notes the studies primarily focused on potentially sensitive populations, such as people with heart or lung diseases, children, and older adults. Although to a lesser extent than $PM_{2.5}$, short-term exposure to PM_{10} has also been associated with increases in mortality, cardiovascular, and respiratory effects in areas with mean 24-hour average concentrations as low as 6.1 µg/m^3, 7.4 µg/m^3, and 5.6 µg/m^3, respectively [USEPA 2009].

TCEQ collected 24-hour average PM samples every 6 days at the Dona Park, Fire Station #5, Huisache, and Navigation stationary air monitors. ATSDR evaluated whether the measured levels of particulate matter were numerically above the NAAQS and did not evaluate the data using the statistical approach used by U.S. EPA under its regulatory authority. The maximum PM_{10} 24-hour level measured was 102 µg/m^3, which is below its NAAQS of 150 µg/m^3. The maximum $PM_{2.5}$ 24-hour level was 38.9 µg/m^3. All but two $PM_{2.5}$ values are below its NAAQS of 35 µg/m^3. But both PM_{10} and $PM_{2.5}$ maximum levels exceed the more conservative WHO AQGs. As stated previously, it is not uncommon for PM measurements to exceed WHO's AQGs.

The U.S. EPA's Web site has an Air Quality Index (AQI) online tool known as "AIRNow AQI Calculator", which can be used to estimate potential health effects from known 24-hour levels of PM_{10} and $PM_{2.5}$ (see http://airnow.gov/index.cfm?action=resources.conc_aqi_calc). Based on the PM_{10} maximum 24-hour concentrations in Refinery Row air, U.S. EPA's online calculator finds that the "air quality is acceptable" and classifies the air quality index as "moderate" [USEPA 2015]. Although at these maximum PM_{10} concentrations, U.S. EPA cautions that "unusually sensitive people should consider reducing prolonged or heavy exertion" outdoors [USEPA 2015]. Overall, 24-hour PM_{10} air concentrations along Refinery Row are below the current NAAQS and therefore, ATSDR does not expect that short-term exposures would result in harmful health effects.

Most $PM_{2.5}$ samples (i.e., over 71%) showed levels less than or equal to 12 µg/m^3, which the U.S EPA online calculator classifies as "good" [USEPA 2015]. About 28% of the $PM_{2.5}$ samples collected are classified as "moderate", which U.S. EPA considers acceptable to breathe but cautions that "unusually sensitive people should consider reducing prolonged or heavy exertion" outdoors [USEPA 2015]. Only two $PM_{2.5}$ 24-hour concentrations in Refinery Row air (i.e., pre-2005 maximum concentrations found at the Huisache and Navigation air monitoring sites) are classified by U.S. EPA's online calculator as "unhealthy for sensitive groups" and "people with respiratory or heart disease, the elderly, and children are the groups most at risk" [USEPA 2015]. Using this online calculator, ATSDR concludes that these maximum $PM_{2.5}$ air concentrations along Refinery Row in the past, while rare, are numerically above NAAQS and represent an increased likelihood of respiratory and cardiopulmonary symptoms in sensitive individuals. Although current $PM_{2.5}$ levels are below NAAQS, the data are limited because only two stationary air monitors along Refinery Row currently monitor $PM_{2.5}$ levels.

Long-term noncancer exposure: In 2006, U.S. EPA revoked the annual PM_{10} standard because available evidence generally did not suggest a link between long-term exposure to coarse particles and health problems. ATSDR therefore evaluates average $PM_{2.5}$ levels, not average PM_{10} levels, to determine the likelihood of noncancer health effects from chronic exposure to particulate matter.

As stated previously, in 2012, the U.S. EPA completed a review and assessment of numerous recent studies that were not included in their 2009 PM assessment [USEPA 2012d]. Generally, there is evidence for an association between long-term exposure to $PM_{2.5}$ and mortality (i.e., all-cause and cardiovascular) within the range of long-term mean $PM_{2.5}$ concentrations of 10–32 µg/m^3 [USEPA 2012d]. Studies provide evidence for respiratory symptoms and incident asthma, as well as respiratory hospitalizations, at long-term mean $PM_{2.5}$ concentrations ranging from 9.7–27 µg/m^3 [USEPA 2012d]. U.S. EPA also finds that

- "Evidence is accumulating from epidemiologic studies for effects on low birth weight and infant mortality, especially due to respiratory causes during the post-neonatal period. The mean $PM_{2.5}$ concentrations during the study periods ranged from 5.3–27.4 µg/m^3" [US EPA 2009].
- "Recent evidence remains inconsistent for the association between exposure to $PM_{2.5}$ and preterm birth, with some studies providing evidence for an association (Chang et al. 2012; Wu et al. 2009), while others did not (Rudra et al. 2011; Darrow et al. 2009)" [EPA 2012d].

As noted earlier in this section, WHO currently recommends an annual $PM_{2.5}$ concentration of 10 µg/m^3. However, WHO acknowledges this guideline "represents the lower end of the range over which significant effects on survival were observed in the American Cancer Society's (ACS) study (Pope et al. 2002)" [WHO 2006]. The guideline also "places significant weight on the long-term exposure studies that use the ACS and the Harvard Six-Cities data (Dockery et al. 1993; Pope et al. 1995, 2002; HEI 2000; Jerrett 2005)" [WHO 2006]. Thresholds (exposure levels where health effects are first seen) are not apparent in these studies [WHO 2006]. The historical average $PM_{2.5}$ concentration was 18 µg/m^3 (range 11.0–29.6 µg/m^3) in the Six-Cities Study and 20 µg/m^3 (range 9.0–33.5 µg/m^3) in the ACS study [WHO 2006]. In the ACS study, statistical uncertainty in the risk estimates becomes apparent at concentrations of about 13 µg/m^3, below which the confidence bounds significantly widen because of the variability in the exposure concentrations. The results of the Dockery et al. (1993) study found the risks are similar in the cities with the lowest long-term $PM_{2.5}$ concentrations (i.e., 11 µg/m^3 and 12.5 µg/m^3). Increases in risk are apparent in the city with the next lowest long-term $PM_{2.5}$ average concentration (14.9 µg/m^3), indicating that when annual mean concentrations are in the range of 11–15 µg/m^3, health effects can be expected [WHO 2006].

In Refinery Row air, the mean concentrations of $PM_{2.5}$ ranged from 9.1–11 µg/m^3. Most $PM_{2.5}$ mean levels are above the more conservative annual average WHO AQGs. However, all airborne $PM_{2.5}$ means are lower than the annual average U.S. EPA NAAQS of 12 µg/m^3. Thus, ATSDR concludes average $PM_{2.5}$ levels in Refinery Row air are not expected be associated with harmful health effects.

Cancer risk: Although PM has been linked to some cancers, because of the varying composition of PM, a chemical-specific cancer risk cannot be calculated for PM as a whole. The cancer risks due to some of the metals that were speciated from the PM samples are discussed in their respective sections. These metals include arsenic, cadmium, chromium, cobalt, and lead.

7.8. Sulfur Dioxide

Sulfur dioxide is a gas formed when fuels containing sulfur (e.g., coal) are burned, when metal is smelted, and when other industrial processes occur. On a national level, manufactured sulfur dioxide emissions are principally from fuel combustion at electricity-generating facilities and other industrial sources; fuel combustion in mobile sources accounts for smaller amounts [USEPA 2008a, 2008b]. Cement manufacturing facilities and steel mills also emit sulfur dioxide. Sulfur is a component of crude oil and gaseous sulfur compounds such sulfur dioxide are emitted during removal and treatment of sulfur at petroleum refineries [IARC 1989]. A U.S. EPA review of 1-hour ambient sulfur dioxide samples from air monitors both inside and outside consolidated metropolitan statistical areas (CMSAs) found an average of concentration of 4 ppb for both datasets. The maximum values found were 714 ppb inside CMSAs and 636 ppb outside CMSAs [USEPA 2008b]. ATSDR notes that ambient data are mentioned to put background concentrations into perspective for the reader—not to imply the acceptability of the levels from a public health perspective.

ATSDR has an acute EMEG/MRL of 10 ppb, and the U.S. EPA has a NAAQS 1-hour standard of 75 ppb. IARC considers sulfur dioxide "not classifiable" as a carcinogen.

Short-term exposure: High sulfur dioxide concentrations in air affect breathing and might aggravate ongoing respiratory and cardiovascular disease. Human health studies (clinical investigations and epidemiologic studies) have provided strong evidence of a causal relationship between sulfur dioxide and respiratory diseases in people with asthma. Children and older adults have also been identified as groups sensitive to the health problems associated with breathing sulfur dioxide [USEPA 2010a, 2008b].

Sulfur dioxide exposure can result in both symptomatic (i.e., coughing, wheezing, chest tightness) and asymptomatic (i.e., bronchoconstriction) health effects. In the general population (including healthy people with no preexisting respiratory illness), respiratory effects such as increased airway resistance and decreased forced expiratory volume begin to occur around 1,000 ppb. During times of elevated inhalation rates (e.g., breathing harder during exercise), sensitive persons such as children, elderly, those with asthma, and those with other respiratory conditions might cough, wheeze, and experience chest tightness at concentrations as low as 400 ppb [USEPA 2008a; ATSDR 1998]. Multiple studies have documented asymptomatic effects such as bronchoconstriction (when the airways of the lungs constrict) in those with mild to moderate asthma during physical activity (e.g., exercising) when exposed to 200-ppb sulfur dioxide for 5-10 minutes [Horstman et al. 1986; Boushey and Holtzman 1985]. The lowest documented asymptomatic effects have been observed in persons with asthma at concentrations as low as 100 ppb when sulfur dioxide was administered via mouthpiece [Koenig et al. 1990; Sheppard et al. 1981]. These exposures, however, cannot be directly compared with exposures among freely breathing subjects.

Short-term exposure to sulfur dioxide has also been linked to cardiovascular disease. One study on older adults (65+ years) in Los Angeles County found a 14% excess risk in hospital cardiovascular admissions per 10 ppb increase in the sulfur dioxide 24-hour average level. The median sulfur dioxide 24-hour average for Los Angeles County was 2 ppb during the study period [Moolgavkar 2000].

The above-referenced critical studies were performed under laboratory conditions with controlled humidity and temperature, whereas actual exposures might occur in colder and dryer conditions reported to result in an increased response [Bethel et al. 1984; Linn et al. 1985]. In addition, some of these studies did not include potentially more sensitive populations (children, obese individuals, individuals with pro-inflammatory state like diabetics, adults more than 65 years of age, and persons with preexisting respiratory and cardiopulmonary disease) who might be at risk for effects at lower sulfur dioxide concentrations or more severe effects at equivalent concentrations. Sensitive populations might also experience more symptoms when there is exposure to other chemicals in addition to sulfur dioxide in the air. Because of the above limitations of the critical studies and the fact that bronchoconstrictive responses to sulfur dioxide are also highly variable among persons with asthma [Horstman et al. 1986], a potential for harmful health effects remains for sensitive persons at sulfur dioxide levels below 200 ppb.

The ATSDR 10-ppb acute EMEG/MRL is based on an acute human study that found a LOAEL of 100 ppb for significant increases in airway resistance during moderate exercise by persons with asthma breathing via a mouthpiece (oral breathing), which bypasses the nasal mucosa's protective effect [Sheppard et al. 1981; ATSDR 1998]. This LOAEL was treated with an uncertainty factor of 9 (3 for use of a LOAEL and 3 for human variability) to achieve the ATSDR acute EMEG/MRL.

Overall, sulfur dioxide was detected in 37% of the stationary air monitor 1-hour samples and exceeded ATSDR's acute EMEG/MRL in 1.5% of these samples. All stationary air sampling locations exceeded the acute EMEG/MRL at some point in time, with maximum concentrations of sulfur dioxide ranging from 19.2–630 ppb.

Samples collected during mobile monitoring events were higher, and the maximum concentrations from various data ranged from 73–6,745 ppb. In all, 44% of the mobile monitoring samples exceeded the 10-ppb acute EMEG/MRL. Before 1996, these data indicated maximum sulfur dioxide levels were rarely above 1,000 ppb, which is the effect level documented for the general population. Table 22B, Appendix B, provides additional information regarding the mobile monitoring data with regard to the number of sulfur dioxide samples exceeding health-based guidelines as well as exceeding levels found in the clinical studies.

ATSDR believes that peak concentrations—such as 5-minute average measurements—are the best data available for evaluating the health implications of acute sulfur dioxide exposure. Thus far, the sulfur dioxide data presented in this document for the stationary air monitors uses the 1-hour measurements downloadable from TCEQ's TAMIS database. In addition to these datasets, for the 2005−2009 period ATSDR obtained 5-minute average sulfur dioxide measurements for stationary air monitors in a mostly industrial area (Huisache) and in a neighborhood area (Tuloso Midway Middle School). Although these 5-minute average datasets do not include all stationary air monitors or all time frames, they do provide additional information to inform ATSDR's sulfur dioxide public health analysis. The 5-minute stationary monitors exceeded the acute EMEG/MRL in 4.1% of samples, with a maximum concentration of 535 ppb. Table 23B, Appendix B, has additional information regarding the 5-minute average measurements, specifically with regard to the number of sulfur dioxide samples exceeding health-based guidelines as well as exceeding levels found in the clinical studies.

The majority of the continuous, stationary air monitoring data indicate short-term exposures to sulfur dioxide levels in Refinery Row air are not expected to result in harmful health effects. That said, however, maximum sulfur dioxide concentrations from the 5-minute and 1-hour averaged stationary air data, although rare, indicate levels that could potentially cause respiratory health effects in sensitive populations (e.g., people with asthma or other related preexisting conditions, children, and older adults) during times of elevated inhalation rates (e.g., breathing harder during exercise). Mobile monitoring data confirm that infrequently detected sulfur dioxide levels could potentially cause acute respiratory and cardiovascular health effects in sensitive populations. Furthermore, before 1996, maximum sulfur dioxide concentrations detected on rare occasions during mobile monitoring events suggested the potential for harmful health effects in the general population (e.g., healthy persons without asthma or other condition that would increase their susceptibility to sulfur dioxide exposure). But after the exposure has ended, these effects will subside.

Long-term noncancer exposure: The overall available evidence from the generally limited number of epidemiologic and animal toxicological studies is inadequate to infer that chronic exposure to sulfur dioxide results in harmful health effects. While some studies have observed increases in respiratory, cardiovascular, and developmental effects and mortality, the available evidence, as a whole, is inconclusive and cannot determine causality [USEPA 2008b, 2010a].

Although some studies have shown long-term exposure to sulfur dioxide is associated with low birth weight, neonatal deaths, and increased risk of sudden infant death syndrome (SIDS), evidence of reproductive and developmental toxicity has been inconclusive because 1) there are inconsistent results across trimesters of pregnancy, 2) evidence is lacking regarding confounding by copollutants, and 3) only a few studies exist on birth defects. One seven county study in Texas between 1997 and 2000 observed a significant increased risk of ventricular septal birth defects when comparing the highest (≥2.7 ppb) and lowest (<1.3 ppb) quartiles of exposure [Gilboa 2005]. Although this is the only study described in the U.S. EPA integrated science assessment to observe the effect of maternal exposure to sulfur dioxide on birth defects, it offers some evidence that the developing embryo and growing fetus are susceptible to maternal air pollution exposure [USEPA 2008b].

Monitors at the Huisache and Tuloso Midway Middle School were the only monitors to record sulfur dioxide concentrations before 2005. Using the 95% confidence interval of the means (see Table 21B, Appendix B), the sample means from both locations from 1998−2004 were statistically higher than those from 2005−2010, which might indicate a decreasing trend in sulfur dioxide concentrations in the area. The highest mean from the stationary monitors was 2.69 ppb. For the 2005–2010 period, mean sulfur dioxide levels in neighborhood areas are all <1 ppb. ATSDR notes that Refinery Row area average sulfur dioxide levels are within levels currently found in the United States. Overall, there is inconclusive evidence for a definitive health conclusion regarding long-term exposure to Refinery Row sulfur dioxide levels.

7.9. Combined Exposure Evaluation—Chemical Mixtures

In this section, ATSDR evaluates exposures to chemical mixtures to the extent health effects information is available. ATSDR's screening approach for the evaluation of chemicals mixtures integrates the use of its toxicological profiles, its interaction profiles, and ATSDR-sponsored research on chemical mixtures, when available. The mixtures evaluation can be used along with community-specific health outcome data and community health concerns to determine public health implications and follow-up activities [ATSDR 2004]. Note that acute toxicity evaluation is based on maximum values that vary with time for each chemical (i.e., maximum values might not occur simultaneously for all chemicals in the mixture). Thus, ATSDR focuses its chemical mixtures screening calculations on long-term noncancer and cancer risk. Short-term exposures to pollutants are only discussed qualitatively.

There are relatively few chemical mixtures studies that have assessed toxic interactions in low dose ranges. ATSDR acknowledges the science of evaluating chemical mixtures is still evolving and recognizes there are many uncertainties in any chemical mixtures evaluation. Overall, ATSDR's analysis of mixtures aims to identify studies that document the health effects of the same or similar chemical mixtures to those found in the Refinery Row area. In absence of these studies, ATSDR compiles toxicological information on the individual contaminants and assumes that contaminants with similar effects will have an additive dose. This assumption of additivity assumes that the contaminants all act independently of each other and does not take in to account any interaction (positive or negative) between contaminants.

7.9.1. Short-term Exposure to Chemical Mixtures

In Section 7, ATSDR's evaluation of individual contaminants found that, on a few occasions, short-term exposure to benzene, hydrogen sulfide, particulate matter, and sulfur dioxide in Refinery Row air could potentially cause harmful respiratory health effects, especially in sensitive populations. ATSDR did not find any studies on this mixture or any similar mixture with which to base its site-specific chemical mixtures evaluation, and assumed exposure to these contaminants results in an additive dose. As stated previously, ATSDR's assumption of additivity assumes that the contaminants all act independently of each other and does not take in to account any interaction (positive or negative) between contaminants. Short-term exposure to the maximum levels of these chemicals in Refinery Row air could potentially lead to a combined acute respiratory health effect greater than that of the individual contaminants if their maximum concentrations occur simultaneously (i.e., occur at the same time and in the same place). Exposure to mixtures of these contaminants could lead to temporary respiratory effects such as nasal and throat irritation, shortness of breath, and neurological effects such as headaches and other effects related to odors in the community. Note that simultaneous exposure to the maximum levels of these compounds was not observed in the available air monitoring data.

7.9.2. Long-term Noncancer Chemical Mixtures

ATSDR recognizes that exposures to chemical mixtures might result in an additive toxicity greater than the toxicity of any individual chemical. To address the additive toxicity of chemical mixtures in Refinery Row air, ATSDR followed the methods described in its Guidance Manual for the Assessment of Joint Toxic Action of Chemical Mixtures [ATSDR 2004]. For long-term noncancer exposure, ATSDR first calculates a hazard quotient (HQ) by dividing the highest mean concentration of the chemical by its MRL or RfC, whichever is lowest. This creates a ratio of the chemical concentration to a health-based value. An HQ equal to and less than 1 means that the chemical is at or below its MRL or RFC, and an HQ above 1 means that the chemical is present above its MRL or RfC. For inclusion in ATSDR's long-term noncancer mixtures evaluation of Refinery Row air, a chemical must

1. Be selected for further consideration based on ATSDR's refined data screening (see Table 2 in Section 4.3.3),
2. Have a noncancer MRL or RfC,
3. Be detected in more than 20% of the samples, allowing ATSDR to calculate a mean concentration based on the procedures described in Appendix G, and
4. Have an HQ equal to or greater than 0.1.

ATSDR's chemical mixtures guidance recommends not including chemicals with an HQ of less than 0.1 in the mixtures analysis [ATSDR 2004]. Table 29B, Appendix B, contains the HQs for those chemicals that meet the first three criteria. From this table, ATSDR chose five compounds (benzene, chromium, hydrogen sulfide, naphthalene, and trichloroethylene) for its noncancer mixtures evaluation based on the last criteria (i.e., having an HQ equal to or greater than 0.1).

For ATSDR's noncancer mixtures analysis, ATSDR first checked its available interaction profiles for these five compounds. Hydrogen sulfide and naphthalene are not mentioned in any interaction profile. The other three are in one or more interaction profiles, but not with any of the other chemicals in Table 30B, Appendix B. ATSDR did not find any studies on this mixture or any similar mixture with which to base this evaluation, and assumed exposure to these contaminants results in an additive dose. As stated previously, ATSDR's assumption of additivity assumes that the contaminants all act independently of each other and does not take in to account any interaction (positive or negative) between contaminants.

ATSDR organized the five compounds based on the types of toxicity they may cause. Because none of these chemicals are expected to have a synergistic effect that would suggest the toxicity of the mixture of chemicals would be higher than the sum of the individual chemical toxicities, the HQs of chemicals exhibiting similar toxicity to the same organ system are summed together to reflect the additive toxicity to each specific system. The hazard index (HI) is the sum of the HQs for a specific endpoint. When the HI is greater than 1, ATSDR assesses whether the overlapping toxicities from the chemicals in the mixture are a potential risk for that organ system.

For ATSDR's Corpus Christi Refinery Row evaluation, the HIs for respiratory effects and neurological effects were greater than 1 (see Table 30B, Appendix B). Although the HI for developmental and reproductive effects was below 1, these effects are included in the mixtures evaluation because 1) ATSDR's health outcome data evaluation found increased levels of adverse developmental and reproductive health outcomes (see Section 8), and 2) the community is concerned about birth defects (see Section 9).

Respiratory effects: Based on the long-term noncancer exposure mixtures analysis, benzene, chromium, hydrogen sulfide, and naphthalene contribute to the potential risk for respiratory effects in the area. Studies have linked chronic exposure to these compounds to nasal and throat irritation (benzene), cellular changes in the nasal cavity (chromium and hydrogen sulfide), and nose and lung inflammation (naphthalene). Although the specific chemical reactions with macromolecules within the cell or the upper respiratory tract might vary, the respiratory effects from these chemicals are similarly based on cellular interactions at the site of exposure. ATSDR notes that $PM_{2.5}$, which was not included in the HQ calculations because it lacks an MRL or RfC, also can contribute to the potential risk for respiratory effects for people who are sensitive to the effects of this pollutant.

Although the screening values of hydrogen sulfide, chromium, and naphthalene are based on studies observing respiratory effects, ATSDR notes that benzene's chronic screening value is not based on the respiratory endpoint. From the ATSDR Toxicological Profile on Benzene [ATSDR 2007], respiratory effects of benzene occur roughly two orders of magnitude higher than hematological effects, which is the critical effect for derivation of the benzene chronic screening value. Although hydrogen sulfide was detected in about 63% of the samples, the highest mean level at any station was about three orders of magnitude below the lowest documented health effect levels. In addition, chromium (VI), the most hazardous chromium species, is believed to be a fraction of the total chromium measured at this site, and the highest mean total chromium concentration (0.0017 µg/m^3) is three orders of magnitude below its 0.1 µg/m^3 RfC. Assuming the total chromium measured in Refinery Row air is all chromium (VI) will likely overestimate the chromium contribution to potential respiratory effects from chemical mixtures. Further, naphthalene was not consistently detected across all sites, and a mean concentration could only be calculated for Oak Park Elementary School prior to 2005. Although the science of evaluating chemical mixtures is still evolving and there are many uncertainties in any chemical mixtures evaluation, for the reasons provided in this paragraph, ATSDR does not expect long-term exposure to chemical mixtures at Refinery Row to be of health concern for healthy individuals for the respiratory endpoint.

Neurological effects: Benzene, hydrogen sulfide, and trichloroethylene contribute to the potential risk for neurological effects. Benzene and hydrogen sulfide have been documented to cause neurological effects at similar concentrations to their hematological and respiratory effect endpoints, respectively, which are the basis for their screening values. However, the neurological effects (i.e., fatigue, dizziness, headache, and nausea) found in the studies are related to acute (or repeated acute) exposures rather than chronic exposures. Further, these neurological effects are from occupational (i.e., worker) exposures that show contaminant levels higher than encountered by the general population. The screening value for trichloroethylene is based on studies documenting immunological and developmental effects, and the neurological effects from trichloroethylene have been documented to occur at higher concentrations. Further, while benzene and hydrogen sulfide were consistently detected at all stationary air monitors in the area, trichloroethylene was not. Thus the contribution of trichloroethylene to potential neurological effects is likely overestimated. Although the science of evaluating chemical mixtures is still evolving and there are many uncertainties in any chemical mixtures evaluation, for the reasons provided in this paragraph, ATSDR does not expect long-term exposure to chemical mixtures at Refinery Row to be of health concern for the neurological endpoint.

Developmental and reproductive effects: Benzene and trichloroethylene contribute to the potential for developmental effects. In addition, particulate matter, which was not included in the HQ calculations because it lacks an MRL or RFC, has been associated with developmental and reproductive effects as well [USEPA 2009]. Chronic exposure to these compounds has been linked to intrauterine growth reduction (benzene and trichloroethylene), fetal heart malformations (trichloroethylene), and alterations to the sperm and testis (benzene and trichloroethylene). ATSDR notes these developmental and reproductive endpoints have varying mechanisms leading to the health effect. Further, while developmental effects are one of the critical effects for the derivation of the trichloroethylene chronic screening value, the screening value for benzene is based of hematological effects which occur more than an order of magnitude lower than developmental effects. Thus the contribution of benzene to potential developmental and reproductive effects may be overestimated. And as noted earlier, trichloroethylene was not consistently detected across all stationary air monitors. Although the science of evaluating chemical mixtures is still evolving and there are many uncertainties in any chemical mixtures evaluation, for the reasons provided in this paragraph, ATSDR does not expect long-term exposure to chemical mixtures at Refinery Row to be of health concern for the developmental and reproductive endpoint.

7.9.3. Cancer Chemical Mixtures

As stated previously, ATSDR calculated cancer risk estimates for chemical carcinogens (see Table 28B, Appendix B). To be included in ATSDR's cancer mixtures evaluation of Refinery Row air, a chemical must be selected for further consideration based on ATSDR's refined data screening of the routine stationary air monitoring results, and be a known or possible air carcinogen with an inhalation unit risk factor derived by Cal. EPA, U.S. EPA, or TCEQ. Because carcinogens are not expected to exhibit a threshold response like most noncarcinogens, ATSDR chose to include carcinogens detected infrequently during routine stationary air monitoring efforts in its cancer chemical mixtures evaluation.

Assuming additive effects, the cumulative cancer risk estimate for Refinery Row is the sum of the individual chemical risk estimates. The cumulative cancer risk for Corpus Christi Refinery Row air exposure is 1.8×10^{-4}, or about 2 additional cases of cancer per 10,000 people. Thus, breathing a mixture of chemicals found in outdoor air for many years results in an increased risk of cancer. The main contributors to cancer risk in Refinery Row air are benzene (31%), 1,2-dibromoethane (26%), and chromium assumed to be in the hexavalent form (11%). ATSDR notes limitations in its cumulative cancer risk estimate that likely overestimates the cancer risk, such as that 1) different contaminants may cause cancers to different areas of the body via different mechanisms, 2) some chemicals like 1,2-dibromoethane were detected in less than 20% of the samples, and 3) only total chromium levels were available (not the more toxic hexavalent chromium levels) for the risk calculations. Conversely, other limitations could lead to an underestimation of cancer risk, such as the lack of routine monitoring of polycyclic aromatic hydrocarbons (PAHs) that are carcinogens and could have increased the cumulative cancer risk estimate if data had been available.

7.10. Public Health Implications Limitations

The public health implication evaluations in Section 7 and Appendix I have several limitations, some of which are noted here. These limitations include the following:

- ATSDR's evaluation required the examination and interpretation of reliable, substance-specific, health effects data. The evaluation included a review of epidemiologic (human) and experimental (animal) studies. A study based on human data would hold the greatest weight in describing relationships between a particular exposure and a human health effect. But in some cases, only animal studies were available. And the number of studies available for a chemical were not always sufficient to provide a clear picture of the true dose-response, especially where the exposure doses were low.
- Some health-based guidance values ATSDR used to evaluate the likelihood of harmful health effects were not based on the inhalation exposure route. This is typically because human studies regarding health effects by the inhalation route of exposure were not available, and most animal studies specifically examined the oral exposure route. To compensate, ATSDR converted available oral CVs to air concentrations using U.S. EPA breathing rate assumptions (16 cubic meters per day (m^3/day) and 10 m^3/day for adults and children, respectively) and body weight (80 kg and 10 kg for adults and children, respectively). But a converted oral CV is nonetheless a limitation—the chemical's toxicity might be different for oral exposure compared to inhalation.
- Some chemicals had no relevant, health-based guidance values protective of the general population; those chemicals had only worker guidelines. But the worker guidelines only apply to healthy adult employees working 40-hour weeks and not to the general population—including children, the elderly, and the sick—who might be subject to continuous environmental exposure. As such, ATSDR used these worker values to put site-specific concentrations of contaminants into perspective, especially when no other non-occupational comparison values were available.
- Some chemicals were analyzed by a method that did not provide ATSDR with complete information. For example, chromium (VI) was not measured in Refinery Row air. Although chromium (VI) is believed to be a fraction of the total chromium measured, ATSDR treated the total chromium measured in Refinery Row area air as chromium (VI). This approach resulted in the most conservative estimate of risk, and the actual risk will likely be lower.

- Some chemicals, such as cadmium and 1,2-dibromoethane, were detected in less than 20% of the samples; thus, ATSDR could not calculate mean values following the procedures outlined in Appendix G. To evaluate long-term exposure risk, ATSDR instead used the highest 95th percentile value for these chemicals, which is generally a more conservative value than the mean. Additionally, two chemicals (chloroprene and 1,1,2-trichloroethane) were detected in less than 5% of the samples at each location, so the 95th percentile represents a nondetect value. As an alternative, ATSDR used the reporting limit of VOCs in TCEQ canisters (0.01 ppb) divided by the square root of 2 as the concentration to assess long-term noncancer health effects and cancer risk for these chemicals. This approach resulted in the most conservative estimate of risk, and the actual risk will likely be lower.
- The stationary monitoring data may not capture all of the releases the community experiences because these data are not available for all pollutants, over all time frames, and across all locations of interest. Note there are more stationary air monitors focused on measuring levels of volatile compounds like benzene in the outdoor air than monitors focused on measuring levels of metals and particulate matter. However, ATSDR believes the locations of the current monitors provide good coverage overall, especially when combined with the mobile monitoring data. ATSDR also integrates the stationary air monitoring data with the other environmental and health information about the area to provide a more complete picture of Refinery Row air exposures.
- ATSDR completed its evaluation of chemical mixtures for the Refinery Row air shed as a whole. Chemical-specific risk was summed across stationary air monitor locations for its cumulative risk estimates. The agency assumed that contaminants with similar effects will have an additive dose. This assumption of additivity assumes that the contaminants all act independently of each other and does not take in to account any interaction (positive or negative) between contaminants. Note also that because chemical values can spatially vary with each chemical (i.e., the highest values might not occur simultaneously for all chemicals in the mixture at the same location), the actual risk of the chemical mixture will likely be lower.
- The quality of the 1980s metals data is questionable; these historical data might not fully represent ambient air conditions. Although the 1980s data used at the time a widely accepted sampling and analytical approach, more current research suggests that the approach is inappropriate. ATSDR concluded that the metals data collected in the 1980s are of unknown quality. These data were used for screening purposes, but not for drawing definitive health conclusions.
- ATSDR compiled mobile monitoring event data from TCEQ toxicology reports; neither the original laboratory reports nor the data quality procedures were reviewed. Nevertheless, for this public health evaluation, ATSDR assumed the TCEQ toxicology reports contained valid data.

Overall, there are recognized uncertainties in ATSDR's public health evaluation. But providing a framework that puts site-specific exposures and the potential for harm into perspective is one of the primary goals of this health evaluation process [ATSDR 2005a].

8. Health Outcome Data Evaluation

Residents in neighborhoods near Corpus Christi's Refinery Row believe they have higher-than-normal occurrences of

- Asthma
- Birth defects
- Cancers
- Developmental disabilities
- Diabetes
- Nonasthma respiratory illness such as emphysema, chronic bronchitis, and shortness of breath
- Skin disorders

To respond to community concerns, ATSDR reviewed available health outcome data to help determine increased illness patterns in the Corpus Christi Refinery Row area.

The Texas Department of State Health Services[27] routinely collects information on the health of populations within geographic areas throughout the state. For ATSDR's evaluation of residents' health in the Refinery Row area, several state health service programs provided data and provided technical assistance in the appropriate use of those data. This health outcome data evaluation examined data from the Texas Asthma Control Program (TACP), the Texas Birth Defects Registry, the Texas Cancer Registry, and the Texas Diabetes Program. Data sources were not readily available for site-specific evaluation of nonasthma respiratory illness, developmental disabilities, or skin disorders.

ATSDR reviewed available, relevant health outcome data for indications of increased illness in the Refinery Row area. Appendix L provides the technical details of ATSDR's health outcome data evaluation and Section 9 (Community Concerns Evaluation) of the main text provides ATSDR's responses to birth defects, cancer, and asthma concerns.

In summary, the agency's health outcome data evaluation showed increased illness in the following areas:

- In 2009, asthma hospitalization rates among children were higher in Nueces County compared to both San Patricio County and Texas statewide. However, asthma hospitalization rates among adults were similar for Nueces County, San Patricio County, and Texas statewide.
- From 2005 through 2008, asthma hospitalizations among children were markedly higher in Nueces County and San Patricio County than in Texas statewide.
- Compared with mothers living more than 10 miles from Refinery Row[28], mothers living within 2 miles of Refinery Row were about 1.5 times more likely to have offspring with a ventricular septal defect.

[27] Referred to throughout this public health assessment as "Department of State Health Services" (DSHS).

[28] Refers to children of mothers living more than 10 miles from Refinery Row but still within the tri-county (Nueces, San Patricio, and Kleberg) Corpus Christi area.

- Hispanic/Latino mothers living within 2 miles of Refinery Row were 1.8 times more likely to have a child born with "other anomalies of the aorta" than Hispanic/Latino mothers living 10 or more away; and, even after adjustment for maternal education and age, this association persisted.
- Comparisons based on statewide cancer rates show the number of male colon and rectum, bladder, kidney, and liver cancer cases reported for the Corpus Christi Refinery Row area[29] was statistically greater than expected.

Interpretation of ATSDR's health outcome evaluation is limited in that analysis does not include a measure of an individual's actual exposure to toxicants. ATSDR could not therefore make any definitive conclusions about associations between Refinery Row facilities and increased levels of adverse health outcomes. Other limitations are provided in Appendix L.

9. Community Concerns Evaluation

During the public health evaluation process, concerns that community members expressed to ATSDR staff divide into four main groups: 1) odor concerns, 2) health concerns, 3) environmental concerns, and 4) miscellaneous concerns. In this section, ATSDR provides a short summary of its odor concerns analysis (see Appendix N for the detailed discussion). Birth defects, cancer, and respiratory illness (i.e., asthma) are also discussed in this section. ATSDR provides a comprehensive evaluation of other health concerns, environmental concerns, and miscellaneous concerns in Appendix N.

9.1. Odor Concerns

In Appendix N, ATSDR first provides background information on odors and health. ATSDR then screens the maximum detected chemical air concentrations from monitoring in Corpus Christi against available odor threshold values. A few chemicals were detected above their respective odor thresholds infrequently, i.e., less than 10% of the time. ATSDR considers it unlikely that any of these chemicals are associated with the concerns expressed by area residents about recurring odors in their communities' air. However, both the stationary monitors and the mobile monitoring events show hydrogen sulfide regularly above its lowest odor threshold. People who live and work along Refinery Row may experience odor-related health symptoms such as eye irritation, headaches, cough, difficulties in breathing, negative mood states, and stress or annoyance when hydrogen sulfide exceeds its lowest odor threshold.

9.2. Health Concerns

Over the years, Refinery Row area residents expressed several health-related concerns

birth defects	abdominal spasms
Cancer	skin rashes
brain tumors (in particular, pituitary tumors)	Diabetes
respiratory illnesses (in particular, asthma)	Alzheimer's disease

[29] The Corpus Christi Refinery Row area for the cancer rate analyses is defined by ZIP codes 78401, 78402, 78404, 78405, 78406, 78407, 78408, 78409, 78410, 78411, 78416, 78417 and 78370, which approximates a 5-mile buffer surrounding Refinery Row.

attention deficit/hyperactivity disorder	Miscarriages
eye irritation	Stress
burning throat	

to ATSDR staff. Birth defects, cancer, and respiratory illness (i.e., asthma) are discussed here and the remaining health concerns are discussed in Appendix N. ATSDR notes that this public health report includes an evaluation of health outcomes that are of concern to stakeholders and community members (see Section 8 of the main text and Appendix L). ATSDR also notes that similar health outcome data evaluations have been ongoing for decades. The Texas Department of Health (TDH), renamed DSHS in 2004, conducted several investigations of state surveillance data. Their publications have shown increased asthma prevalence in children [TDH 1995], increased birth defects rates [TDH 2001a, 2001b, 2002, 2003; DSHS 2006, 2008a], and an increased incidence of certain cancers in the Corpus Christi area [DSHS 2008b].

9.2.1. Birth Defects

Birth defects can occur during any stage of pregnancy. Most birth defects are thought to be caused by a complex mix of factors, including people's genes, people's behaviors, and things in the environment. For most birth defects, the cause is not known. However, certain things can increase the chances of having a baby with a birth defect and include [CDC 2011]

- Smoking, drinking alcohol, or taking certain "street" drugs during pregnancy.
- Having certain medical conditions, such as being obese or having uncontrolled diabetes before and during pregnancy.
- Taking certain medications, such as isotretinoin (a drug used to treat severe acne).
- Having someone in your family with a birth defect.
- Being an older mother, typically over the age of 34 years.

For over a decade, the DSHS Birth Defects Epidemiology and Surveillance Branch has been investigating birth defect rates in the Corpus Christi area and has published numerous reports documenting elevated birth defects rates in Corpus Christi. Section 4C in Appendix C provides a summary of each of these reports.

For this public health evaluation, ATSDR evaluated chemical levels in outdoor air in the Refinery Row area. The compounds benzene, particulate matter, and trichloroethylene are associated with developmental and reproductive effects. However, these compounds were not found in Refinery Row air at levels of public health concern for developmental and reproductive effects.

As part of the public health evaluation process, the agency did evaluate available birth defects rates (see Appendix L). ATSDR's birth defects health outcome data analysis attempts to answer the question: "Are birth defects more frequent in offspring of mothers living in close proximity to Refinery Row compared to mothers living further away?" ATSDR looked at prevalence rates for specific spatial boundaries, which are defined as up to 2 miles, 2 to 5 miles, 5 to 10 miles, and more than 10 miles from Refinery Row. ATSDR's analysis of the birth defects data showed 2 heart defects (ventricular septal defect and "other anomalies of the aorta") were slightly more common in children based on proximity to Refinery Row. These birth defect increases could be by chance or caused by other risk factors not available for review in this analysis.

Overall, ATSDR continues to find that limits on current science prevent any conclusions that might directly connect Refinery Row industrial sites, releases from those sites, and high birth defect rates. However, the agency supports such ongoing public health efforts as

1. The Texas Birth Defects Registry continuing to monitor birth defects in the Corpus Christi area,
2. The Regional Health Awareness Board (RHAB) organizing meetings with the March of Dimes and others to develop community intervention strategies to prevent birth defects, and
3. RHAB partnering with the public school systems to provide information to young girls about the importance of good nutrition and health care.

Additional resources could provide needed health education programs about the importance of prenatal health care and the dangers to an unborn child of obesity and uncontrolled diabetes, which have been shown to increase the risk of certain birth defects.

Also of note regarding birth defects, U.S. EPA is currently conducting research to examine associations between birth defects and environmental exposures in this region [Wade et al. 2015]. This research is being undertaken as a collaboration between researchers at the DSHS Birth Defects Epidemiology and Surveillance Branch, U.S. EPA's National Health and Environmental Effects Research Laboratory and National Center for Environmental Assessment, and U.S. EPA Region 6. U.S. EPA Region 6 provided locally collected data to be integrated into the research. The research has the following objectives:

1. Explore associations between waterborne exposures, water sources, and proximity to hazardous waste sites and birth defects.
2. Investigate the association between ambient air pollutants (particulate matter, ozone, carbon monoxide, sulfur oxides, nitric oxides, and lead) and birth defects, specifically examining whether the associations differ by maternal age, paternal age, pregnancy-induced hypertension/pre-eclampsia, body mass index, or roadway proximity/intensity [Vinikoor-Imler et al. 2015].
3. Explore the influences of residential proximity to stationary sources of air pollutants identified from the National Emissions Inventory (NEI) and Toxic Release Inventory (TRI) (i.e., incinerator, battery recycling plant, military airfields) and meteorological conditions on the distribution of birth defects in Nueces County, Texas.

This U.S. EPA research project is expected to be completed in the last quarter of 2017.

9.2.2. Cancer

Cancer is not a single disease. It is a group of more than 200 different diseases [ATSDR 2002]. Cancer can be generally described as an uncontrolled growth and spread of abnormal cells in the body. The extra cells may form a mass of tissue called a tumor. Tumors can be benign or malignant.

- Benign tumors are not cancerous and can often be removed. Cells in benign tumors do not spread to other parts of the body.
- Malignant tumors are cancerous. Cells in these tumors can invade nearby tissues and spread to other parts of the body.

Some cancers do not form tumors. For example, leukemia is a cancer of the bone marrow and blood [NCI 2012].

Because cancer is not a single disease, it does not have a single cause. Further, the causes of cancer are very complex, involving both the cell and factors in the environment. Most cancers do not have known causes from a chemical, environmental, genetic, immunologic, or viral origin [ATSDR 2002].

As part of its public health evaluation analysis, ATSDR reviewed the levels of potential carcinogens in the outdoor air and calculated cancer risk estimates. As shown in Table 28B, Appendix B, ATSDR determined that long-term exposure to

- Benzene, cadmium, chromium, 1,2-dibromoethane, and naphthalene in Refinery Row air are associated with a low additional risk of cancer.
- Arsenic, 1,3-butadiene, carbon tetrachloride, chloroform, chloroprene, cobalt, 1,2-dichloroethane, 1,2-dichloropropane, 1,1,2,2,-tetrachloroethane, trichloroethylene, and vinyl chloride in Refinery Row air are associated with a very low additional risk of cancer.
- Isoprene, lead, and 1,1,2-trichloroethane in Refinery Row air are associated with an insignificant risk of cancer.

To address chemical mixtures, ATSDR also calculated the cumulative cancer risk for exposure to the mixture of carcinogenic chemicals in Refinery Row air. The cumulative cancer risk is 1.8×10^{-4}, which is about 2 additional cases of cancer per 10,000 people; thus, breathing a mixture of chemicals found in outdoor air for many years results in an increased risk of cancer. The main contributors to cancer risk in Refinery Row air are benzene, 1,2-dibromoethane, and chromium[30].

From the health outcome data evaluation in Appendix L, the Corpus Christi Refinery Row area[31] shows a statistically higher rate of the following cancers in men: colon and rectum, bladder, kidney, and liver. No increase in cancer rates was observed in women. Of the three major contributors to cancer risk, only benzene, which has been linked to cancers of the blood and liver, is associated with one of the elevated types of cancer found in the Corpus Christi area. Both 1,2-dibromoethane and chromium are most often associated with cancers of the lung.

Although being exposed to certain chemicals can increase the risk of cancer, it is often difficult to determine if cancers are associated with environmental exposures. First, there is typically a long latency period before cancer development, but usually very little information regarding potential environmental exposures that occurred years ago. Further, there are relatively few chemical mixtures studies that have assessed toxic interactions in low dose ranges. In addition, other variables, like behavioral risk factors,

[30] ATSDR notes limitations in its estimates that likely overestimate the cancer risk, such as that 1) some chemicals like 1,2-dibromoethane were detected in less than 20% of the samples, and 2) only total chromium levels were available (not the more toxic hexavalent chromium levels) for the risk calculations. Conversely, other limitations could lead to an underestimation of cancer risk, such as the lack of routine monitoring of polycyclic aromatic hydrocarbons (PAHs) that are carcinogens and could have increased the cumulative cancer risk estimate if data had been available.

[31] The Corpus Christi Refinery Row area for the cancer rate analyses is defined by ZIP codes 78401, 78402, 78404, 78405, 78406, 78407, 78408, 78409, 78410, 78411, 78416, 78417 and 78370, which approximates a 5-mile buffer surrounding Refinery Row.

must be accounted for before making any associations of the disease outcome to a given chemical exposure [ATSDR 2002].

ATSDR recognizes there are uncertainties in evaluating the cumulative effects of carcinogenic chemicals and chemical mixtures. At this time, current science allows for the calculation of cancer risk estimates but does not allow conclusions that might directly connect Refinery Row industrial sites, releases from those sites, and cancer.

9.2.3. Respiratory Illnesses (in particular, asthma)

Respiratory illnesses include chronic diseases of the airways and other structures of the lung. Some of the most common are asthma, chronic obstructive pulmonary disease (COPD), pulmonary hypertension, and respiratory allergies. The main risk factors for chronic respiratory diseases are tobacco smoking, indoor air pollution, outdoor air pollution, and allergens [WHO 2012].

Asthma, a chronic inflammatory disease of the airways, can be aggravated by air pollution [USEPA 2012b]. Asthma causes repeated episodes of wheezing, breathlessness, chest tightness, and nighttime or early morning coughing. Asthma can be controlled by knowing the warning signs of an attack, staying away from things that trigger an attack, and following the advice of doctors or other medical professionals [CDC 2009].

In Section 7, ATSDR's evaluation found that exposure to the maximum levels of benzene, hydrogen sulfide, particulate matter, and sulfur dioxide detected in Refinery Row air, although rare, indicated levels that could potentially result in in respiratory health effects in susceptible populations like people with asthma or other related respiratory illness. Short-term exposure to a mixture of these four compounds in Refinery Row air could potentially lead to a combined acute respiratory health effect greater than that of the individual contaminants if their maximum concentrations occur simultaneously (i.e., occur at the same time and in the same place). Note that simultaneous exposure to the maximum levels of these compounds was not observed in the available air monitoring data. In addition, people who live, visit, and work along Refinery Row may experience upper respiratory symptoms when hydrogen sulfide exceeds it odor threshold.

ATSDR notes from its health outcome data evaluation in Appendix L that Nueces County has a higher rate of asthma hospitalizations among children than Texas as a whole. Exposure to petroleum refinery emissions has been shown to increase adverse respiratory effects in children [Rusconi et al. 2011]. To address the social and economic burden of asthma in Texas, TACP provides asthma-control data, educational materials, and other resources for health care professionals, community-based organizations, schools, and the public. Through its educational partners, TACP provides activities throughout the state (see http://www.dshs.state.tx.us/asthma/default.shtm).

10. Conclusions

In this public health report, ATSDR evaluated whether the chemicals detected in ambient (i.e., outdoor) air along Refinery Row are or have been at levels potentially high enough to cause harm to the health of area residents. ATSDR first evaluated on a chemical-by-chemical basis the detected levels of chemicals found in Refinery Row air within the context of the available data on levels known to cause harmful health effects in animals and humans. Although relatively few studies have assessed toxic interactions in low dose ranges, ATSDR also evaluated the chemical levels detected in Refinery Row air with respect to chemical mixtures to the extent information was available.

After reviewing more than 150 chemicals detected in Refinery Row air, ATSDR reached two health-based conclusions.

1. **Short-term exposure risk:** Benzene, hydrogen sulfide, particulate matter, and sulfur dioxide in Refinery Row outdoor air rarely reached levels associated with harmful acute health. On those rare occasions, ATSDR concludes that breathing the maximum levels measured of these compounds in the past and present in air could potentially harm people's health, especially sensitive populations such as children, older adults, and those with preexisting health conditions.

    - **Benzene**: The ATSDR acute benzene health-based comparion value (CV)[32] was exceeded in 2.7% of the samples from stationary air monitors and in 35% of the samples from mobile monitors. One stationery monitor (Huisache) and several mobile monitors found that maximum benzene levels rarely approach and exceed health effect levels. At the highest levels detected, benzene could potentially cause respiratory irritation and a decrease in various types of blood cells.

      ATSDR notes that the Huisache stationary air monitor is in a sparsely populated area, and the mobile monitors recording the highest levels were on or near facility boundaries. Therefore, workers and people walking, running, and biking near the facilities and the ship channel are more likely to be the ones who might, on rare occasions, be exposed to these higher levels of benzene.

    - **Hydrogen Sulfid**e: Twenty-five out of 349,528 (0.007%) stationary air monitoring samples exceeded the ATSDR acute hydrogen sulfide CV. Hydrogen sulfide exceeded its acute CV in 16% of the mobile monitoring samples.

      Two stationery monitors (Huisache and JI Hailey) and several mobile monitors found maximum hydrogen sulfide levels that are at and approaching health effect levels. These maximum levels of hydrogen sulfide in Refinery Row air, although rare, indicate levels that could potentially cause respiratory effects in people with asthma. The Huisache monitor is in a sparsely populated area, whereas JI Hailey is to the north of Refinery Row and not near any homes. Workers and people walking, running, and biking near the facilities and the ship

[32] Health-based comparison values (CVs) are estimates of daily human exposure to a chemical that is not likely to result in harmful health effects over a specified exposure duration, which are acute (1-14 days), intermediate (15-365 days), and chronic (365 days and longer). Although concentrations at or below a CV represent low or no risk, concentrations above a CV are not necessarily harmful.

channel are more likely to be the ones who might, on rare occasions, be exposed to these higher levels of hydrogen sulfide.

ATSDR also found that the community concern about recurring odors throughout Refinery Row may be associated with hydrogen sulfide in the air. All stationary air monitors and mobile monitors found hydrogen sulfide regularly above its lowest odor threshold, which can lead to odor-related health symptoms, such as eye irritation, headaches, cough, difficulties in breathing, negative mood states, and stress or annoyance.

- **Particulate Matter**: Air samples were tested for two types of particulate matter (PM)
  - PM_{10} – particles smaller than 10 microns in diameter
  - $PM_{2.5}$ – particles smaller than 2.5 microns in diameter

  ATSDR found that PM_{10} 24-hour concentrations are below U.S. Environmental Protection Agency's (U.S. EPA) National Ambient Air Quality Standards (NAAQS) and therefore are not expected to harm people's health.

  Only two $PM_{2.5}$ 24-hour concentrations in Refinery Row air (specifically, pre-2005 maximum concentrations found at the Huisache and Navigation air monitoring sites) were above U.S. EPA's NAAQS[33]. The Huisache monitor currently operates in a sparsely populated area, whereas the Navigation monitor operated in the past in a residential neighborhood.

  The U.S. EPA has an Air Quality Index (AQI) online tool known as "AIRNow AQI Calculator", which can be used to estimate potential health effects from known 24-hour levels of $PM_{2.5}$. Using this online AQI calculator, ATSDR found that the maximum $PM_{2.5}$ air concentrations along Refinery Row in the past, although rare, are numerically above NAAQS and represent an increased likelihood of respiratory and cardiopulmonary symptoms in sensitive people, especially those with heart or lung diseases, children, and older adults. Although current $PM_{2.5}$ levels are below NAAQS, the data are limited because only two stationary air monitors along Refinery Row currently monitor $PM_{2.5}$ levels.

- **Sulfur Dioxide**: This chemical exceeded the ATSDR acute CV in 1.5% of the stationary air monitoring samples and 44% of the mobile monitoring samples. From 1996–2010, maximum sulfur dioxide concentrations from the 5-minute and 1-hour averaged stationary air data, as well as from the mobile monitors, infrequently approached and exceeded health effect levels. Therefore, short-term exposures to the highest concentrations of sufur dioxide measured in Refinery Row air, although rare, indicate levels that could potentially cause harmful respiratory health effects in people with asthma or other related preexisting conditions, children, and older adults during times of elevated inhalation rates (e.g., breathing harder during exercise).

  Before 1996, maximum sulfur dioxide concentrations—although detected rarely during mobile monitoring events—suggested the potential to cause harmful health effects in the general population (including healthy persons without asthma or other conditions that might increase sulfur dioxide exposure susceptibility). Such effects are temporary and go

[33] ATSDR evaluated whether the measured levels of particulate matter were numerically above the NAAQS and did not evaluate the data using the statistical approach used by U.S. EPA under its regulatory authority.

away when not breathing those former maximum sulfur dioxide levels (i.e., after the exposure ended).

- **Chemical Mixtures**: Although the science of evaluating chemical mixtures is still evolving and many uncertainties exist in any chemical mixtures evaluation, ATSDR assumes that pollutants with similar effects will have an additive dose. Thus, short-term simultaneous exposure to the maximum levels of these four compounds (benzene, hydrogen sulfide, particulate matter, and sulfur dioxide) in Refinery Row air could potentially lead to a combined acute respiratory health effect greater than that of the individual compounds. Exposure to mixtures of these compounds could lead to temporary respiratory effects such as nose and throat irritation and shortness of breath; and neurological effects such as headaches and other effects related to odors in the community. Note that simultaneous exposure to the maximum levels of these compounds was not observed in the available air monitoring data.
- **Limitations**: ATSDR notes limitations in its evaluation of short-term exposures, such as that some chemicals only had experimental (animal) health effects studies available and not epidemiological (human) studies. The agency also notes that the stationary monitoring data may not capture all of the releases the community experiences because these data are not available for all pollutants, over all time frames, and across all locations of interest. However, ATSDR believes the locations of the current monitors provide good coverage, especially when combined with the mobile monitoring data.

2. **Long-term exposure cancer risk:** ATSDR concludes long-term exposure to the average levels of benzene, cadmium, chromium, 1,2-dibromoethane, and naphthalene results in a low additional risk of cancer (i.e., the chance of getting cancer from breathing each chemical alone is low). ATSDR estimates that breathing a mixture of chemicals found in Refinery Row outdoor air for many years increases the risk of cancer.

   Long-term exposure noncancer risk: ATSDR concludes that long-term exposure to the average levels of chemicals detected in Refinery Row air is not expected to cause harmful noncancer health effects.

   - **Individual Pollutants Cancer Risk**: ATSDR estimated the proportion of a population that may be affected by a carcinogen during a lifetime of exposure. The cancer risk estimates for benzene, cadmium, chromium, 1,2-dibromoethane, and naphthalene were each at least 1 additional case of cancer per 100,000 persons. These estimates are within U.S. EPA's target risk range[34] and exposure to each chemical alone results in a low additional risk of cancer.

     Long-term benzene exposure had the highest calculated cancer risk of these carcinogens. ATSDR notes that benzene concentrations are influenced by wind conditions and time of day, and increase with proximity to the Huisache stationary air monitor. Therefore, neighborhoods such as Oak Park, Dona Park, and Hillcrest may have higher concentrations of benzene, depending on wind direction. Overall trends show benzene levels have dropped over the years

[34] For carcinogens, U.S. EPA's target risk range is between 10^{-4} (1 in 10,000) and 10^{-6} (1 in 1,000,000).

- **Chemical Mixtures Cancer Risk**: Assuming additive effects, the cumulative cancer risk estimate for Refinery Row is the sum of the individual chemical risk estimates. The main contributors to cumulative cancer risk in Refinery Row air are benzene (31%), 1,2-dibromoethane (26%), and chromium (11%). The cumulative cancer risk for a mixture of Refinery Row chemicals is 1.8×10^{-4} (or about 2 additional cancer cases per 10,000 people). Thus, breathing a mixture of chemicals found in outdoor air for many years results in an increased risk of cancer.
- **Individual Pollutants Noncancer Risk**: Long-term exposures to the average concentrations of chemicals detected in Refinery Row outdoor air were and are below levels known to cause noncancer health effects in humans or animals. Therefore, breathing air over the long-term containing these chemicals is not expected to cause harmful noncancer health effects.
- **Limitations**: ATSDR notes limitations in its estimates that likely overestimate the cancer risk for some chemicals, such as that 1) cadmium and 1,2-dibromoethane were detected in less than 20% of the samples so an average concentration could not be used in the calculations[35], and 2) only total chromium levels were available (not the more harmful hexavalent chromium levels) for the cancer estimates[36]. The chemical mixtures estimate assuming additive effects likely overestimates cancer risk because different contaminants may cause cancers to different areas of the body via different mechanisms. Other limitations could lead to an underestimation of cancer risk, such as the lack of routine monitoring of polycyclic aromatic hydrocarbons (PAHs) that are carcinogens and could have increased the cumulative cancer risk estimate if data had been available.

In addition, ATSDR evaluated health outcome data for the Corpus Christi Refinery Row area, including asthma hospitalization and birth defect rates. DSHS evaluated several types of cancers in the Corpus Christi Refinery Row area.

- **Asthma Hospitalizations**: ATSDR found that Nueces County has a higher rate of asthma hospitalizations among children than Texas as a whole. ATSDR's air evaluation found that exposure to benzene, hydrogen sulfide, particulate matter, and sulfur dioxide detected in Refinery Row outdoor air indicated levels which, although infrequent, could potentially result in respiratory health effects in susceptible populations like people with asthma or other related respiratory illnesses.
- **Birth Defects**: ATSDR looked at 63 birth defects to see whether these defects were more common in children of mothers living within 2 miles of Refinery Row compared with children of mothers living 10 or more miles away[37]. Although these types of comparisons

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[35] The highest 95th percentile, which is generally a more conservative value than the average, was used to estimate chronic exposure risk.

[36] Although hexavalent chromium is believed to be a fraction of the total chromium measured, to arrive at the most conservative risk estimates, ATSDR treated the total chromium measured in Refinery Row air as hexavalent chromium.

[37] Refers to children of mothers living more than 10 miles from Refinery Row but still within the tri-county (Nueces, San Patricio, and Kleberg) Corpus Christi area.

cannot be used to directly link birth defects to chemicals found in the air, they can help health agencies focus on prevention efforts. Overall, ATSDR found that 2 heart defects (ventricular septal defect and "other anomalies of the aorta") were slightly more common in children who lived near Refinery Row. These birth defect increases could be by chance or caused by other risk factors not available for review in this analysis.

- **Cancer**: Comparisons based on statewide cancer rates show the number of male colon and rectum, bladder, kidney, and liver cancer cases reported for the Corpus Christi Refinery Row area[38] was statistically greater than expected. Although benzene is associated with one of the elevated types of cancer (i.e., liver cancer), ATSDR cannot determine if these increases are due to air pollution from industries along Refinery Row. No increase in cancer rates was observed in women.
- **Limitations**: ATSDR's air data evaluation and health outcome data evaluation cannot determine whether air pollutants in the Corpus Christi Refinery Row area caused any observed increases in health problems. The available data do not include a measure of an individual's actual exposure to Refinery Row pollutants.

11. Recommendations

After its review of available information, ATSDR recommends

1. Stationary and mobile monitoring efforts by industry, The University of Texas (UT) and TCEQ continue to track chemical levels in Refinery Row ambient air.
2. Routine stationary monitoring programs consider adding PAHs to the chemicals tracked in Refinery Row ambient air.
3. Refinery Row area facilities consider using the best available pollution control technology to reduce point-source chemical releases into the air as well as promote innovative ideas to further reduce fugitive air emissions, especially for compounds identified as posing an increased noncancer or cancer risk to area residents.
4. Local organizations and government agencies continue to develop and promote asthma education and distribute asthma information to area residents.
5. The Texas Department of State Health Services (DSHS)[39] continue plans to monitor Corpus Christi area birth defects and works with local organizations to develop community intervention strategies.
6. DSHS continue plans to update its cancer investigation as more recent data become available.
7. U.S. EPA continue conducting research on environmental exposures and birth defects.

[38] The Corpus Christi Refinery Row area for the cancer rate analyses is defined by ZIP codes 78401, 78402, 78404, 78405, 78406, 78407, 78408, 78409, 78410, 78411, 78416, 78417 and 78370, which approximates a 5-mile buffer surrounding Refinery Row.

[39] Referred to throughout this public health assessment as "Department of State Health Services" (DSHS).

12. Public Health Action Plan

The purpose of the public health action plan is to ensure that this evaluation not only identifies potential and ongoing public health hazards, but also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment.

ATSDR's recommendations will be provided to local organizations, government agencies and industry. ATSDR supports continued efforts by these entities to address the health concerns of Corpus Christi residents and to identify and reduce exposure to airborne chemicals in the environment wherever possible.

Also, ATSDR has provided technical and health information to community members, including fact sheets on contaminants and historic exposures and will continue to do so as requested. ATSDR will continue to maintain a website dedicated to this site (see http://www.atsdr.cdc.gov/sites/corpuschristi/).

13. Preparers

Danielle M. Langmann, MS
Environmental Health Scientist
Central Branch
Division of Community Health Investigations

James T. Durant, MSPH, CIH
Environmental Health Scientist
Science Support Branch
Division of Community Health Investigations

Wendy A. Wattigney, M Stat
Mathematical Statistician
Environmental Epidemiology Branch
Division of Toxicology and Human Health Sciences

Aaron Young, PhD
Senior Service Fellow
Science Support Branch
Division of Community Health Investigations

Rachel R. Worley, MA
Environmental Health Scientist
Science Support Branch
Division of Community Health Investigations

Amy L. Lang, MCP
GIS Analyst

Office of the Director
Division of Toxicology and Human Health Sciences

René J. Suárez-Soto, EIT, MSEnvE
Environmental Health Scientist
Science Support Branch
Division of Community Health Investigations

Karen Scruton, MS
Environmental Health Scientist
Science Support Branch
Division of Community Health Investigations

Lourdes Rosales-Guevara, MD
Medical Officer
Science Support Branch
Division of Community Health Investigations

David S. Sutton, PhD, PE
Environmental Health Scientist
Science Support Branch
Division of Community Health Investigations

David A Fowler, PhD
Toxicologist (retired)
Office of the Director
Division of Community Health Investigations

14. Technical Advisors

George Pettigrew
Regional Director
Central Branch
Division of Community Health Investigations

Wallace K. Sagendorph, JD
Writer-Editor (retired)
Office of the Director
National Center for Environmental Health

Sylvia Allen-Lewis
Health Education Specialist
Central Branch
Division of Community Health Investigations

Germaine M. (Jamie) Vazquez, MS
Health Communication Specialist
Office of Communication
Office of the Director

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Appendix A. Figures

Figure 1A. Corpus Christi, TX

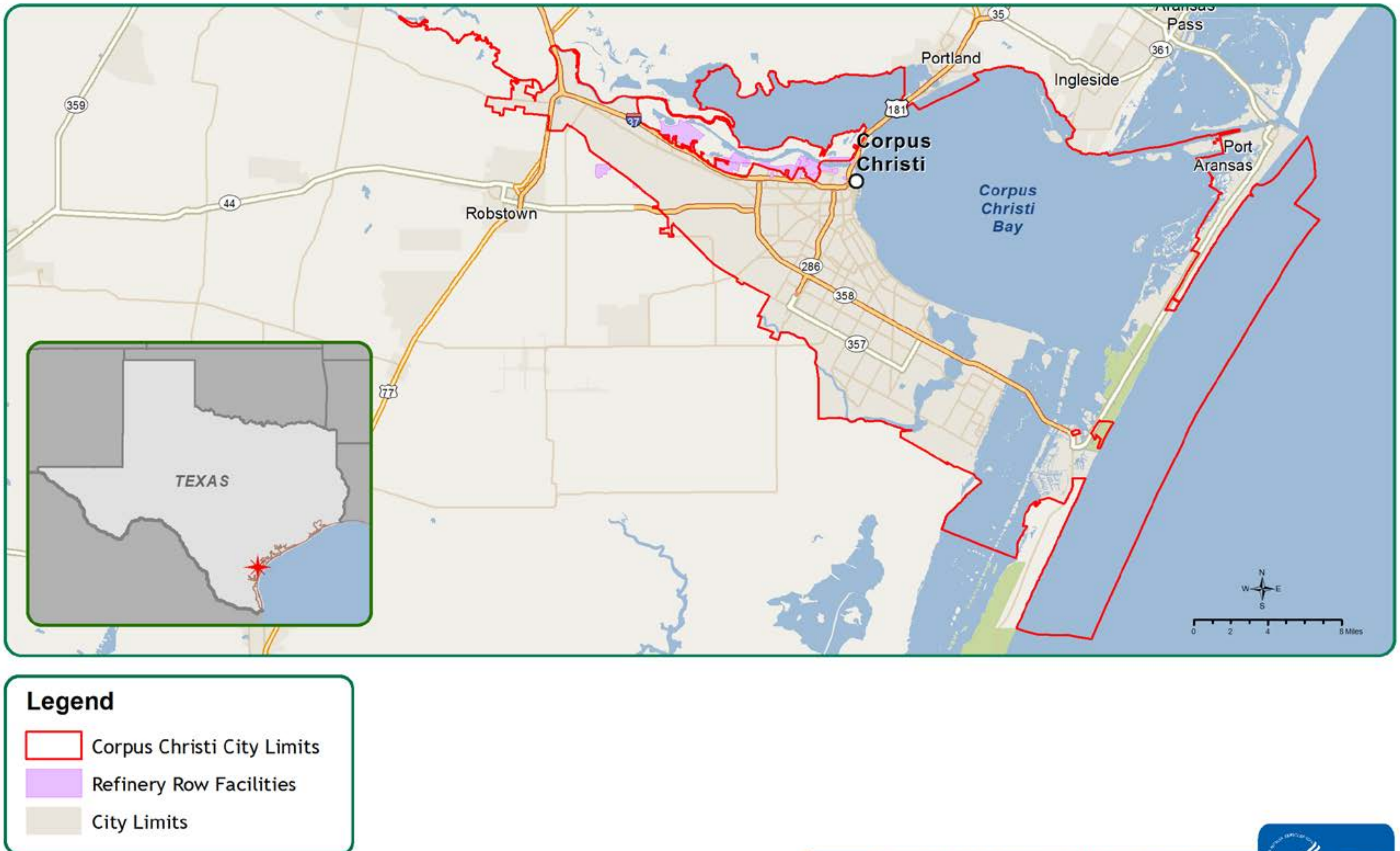

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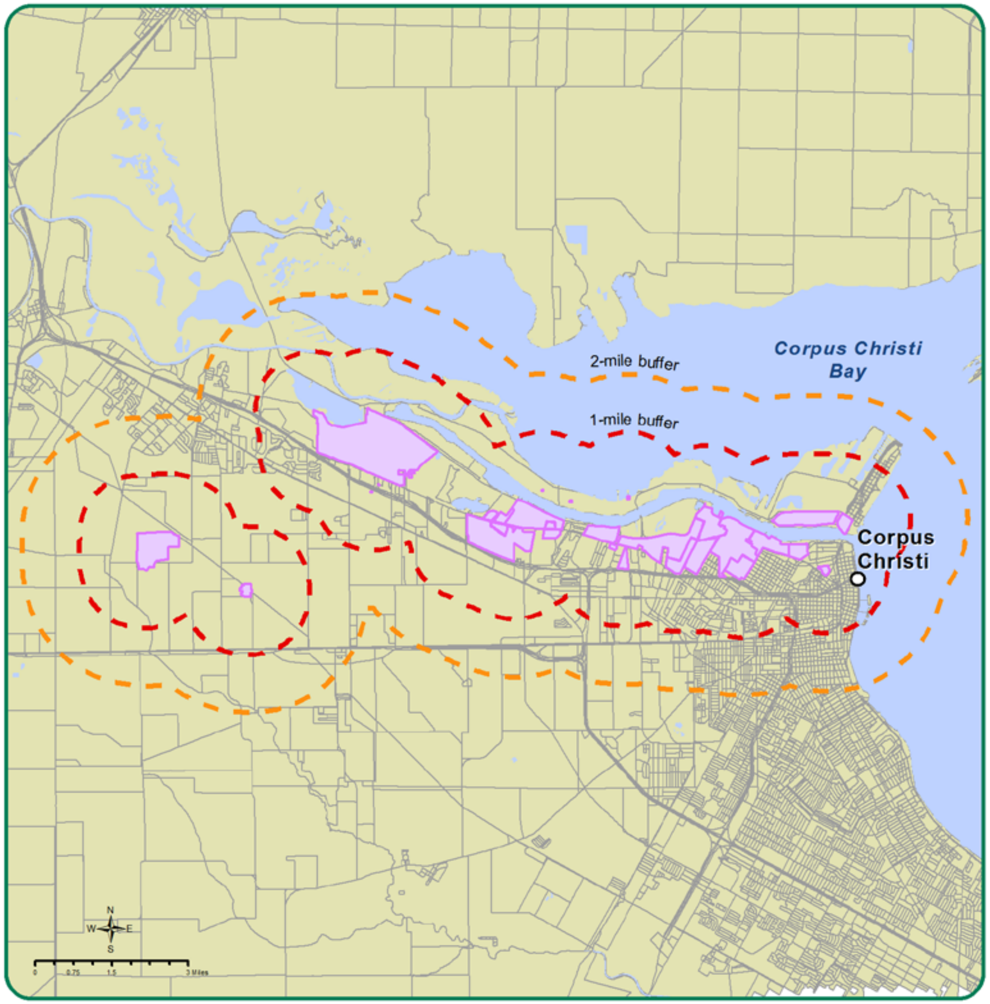
Figure 2A. Demographic Statistics for the Industrial Corridor, Corpus Christi, TX



Demographic Statistics Within Areas of Concern*	1 mile	2 mile
Total Population	21,684	53,085
White Alone	16,048	40,890
Black Alone	2,083	2,940
Am. Indian & Alaska Native Alone	143	387
Asian Alone	74	200
Native Hawaiian & Other Pacific Islander Alone	8	14
Some Other Race Alone	2,750	7,298
Two or More Races	571	1,355
Hispanic or Latino**	14,798	37,906
Children Aged 6 and Younger	2,096	5,645
Adults Aged 65 and Older	2,840	6,593
Females Aged 15 to 44	4,046	10,174
Total Housing Units	8,769	21,306

Demographics Statistics Source: 2010 U.S. Census
* Calculated using an area-proportion spatial analysis technique
** People who identify their origin as Hispanic or Latino may be of any race.

Legend

Buffers
1 - mile
2 - mile
Refinery Row Facilities
Census Block Boundaries

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Division of Community Health Investigations

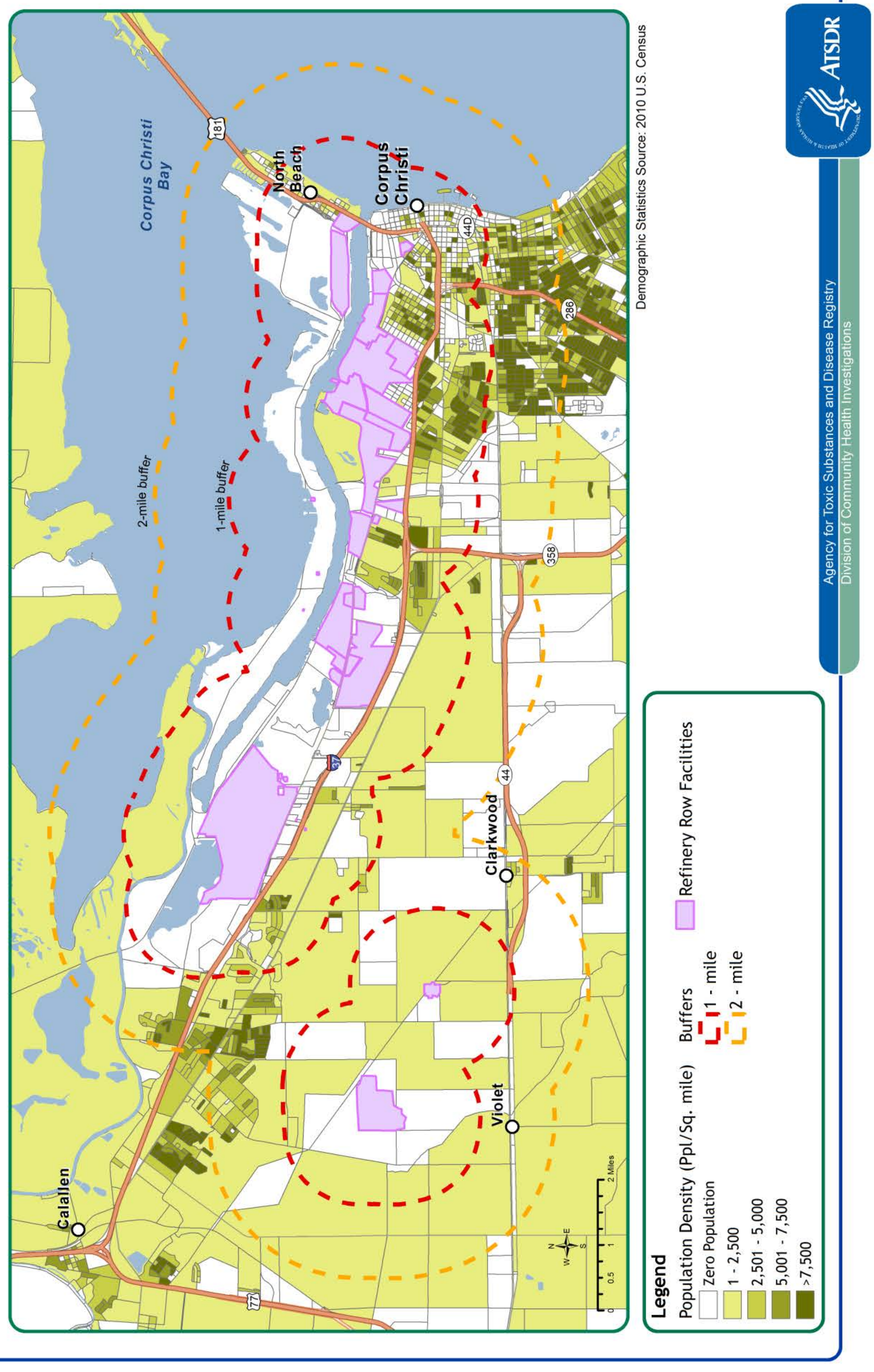


Figure 3A. Population Density by Census Block for the Industrial Corridor, Corpus Christi, TX

Figure 4A. Percent Hispanic/Latino by Census Block for the Industrial Corridor, Corpus Christi, TX

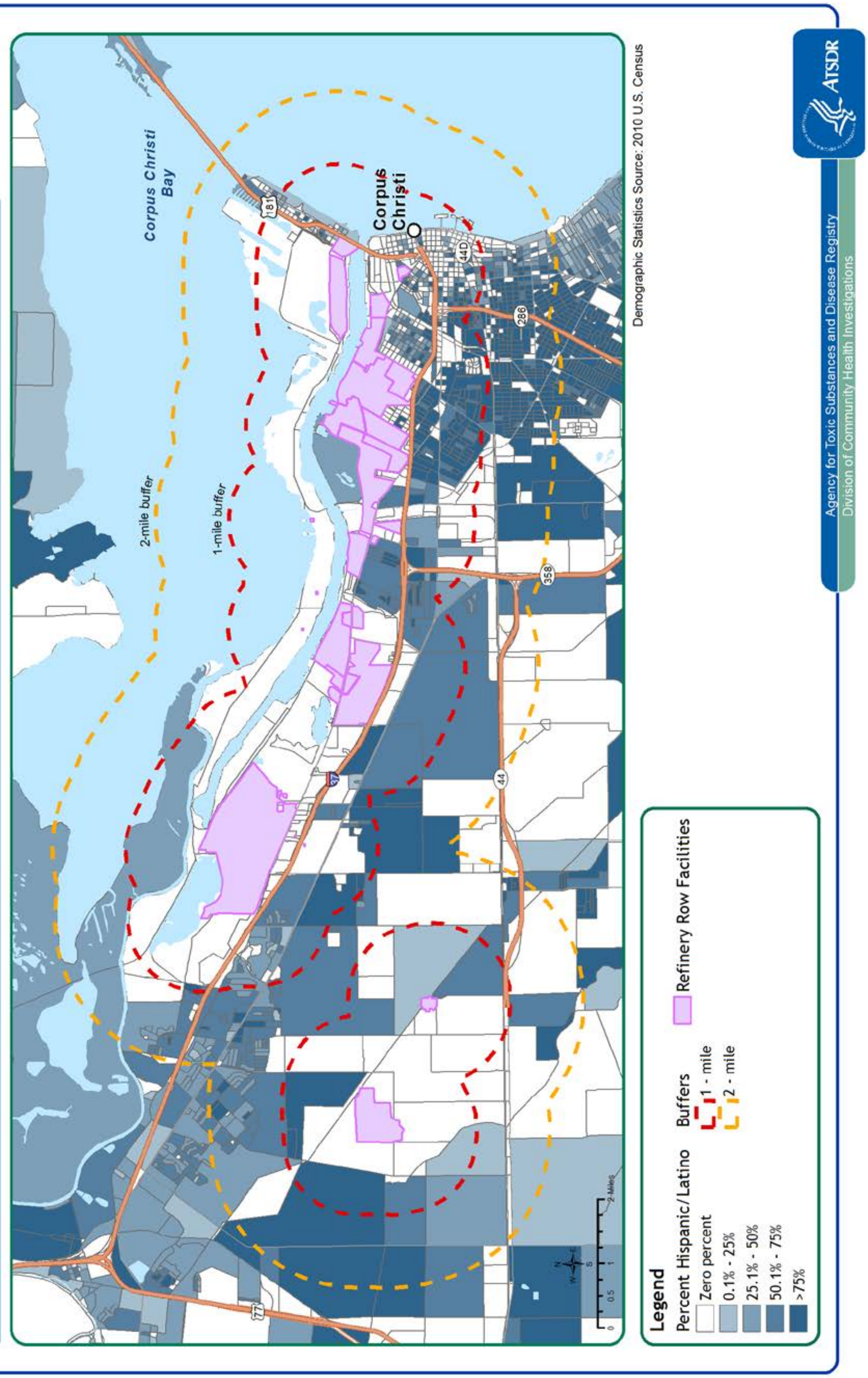
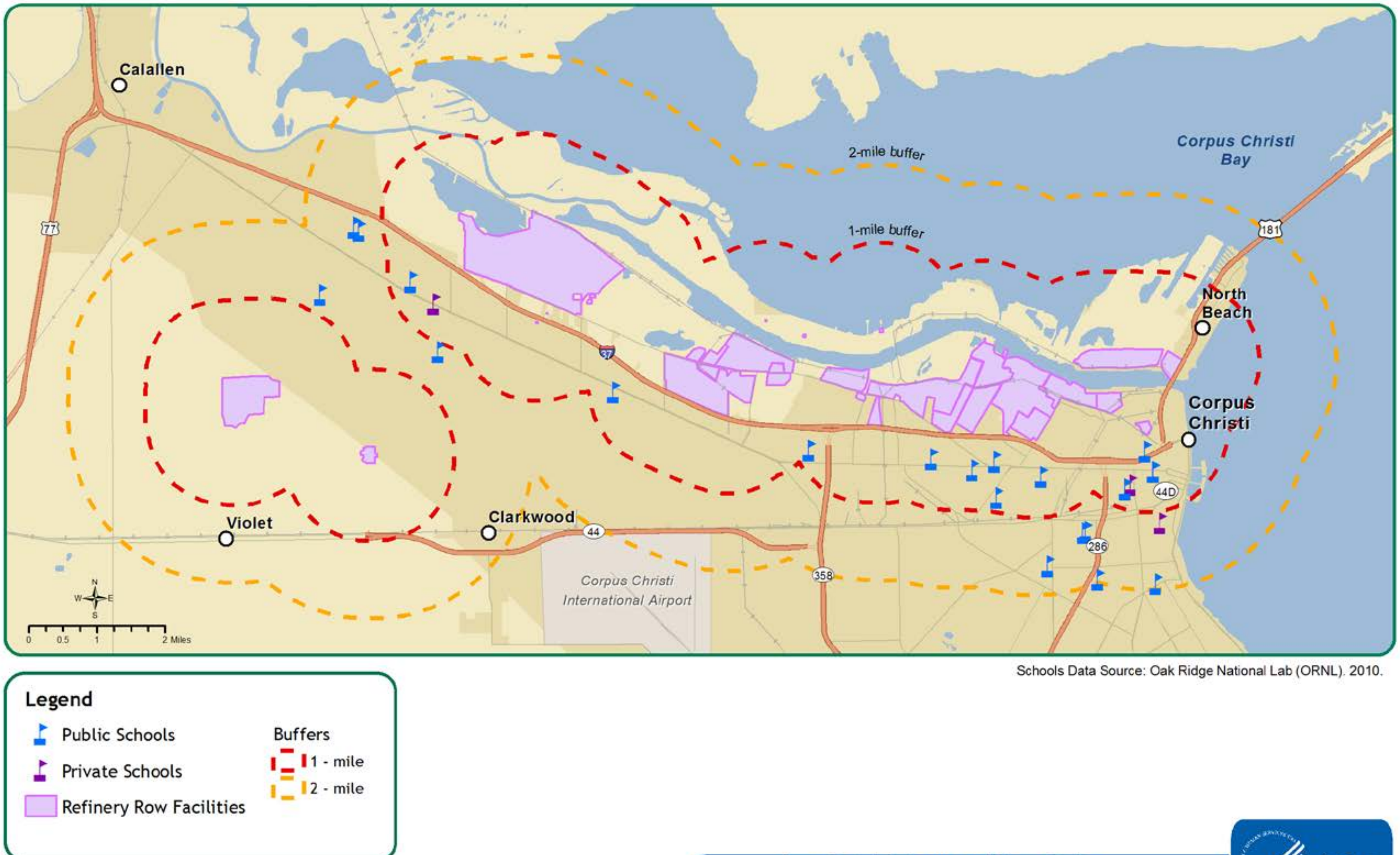


Figure 5A. Schools within the Industrial Corridor, Corpus Christi, TX



Schools Data Source: Oak Ridge National Lab (ORNL). 2010.

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Division of Community Health Investigations

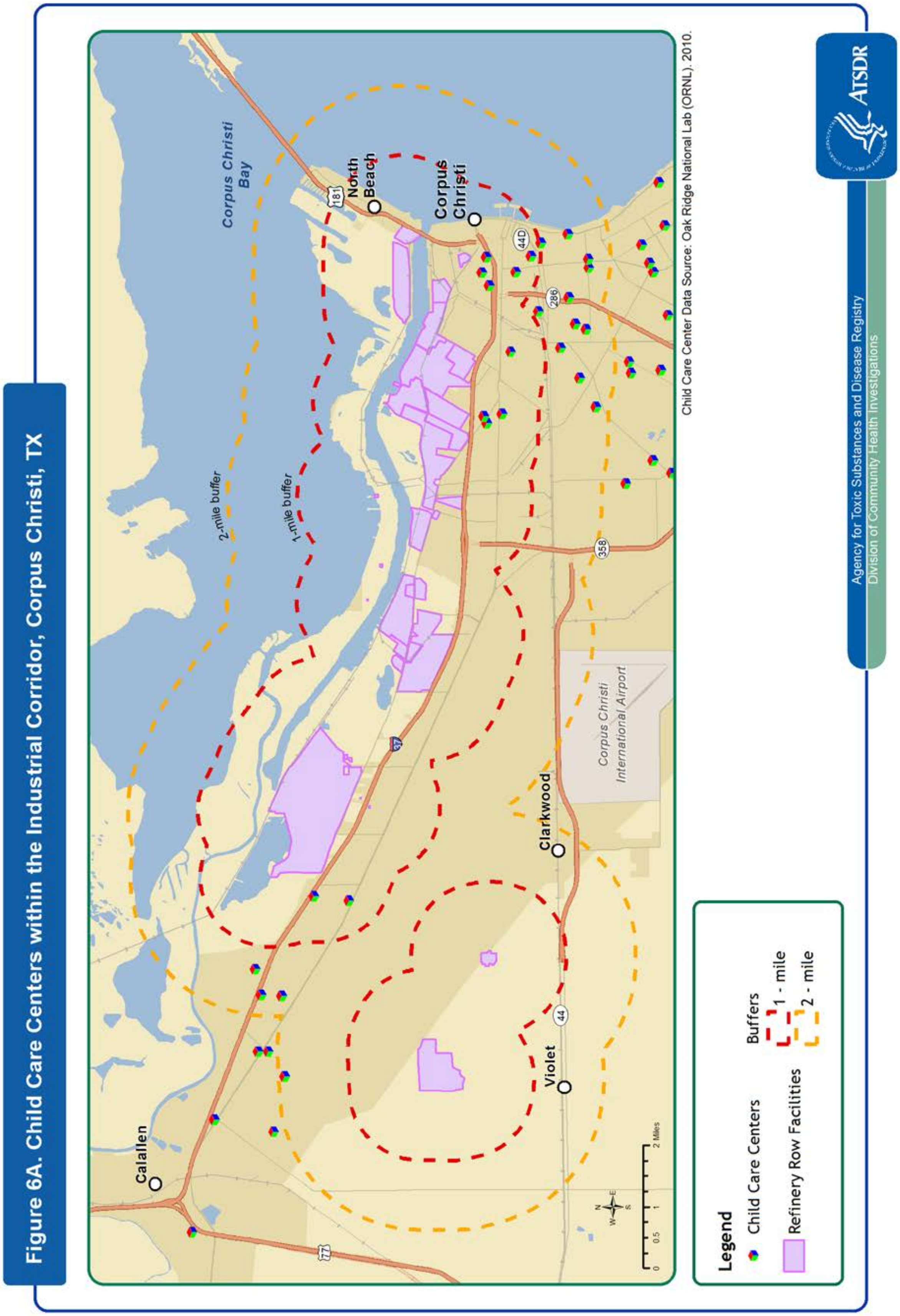
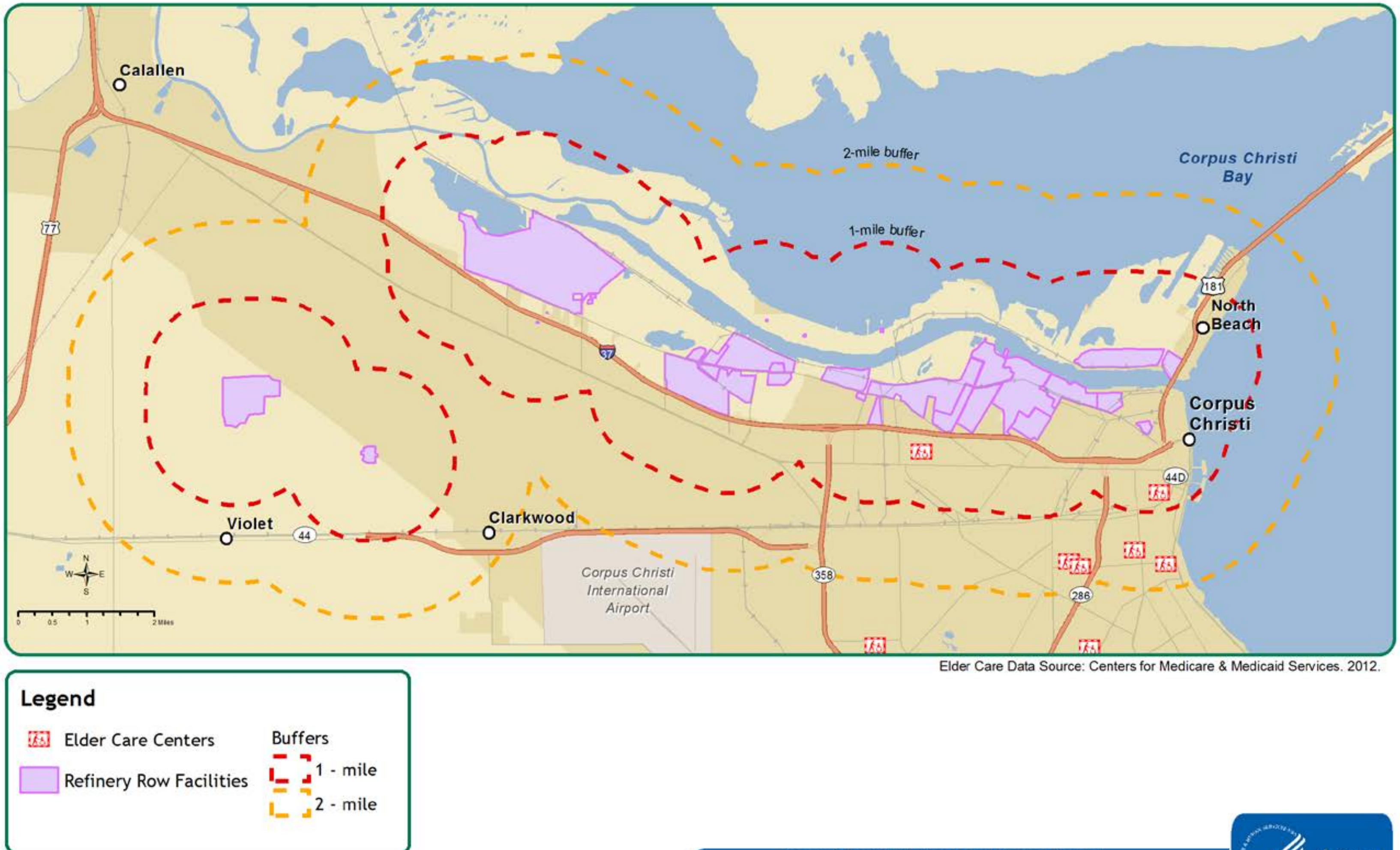


Figure 6A. Child Care Centers within the Industrial Corridor, Corpus Christi, TX

Figure 7A. Elder Care Centers within the Industrial Corridor, Corpus Christi, TX



Elder Care Data Source: Centers for Medicare & Medicaid Services. 2012.

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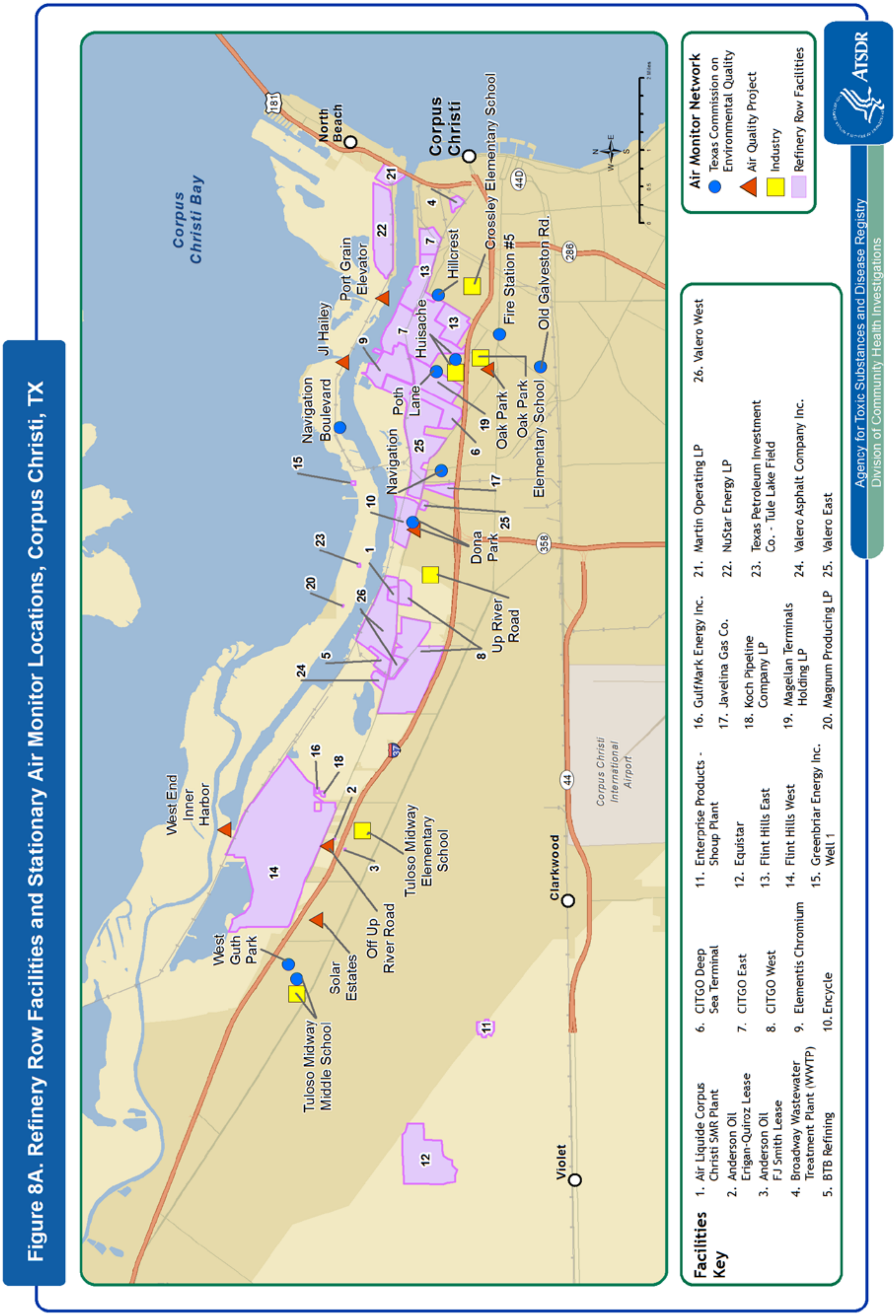
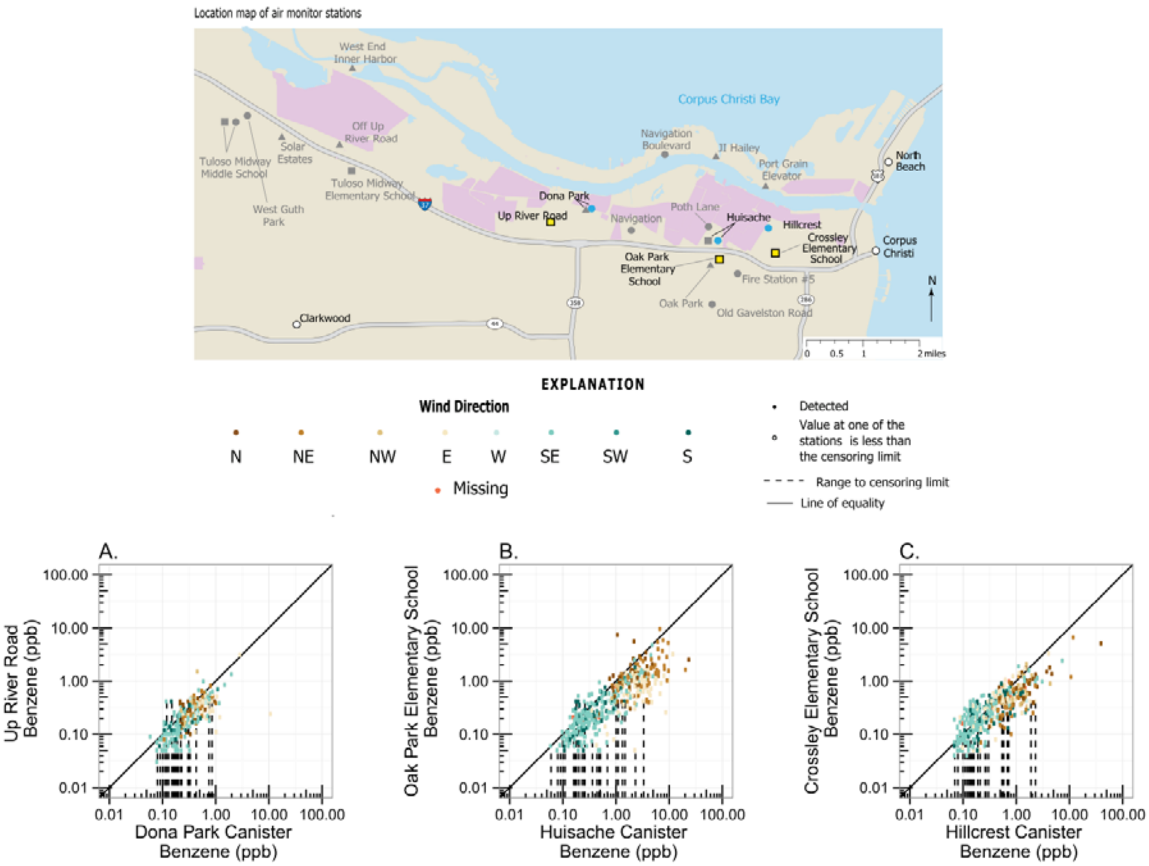


Figure 8A. Refinery Row Facilities and Stationary Air Monitor Locations, Corpus Christi, TX

Figure 9A. Comparison of Benzene Data from TCEQ and Industry 24-hour Canisters, Corpus Christi, TX*



A. Comparison of Dona Park (TCEQ) and Up River Road (industry) benzene data.
B. Comparison of Huisache (TCEQ) and Oak Park Elementary School (industry) benzene data.
C. Comparison of Hillcrest (TCEQ) and Crossley Elementary School (industry) benzene data.

Data Sources:

Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through three separate queries performed with the target list "Canister Parameters" group, 24-hour concentrations for dates within the range >=1/1/1990 to <1/1/2011 for monitors in the Corpus Christi area. Data queried on 29 May 2013.

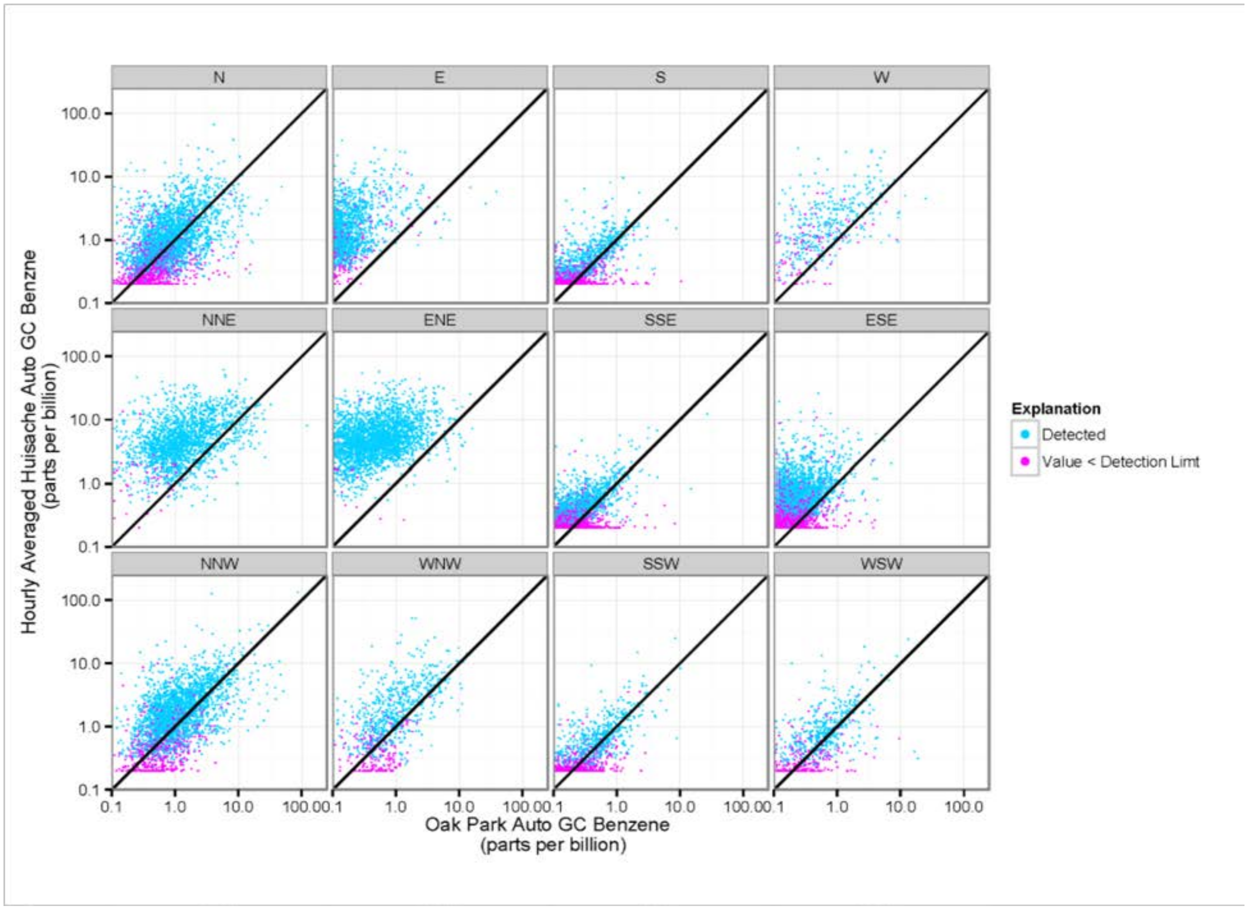
Texas Commission on Environmental Quality. 2014. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through three separate queries performed with the target list "Meteorological Parameters" group, 1-hour values for dates within the range >=1/1/1993 to <1/1/2011 for locations Huisache, Hillcrest, and Dona Park . Data queried on 20 March 2014.

ToxStrategies, Inc. 2011. September 8th email from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005−2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

* The comparisons include wind direction. The wind direction on the figure shows when the wind comes from a specific direction toward an air monitor.

ppb parts per billion
TCEQ Texas Commission on Environmental Quality

Figure 10A. Comparison of Benzene Data from AQP Oak Park and Industry Auto GCs by Wind Direction, Corpus Christi, TX* (page 1 of 2)



Data Sources:

Texas Commission on Environmental Quality. 2010. Data posted to FTP site by Melanie Hotchkiss, TCEQ, and downloaded by John Wilhelmi, Eastern Research Group, Inc. Contains continuous 2005-2009 sulfur compound and volatile organic compound data for both TCEQ and Corpus Christi Air Quality Project air monitoring sites. Austin, TX.

ToxStrategies, Inc. 2011. September 8th email from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005–2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

The University of Texas. 2011. April 25th email from Dr. David Sullivan, The University of Texas at Austin, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing an Excel attachment with the continuous 2010 volatile organic compounds data for the Solar Estates and Oak Park air monitoring sites. Austin, TX.

* Wind direction was categorized by the four cardinal directions (North, East, South, and West) and 8 intra-cardinal directions (North by Northeast (NNE), East by Northeast (ENE), East by Southeast (ESE), South by Southwest (SSW), West by Southwest (WSW), West by Northwest (WNW), and North by Northwest(NNW)). The wind direction sectors correspond to 30 degrees of a circle and show when the wind comes from each direction toward the Oak Park air monitor. See Table 32B, Appendix B, for the Kendall's Tau and p-values for each comparison by wind direction.

Figure 10A. Comparison of Benzene Data from AQP Oak Park and Industry Auto GCs by Wind Direction* (page 2 of 2)

AQP	Corpus Christi Air Quality Project
Auto GC	automatic gas chromatograph
ppb	parts per billion

Figure 11A. Industry's Huisache Auto GC Compared with Industry's Canister Benzene Data, Corpus Christi, TX* (page 1 of 2)

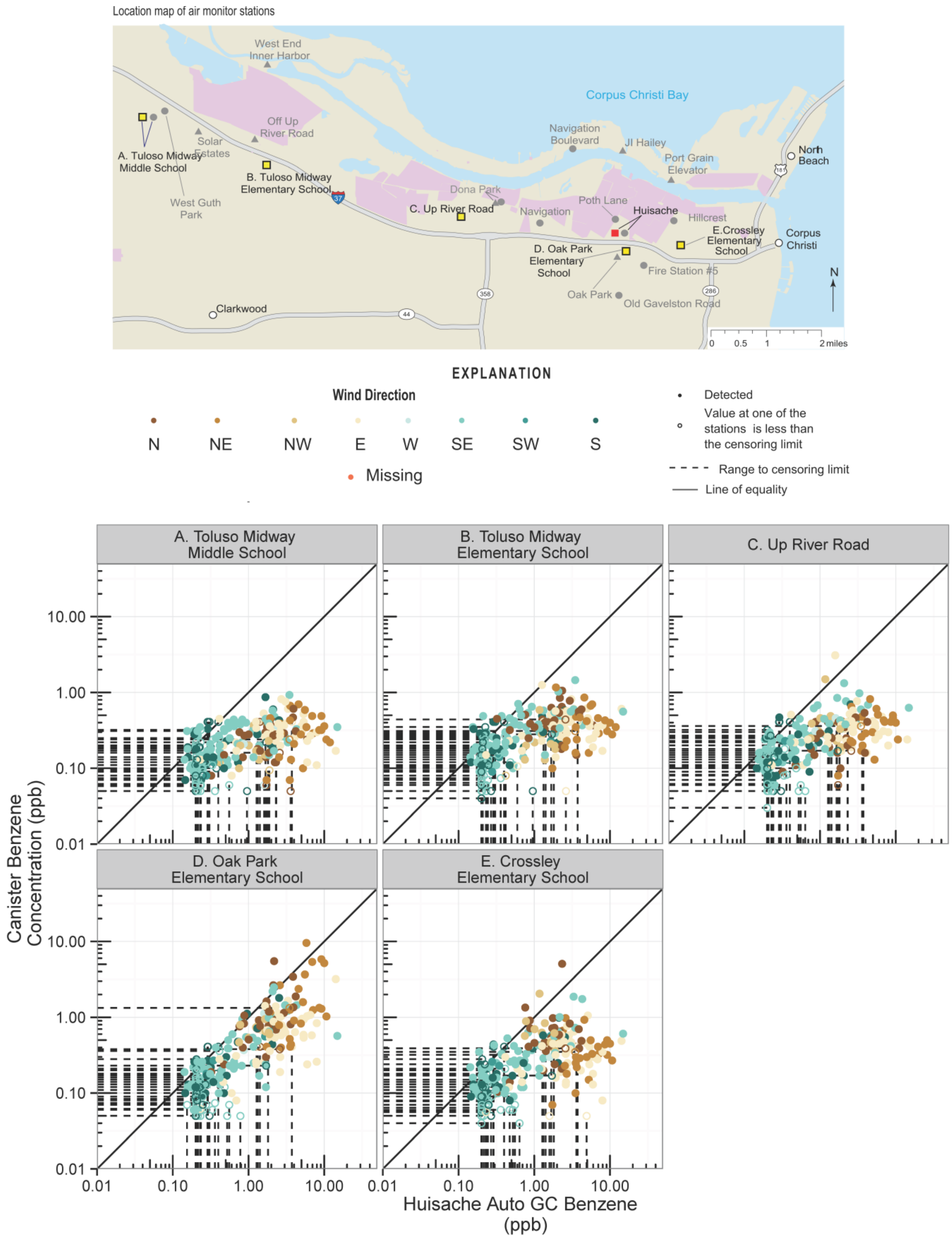


Figure 11A. Industry's Huisache Auto GC Compared with Industry's Canister Benzene Data, Corpus Christi, TX* (page 2 of 2)

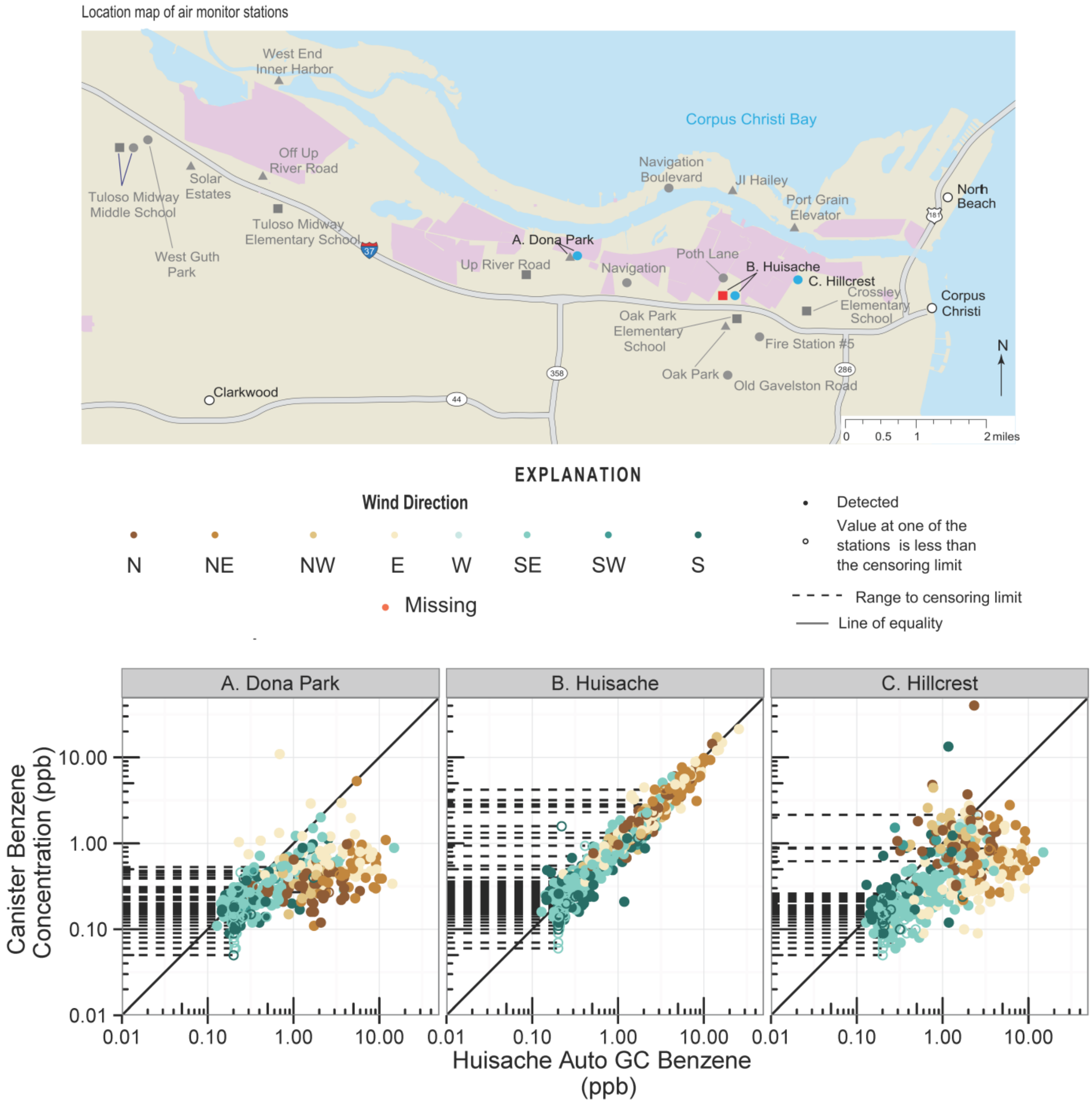
A. Industry's Huisache Auto GC and Tuloso Midway Middle School canister benzene data: Kendall's Tau = 0.41, $p < 0.001$
B. Industry's Huisache Auto GC and Tuloso Midway Elementary School canister benzene data: Kendall's Tau = 0.46, $p<0.001$
C. Industry's Huisache Auto GC and Up River Road canister benzene data: Kendall's Tau = 0.46, $p < 0.001$
D. Industry's Huisache Auto GC and Oak Park Elementary School canister benzene data: Kendall's Tau = 0.61, $p < 0.001$
E. Industry's Huisache Auto GC and Crossley Elementary School canister benzene data: Kendall's Tau = 0.45, $p < 0.001$

Data Source: ToxStrategies, Inc. 2011. September 8th email from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005−2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

* The comparisons include wind direction. The wind direction on the figure shows when the wind comes from a specific direction toward an air monitor.

Auto GC	automatic gas chromatograph
ppb	parts per billion

Figure 12A. Industry's Huisache Auto GC Compared with TCEQ's Canister Benzene Data, Corpus Christi, TX* (page 1 of 2)



A. Industry's Huisache Auto GC and TCEQ's Dona Park canister benzene data: Kendall's Tau = 0.53, $p < 0.001$

B. Industry's Huisache Auto GC and TCEQ's Huisache canister benzene data: Kendall's Tau = 0.84, $p < 0.001$

C. Industry's Huisache Auto GC and TCEQ's Hillcrest canister benzene data: Kendall's Tau = 0.51, $p < 0.001$

Figure 12A. Industry's Huisache Auto GC Compared with TCEQ's Canister Benzene Data, Corpus Christi, TX* (page 2 of 2)

Data Sources:

Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through three separate queries performed with the target list "Canister Parameters" group, 24-hour concentrations for dates within the range >=1/1/1990 to <1/1/2011 for monitors in the Corpus Christi area. Data queried on 29 May 2013.

ToxStrategies, Inc. 2011. September 8th email from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005−2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

* The comparisons include wind direction. The wind direction on the figure shows when the wind comes from a specific direction toward an air monitor.

Auto GC	automatic gas chromatograph
ppb	parts per billion

Figure 13A. AQP's Oak Park Auto GC Compared with Industry's Canister Benzene Data, Corpus Christi, TX* (page 1 of 2)

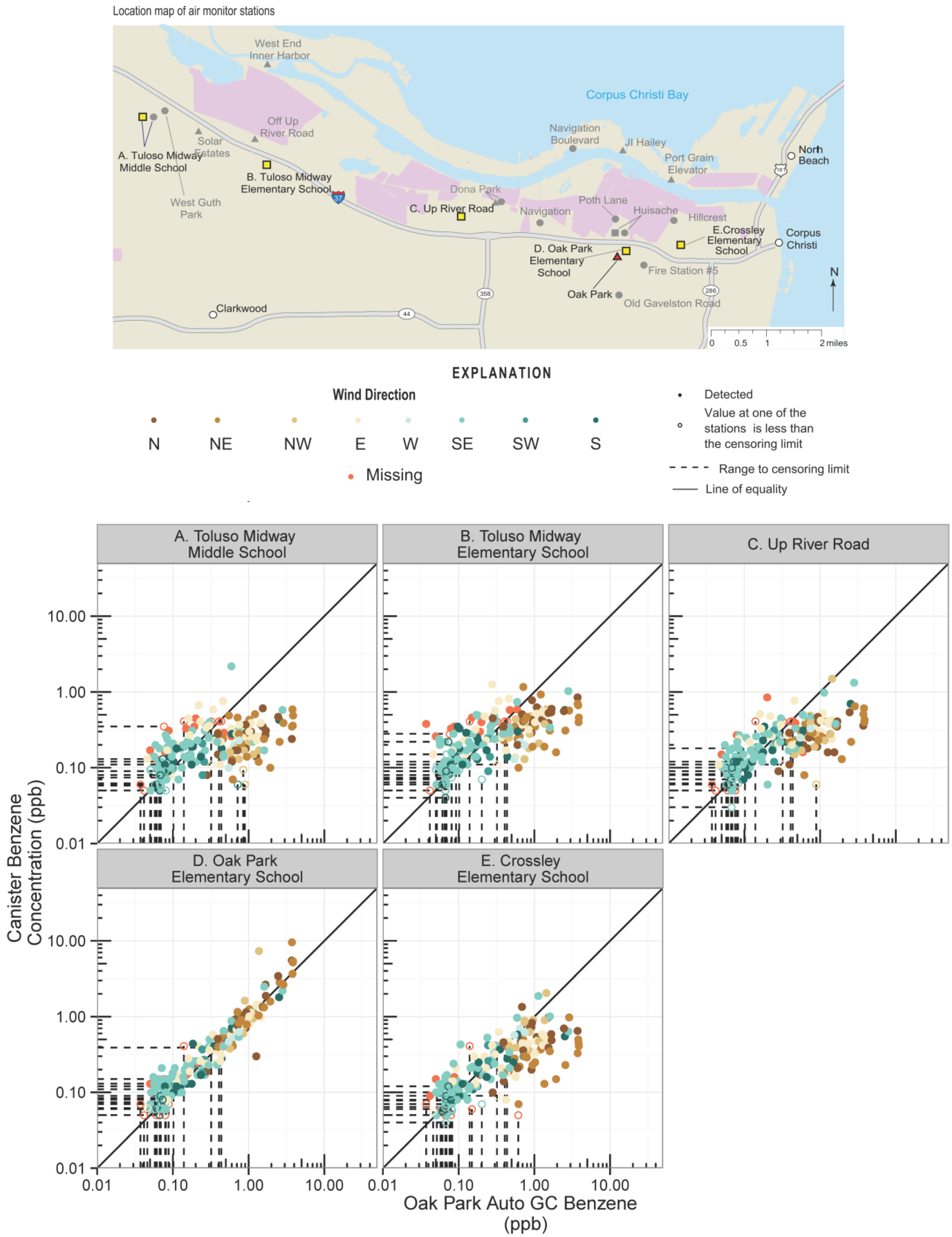


Figure 13A. AQP's Oak Park Auto GC Compared with Industry's Canister Benzene Data, Corpus Christi, TX* (page 2 of 2)

A. AQP's Oak Park Auto GC and industry's Tuloso Midway Middle School benzene data: Kendall's Tau = 0.44, $p < 0.001$
B. AQP's Oak Park Auto GC and industry's Tuloso Midway Elementary School benzene data: Kendall's Tau = 0.54, $p < 0.001$
C. AQP's Oak Park Auto GC and industry's Up River Road benzene data: Kendall's Tau = 0.55, $p < 0.001$
D. AQP's Oak Park Auto GC and industry's Oak Park Elementary School benzene data: Kendall's Tau = 0.80, $p < 0.001$
E. AQP's Oak Park Auto GC and industry's Crossley Elementary School benzene data: Kendall's Tau = 0.61, $p < 0.001$

Data Sources:

Texas Commission on Environmental Quality. 2014. Texas Air Monitoring Information System (TAMIS) web interface. Data downloaded from TAMIS through a query performed with the target list "Meteorological Parameters" for dates within the range >=1/1/2005 to <1/1/2011 for monitor Oak Park . Data downloaded on 26 February 2014.

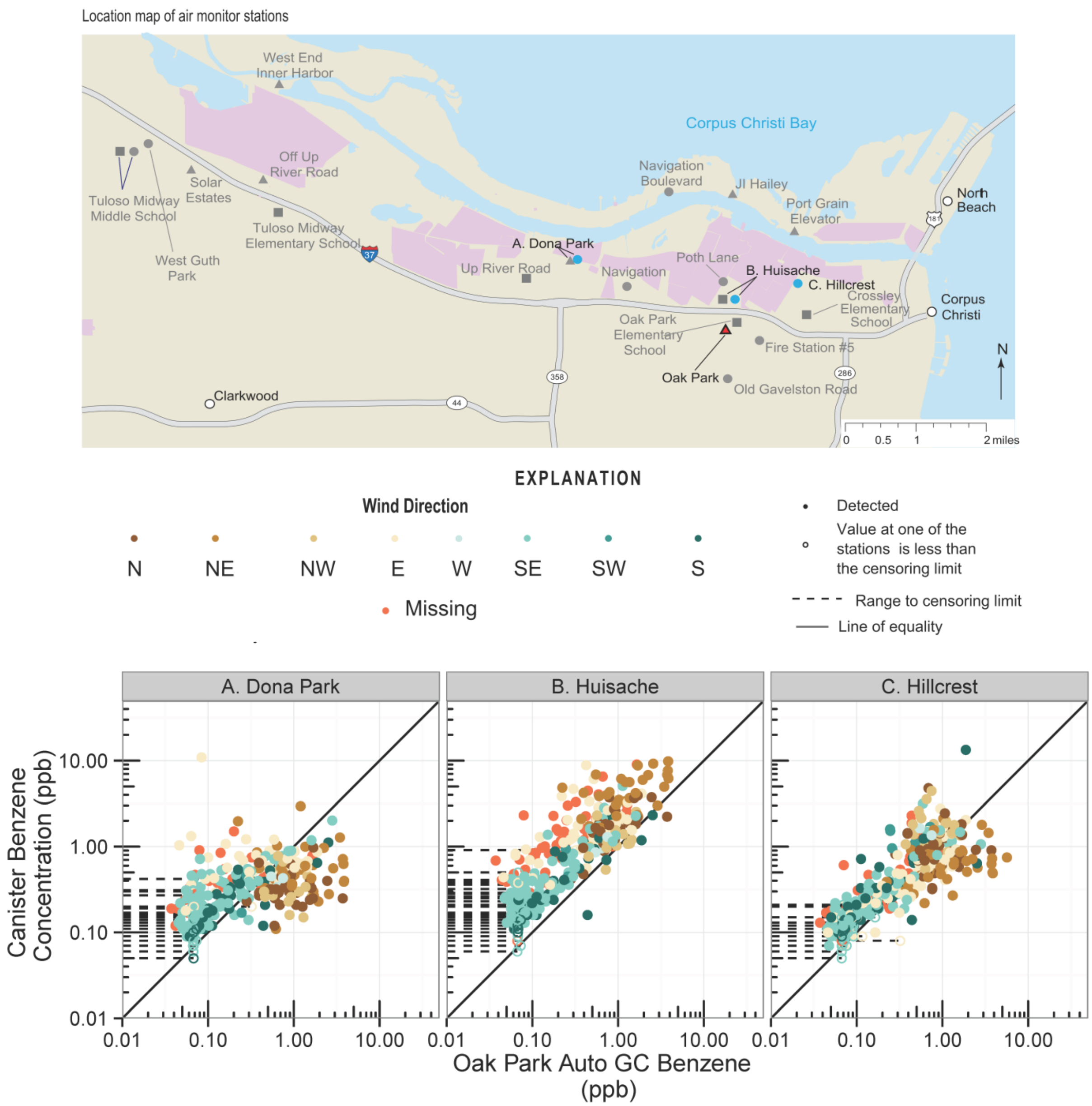
ToxStrategies, Inc. 2011. September 8th email from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005–2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

The University of Texas. 2011. April 25th email from Dr. David Sullivan, The University of Texas at Austin, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing an Excel attachment with the continuous 2010 volatile organic compounds data for the Solar Estates and Oak Park air monitoring sites. Austin, TX.

* The comparisons include wind direction. The wind direction on the figure shows when the wind comes from a specific direction toward an air monitor.

AQP	Corpus Christi Air Quality Project
Auto GC	automatic gas chromatograph
ppb	parts per billion

Figure 14A. AQP's Oak Park Auto GC Compared with TCEQ's Canister Benzene Data, Corpus Christi, TX* (page 1 of 2)



A. AQP's Oak Park Auto GC and TCEQ's Dona Park canister benzene data: Kendall's Tau = 0.44, p < 0.001

B. AQP's Oak Park Auto GC and TCEQ's Huisache canister benzene data: Kendall's Tau = 0.65, p < 0.001

C. AQP's Oak Park Auto GC and TCEQ's Hillcrest canister benzene data: Kendall's Tau = 0.67, p < 0.001

Figure 14A. AQP's Oak Park Auto GC Compared with TCEQ's Canister Benzene Data, Corpus Christi, TX* (page 2 of 2)

Data sources:
Texas Commission on Environmental Quality. 2010. Data posted to FTP site by Melanie Hotchkiss, TCEQ, and downloaded by John Wilhelmi, Eastern Research Group, Inc. Contains continuous 2005–2009 sulfur compound and volatile organic compound data for both TCEQ and Corpus Christi Air Quality Project air monitoring sites. Austin, TX.
Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through three separate queries performed with the target list "Canister Parameters" group, 24-hour concentrations for dates within the range >=1/1/1990 to <1/1/2011 for monitors in the Corpus Christi area. Data queried on 29 May 2013.
Texas Commission on Environmental Quality. 2014. Texas Air Monitoring Information System (TAMIS) web interface. Data downloaded from TAMIS through a query performed with the target list "Meteorological Parameters" for dates within the range >=1/1/2005 to <1/1/2011 for monitor Oak Park . Data downloaded on 26 February 2014.
The University of Texas. 2011. April 25th e-mail from Dr. David Sullivan, The University of Texas at Austin, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing an Excel attachment with the continuous 2010 volatile organic compounds data for the Solar Estates and Oak Park air monitoring sites. Austin, TX.

* The comparisons include wind direction. The wind direction on the figure shows when the wind comes from a specific direction toward an air monitor.

AQP	Corpus Christi Air Quality Project
Auto GC	automatic gas chromatograph
ppb	parts per billion
TCEQ	Texas Commission on Environmental Quality

Figure 15A. AQP's Solar Estates Auto GC Compared to Industry's Canister Benzene Data, Corpus Christi, TX* (page 1 of 2)

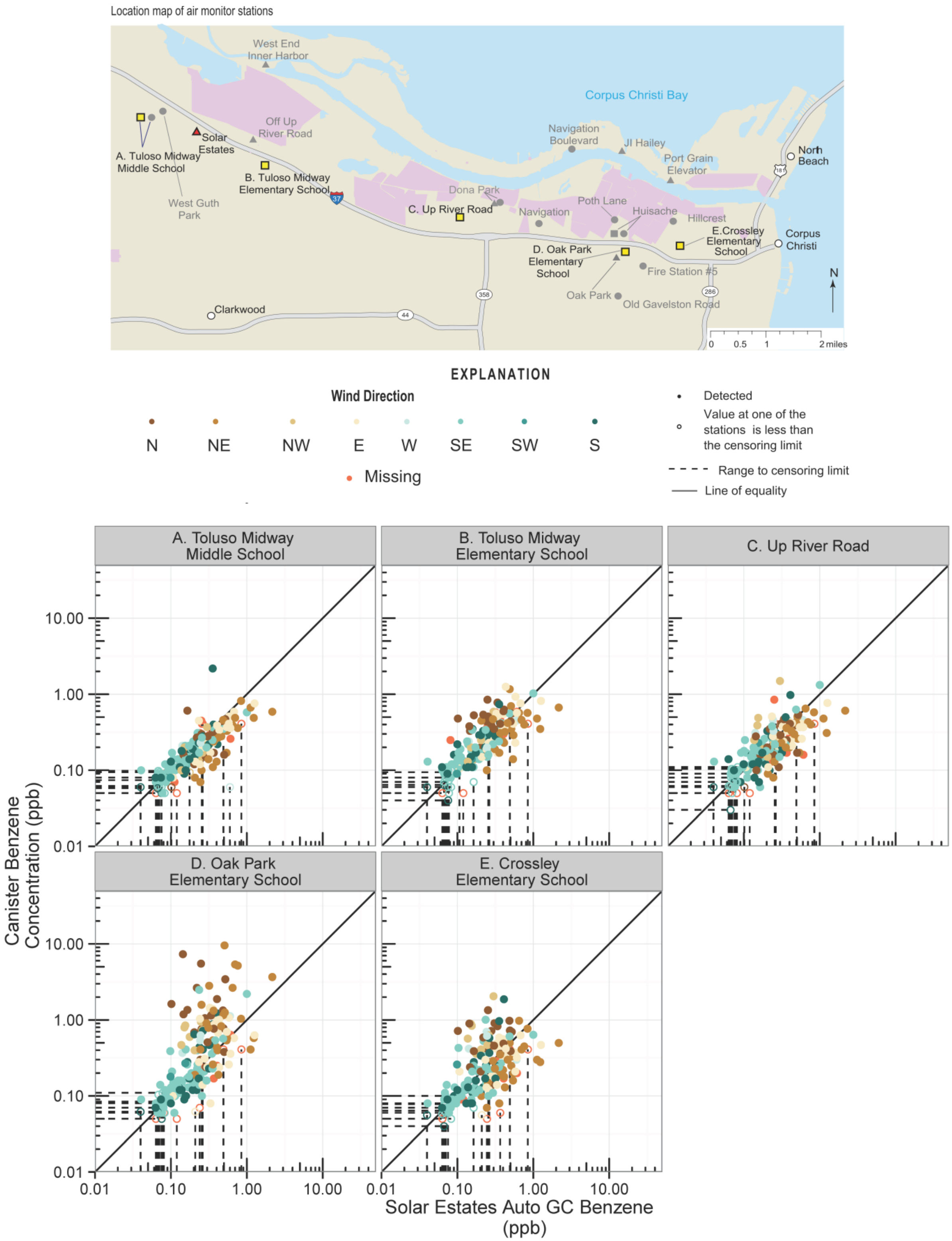


Figure 15A. AQP's Solar Estates Auto GC Compared to Industry's Canister Benzene Data, Corpus Christi, TX* (page 2 of 2)

A. AQP's Solar Estates Auto GC and industry's Tuloso Midway Middle School benzene data: Kendall's Tau = 0.65, $p < 0.001$
B. AQP's Solar Estates Auto GC and industry's Tuloso Midway Elementary School benzene data: Kendall's Tau = 0.59, $p < 0.001$
C. AQP's Solar Estates Auto GC and industry's Up River Road benzene data: Kendall's Tau = 0.56, $p < 0.001$
D. AQP's Solar Estates Auto GC and industry's Oak Park Elementary School benzene data: Kendall's Tau = 0.53, $p < 0.001$
E. AQP's Solar Estates Auto GC and industry's Crossley Elementary School benzene data: Kendall's Tau = 0.46, $p < 0.001$

Data sources:

Texas Commission on Environmental Quality. 2010. Data posted to FTP site by Melanie Hotchkiss, TCEQ, and downloaded by John Wilhelmi, Eastern Research Group, Inc. Contains continuous 2005–2009 sulfur compound and volatile organic compound data for both TCEQ and Corpus Christi Air Quality Project air monitoring sites. Austin, TX.

Texas Commission on Environmental Quality. 2014. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through a query performed with the target list "Meteorological Parameters" for dates within the range >=1/1/2005 to <1/1/2011 for Solar Estates Monitor, area. Data downloaded on 3 March 2014.

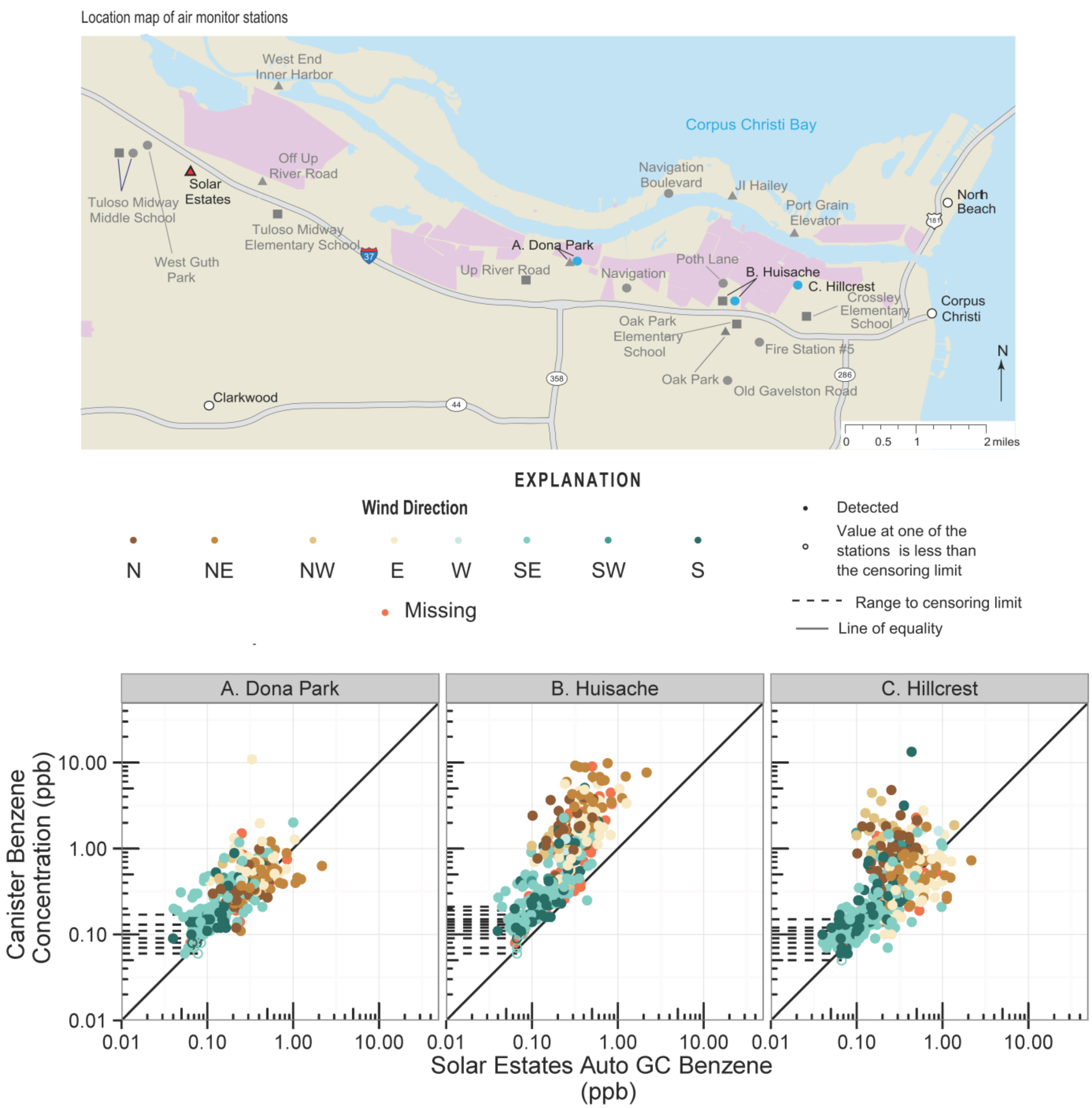
ToxStrategies, Inc. 2011. September 8th e-mail from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005−2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

The University of Texas. 2011. April 25th e-mail from Dr. David Sullivan, The University of Texas at Austin, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing an Excel attachment with the continuous 2010 volatile organic compounds data for the Solar Estates and Oak Park air monitoring sites. Austin, TX.

* The comparisons include wind direction. The wind direction on the figure shows when the wind comes from a specific direction toward an air monitor.

AQP	Corpus Christi Air Quality Project
Auto GC	automatic gas chromatograph
ppb	parts per billion

Figure 16A. AQP's Solar Estates Auto GC Compared to TCEQ's Canister Benzene Data, Corpus Christi, TX* (page 1 of 2)



A. AQP's Solar Estates Auto GC and TCEQ's Dona Park canister benzene data: Kendall's Tau = 0.56, $p < 0.001$
B. AQP's Solar Estates Auto GC and TCEQ's Huisache canister benzene data: Kendall's Tau = 0.61, $p < 0.001$
C. AQP's Solar Estates Auto GC and TCEQ's Hillcrest canister benzene data: Kendall's Tau = 0.49, $p < 0.001$

Figure 16A. AQP's Solar Estates Auto GC Compared to TCEQ's Canister Benzene Data, Corpus Christi, TX* (page 2 of 2)

Data sources:

Texas Commission on Environmental Quality. 2010. Data posted to FTP site by Melanie Hotchkiss, TCEQ, and downloaded by John Wilhelmi, Eastern Research Group, Inc. Contains continuous 2005–2009 sulfur compound and volatile organic compound data for both TCEQ and Corpus Christi Air Quality Project air monitoring sites. Austin, TX.

Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through three separate queries performed with the target list "Canister Parameters" group, 24-hour concentrations for dates within the range >=1/1/1990 to <1/1/2011 for monitors in the Corpus Christi area. Data queried on 29 May 2013.

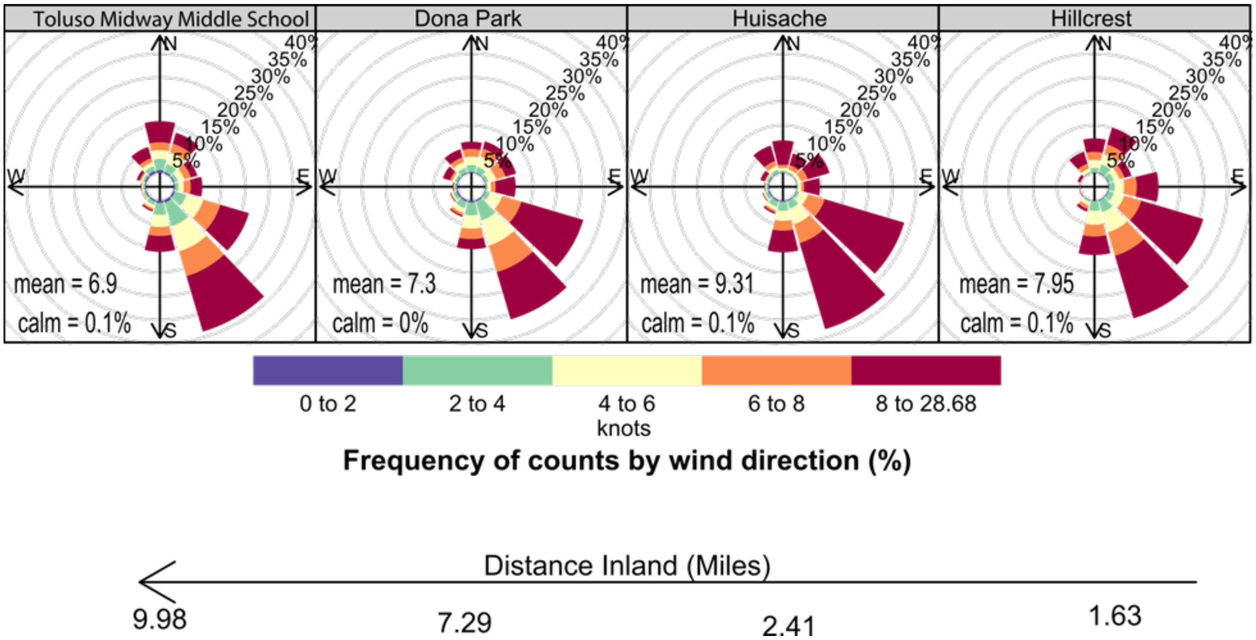
Texas Commission on Environmental Quality. 2014. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through a query performed with the target list "Meteorological Parameters" for dates within the range >=1/1/2005 to <1/1/2011 for Solar Estates Monitor, area. Data downloaded on 3 March 2014.

The University of Texas. 2011. April 25th e-mail from Dr. David Sullivan, The University of Texas at Austin, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing an Excel attachment with the continuous 2010 volatile organic compounds data for the Solar Estates and Oak Park air monitoring sites. Austin, TX.

* The comparisons include wind direction. The wind direction on the figure shows when the wind comes from a specific direction toward an air monitor.

AQP	Corpus Christi Air Quality Project
Auto GC	automatic gas chromatograph
ppb	parts per billion
TCEQ	Texas Commission on Environmental Quality

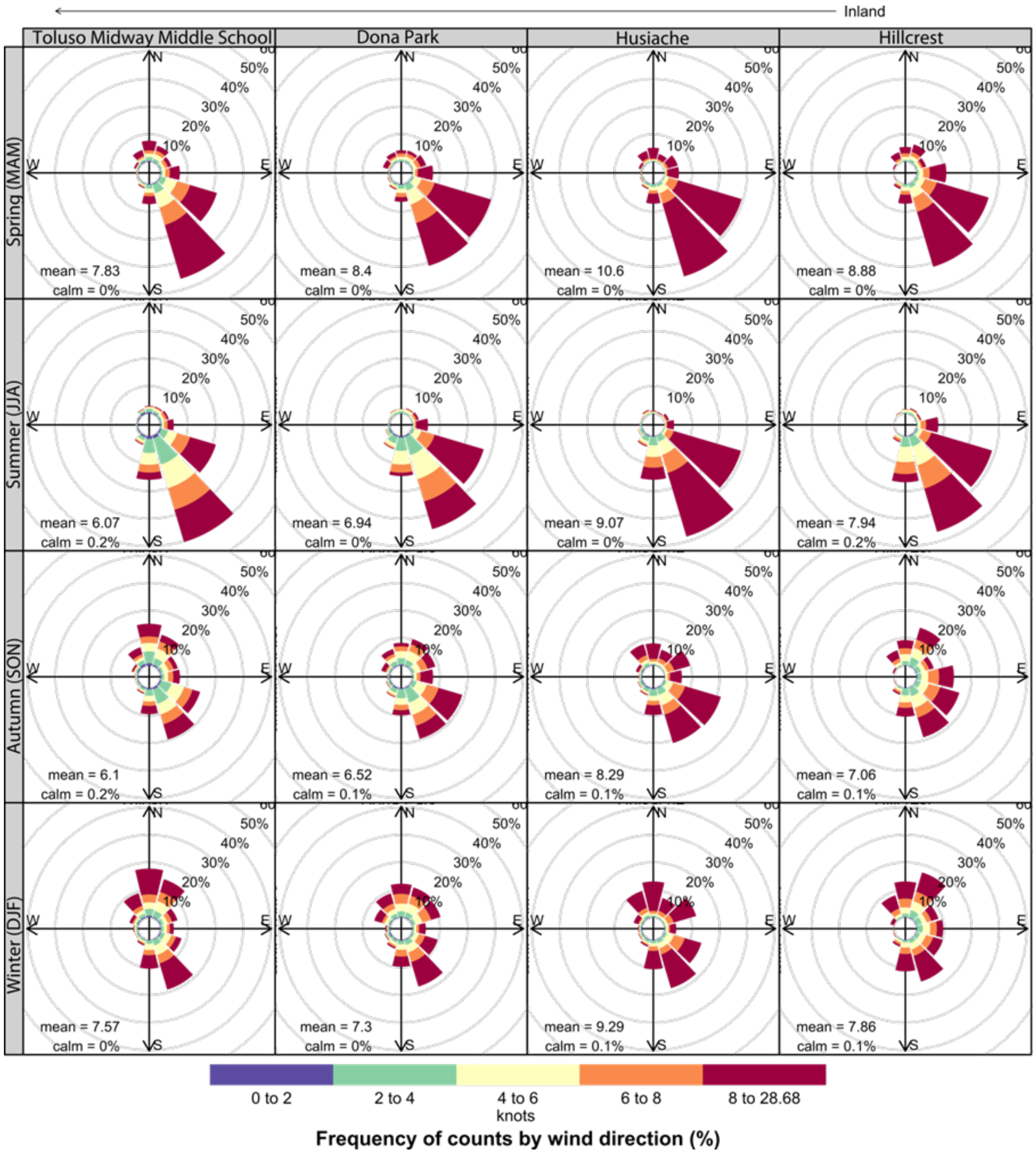
Figure 17A. Wind Roses (2000–2010) for Refinery Row, Corpus Christi, TX*



Data Source: Texas Commission on Environmental Quality. 2012. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through a query performed with the target list "Meteorological Parameters" for dates within the range >=1/1/2000 to <1/1/2011 for monitors in the Corpus Christi area. Data downloaded on 15 and 16 October 2012. Note: Dona Park wind rose data cover 2003–2010

* A wind rose is a way of showing average wind direction and speed. These pictures gives a summary of how often wind comes from a direction towards the weather station (wind from), as well as the wind speed during that time. The weather station is at the center of a wind rose, so an arrow to the east of the center indicates wind from the east. The arrows are labeled with a percent, which indicates the percent of time the wind was coming from that direction at that speed. Relative wind speeds are shown by the color of the arrow.

Figure 18A. Seasonal Wind Roses (2000–2010) for Refinery Row, Corpus Christi, TX* (page 1 of 2)



Data Source: Texas Commission on Environmental Quality. 2012. Texas Air Monitoring Information System (TAMIS) web interface. Data downloaded from TAMIS through a query performed with the target list “Meteorological Parameters” for dates within the range >=1/1/2000 to <1/1/2011 for monitors in the Corpus Christi area. Data downloaded on 15 and 16 October 2012. Note: Dona Park wind rose data cover 2003 –2010.

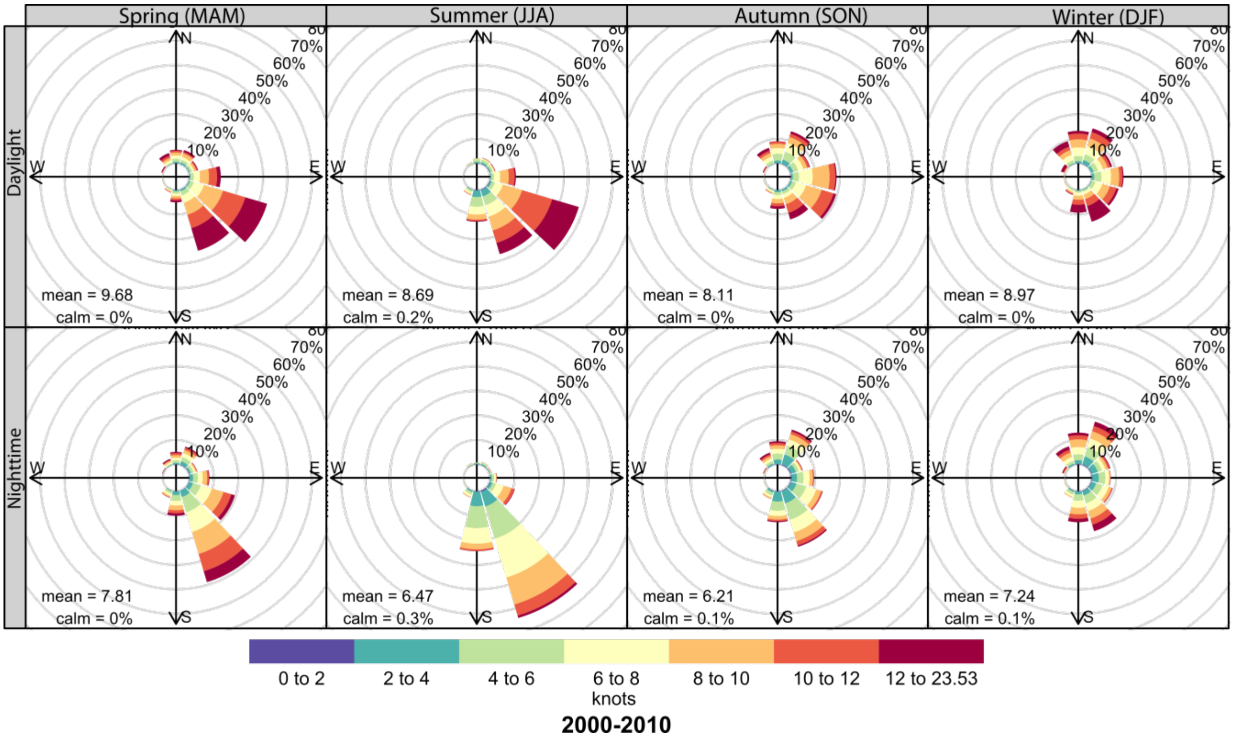
* A wind rose is a way of showing average wind direction and speed. These pictures gives a summary of how often wind comes from a direction towards the weather station (wind from), as well as the wind speed during

Figure 18A. Seasonal Wind Roses (2000–2010) for Refinery Row, Corpus Christi, TX* (page 2 of 2)

that time. The weather station is at the center of a wind rose, so an arrow to the east of the center indicates wind from the east. The arrows are labeled with a percent, which indicates the percent of time the wind was coming from that direction at that speed. Relative wind speeds are shown by the color of the arrow.

DJF	December, January, February
JJA	June, July, August
MAM	March, April, May
SON	September, October, November

Figure 19A. Hillcrest Seasonal Diurnal Wind Roses (2000–2010), Corpus Christi, TX*

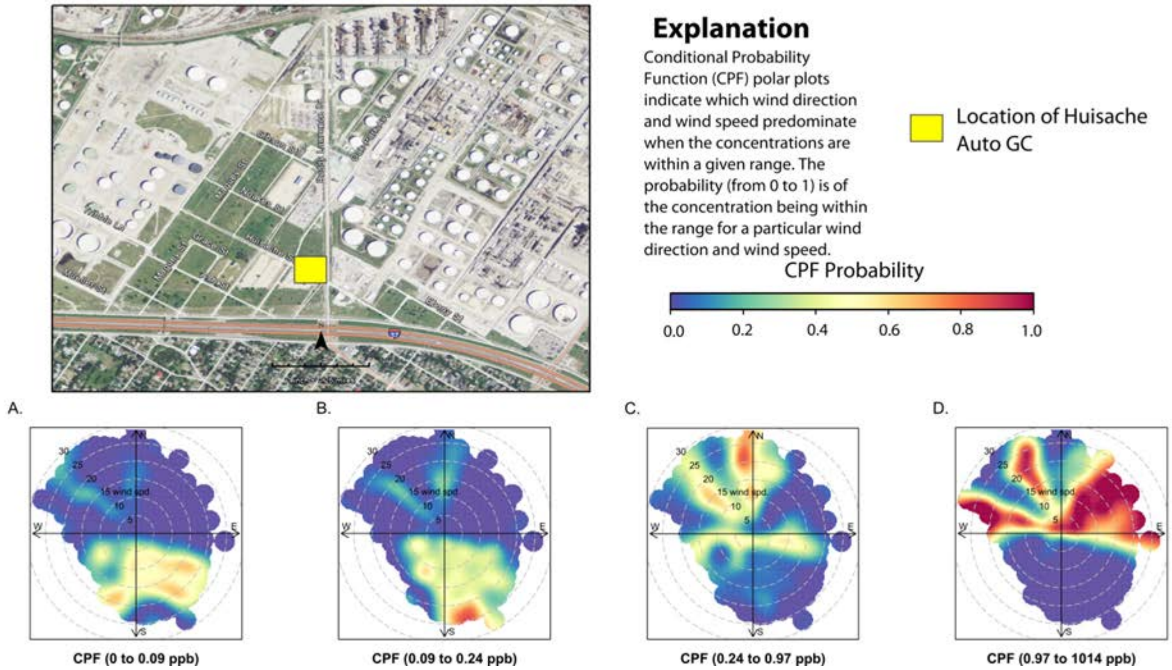


Data Source: Texas Commission on Environmental Quality. 2012. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through a query performed with the target list "Meteorological Parameters" for dates within the range >=1/1/2000 to <1/1/2011 for monitors in the Corpus Christi, area. Data downloaded on 15 and 16 October 2012.

* A wind rose is a way of showing average wind direction and speed. These pictures gives a summary of how often wind comes from a direction towards the weather station (wind from), as well as the wind speed during that time. The weather station is at the center of a wind rose, so an arrow to the east of the center indicates wind from the east. The arrows are labeled with a percent, which indicates the percent of time the wind was coming from that direction at that speed. Relative wind speeds are shown by the color of the arrow.

DJF December, January, February
JJA June, July, August
MAM March, April, May
SON September, October, November

Figure 20A. Huisache Auto GC Benzene Conditional Probability Plots, Corpus Christi, TX*



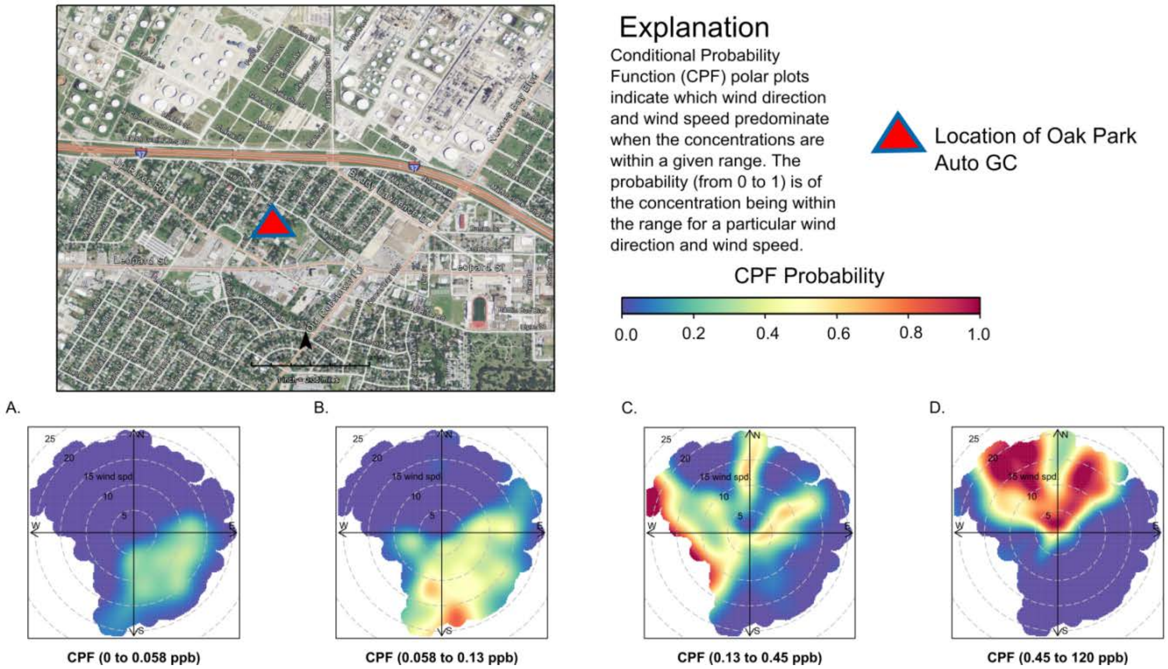
A. Winds from the southeast and southwest were more likely to be associated with the bottom quartile of benzene concentrations.
B. Winds from the south and southeast were more likely to be associated with the 2nd quartile of benzene concentrations.
C. Winds were likely from the north, northwest, and east for the 3rd quartile of benzene concentrations.
D. Winds from Refinery Row, the east to northeast, northwest and west were likely to have concentrations in the top quartile (greater than 0.97 ppb benzene).

Data Source: ToxStrategies, Inc. 2011. September 8th email from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005−2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

* Plots show concentration quartiles (each quartile spans 25% of the concentrations). Wind speed is in knots.

Auto GC	automatic gas chromatograph
CPF	conditional probability function
ppb	parts per billion

Figure 21A. Oak Park Auto GC Benzene Conditional Probability Plots, Corpus Christi, TX*



A. The lower quartile polar plot indicates that southeasterly winds were more likely to be associated with benzene concentrations at the Oak Park Auto GC station that were below 0.058 ppb.
B. Winds from the south as well as the southeast were more likely to result in benzene concentrations in the 2nd quartile.
C. Benzene concentrations were more likely in the 3rd quartile when winds were from the west, as well as the north and northeast.
D. When winds were from the northeast and northwest, the concentration was likely to be greater than 0.45 ppb.

Data Sources:

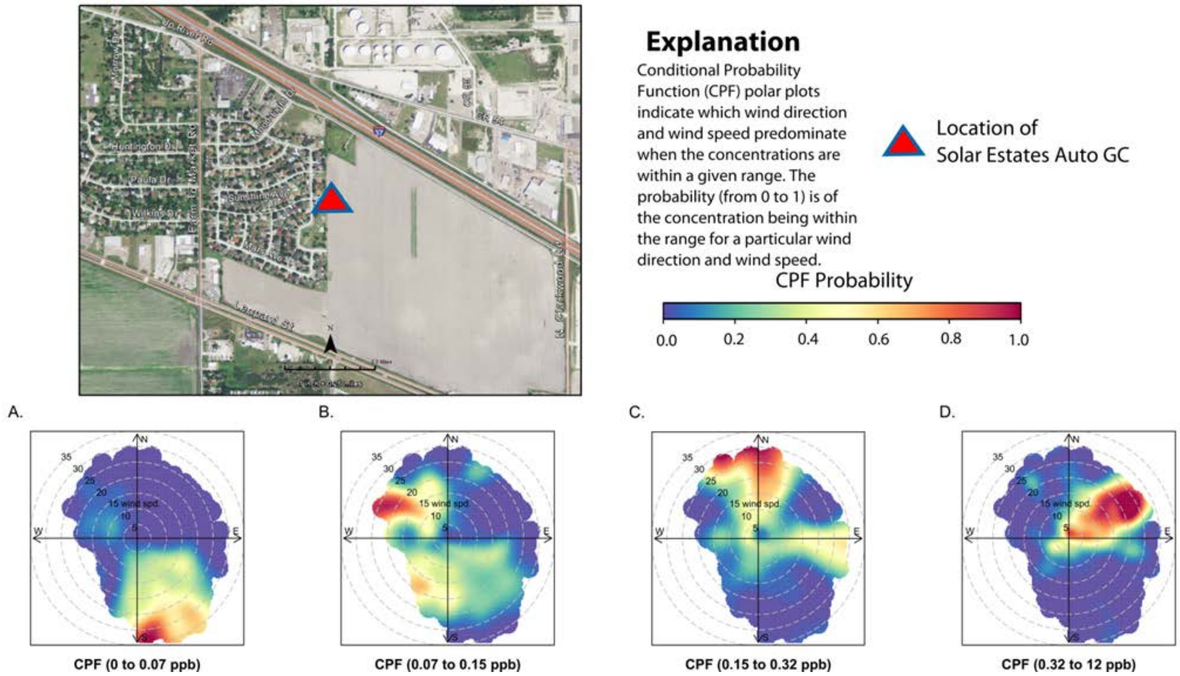
Texas Commission on Environmental Quality. 2014. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through a query performed with the target list “Meteorological Parameters” for dates within the range >=1/1/2005 to <1/1/2011 for Solar Estates Monitor, area. Data downloaded on 3 March 2014.

The University of Texas. 2011. April 25th email from Dr. David Sullivan, The University of Texas at Austin, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing an Excel attachment with the continuous 2010 volatile organic compounds data for the Solar Estates and Oak Park air monitoring sites. Austin, TX.

* Plots show concentration quartiles (each quartile spans 25% of the concentrations). Wind speed is in knots.

Auto GC	automatic gas chromatograph
CPF	conditional probability function
ppb	parts per billion

Figure 22A. Solar Estates Auto GC Benzene Conditional Probability Plots, Corpus Christi, TX*



A. The lower quartile polar plot indicates that when winds were from the south and southeast, benzene concentrations were more likely in the bottom quartile.
B. Winds from the general directions of west-northwest and west-southwest were more likely to result in benzene concentrations in the 2nd quartile.
C. Benzene concentrations were more likely in the 3rd quartile when winds were in the north and east wind directions.
D. Benzene concentrations were likely to be in the top quartile (greater than 0.32 ppb) when winds were from the northeast.

Data Sources:

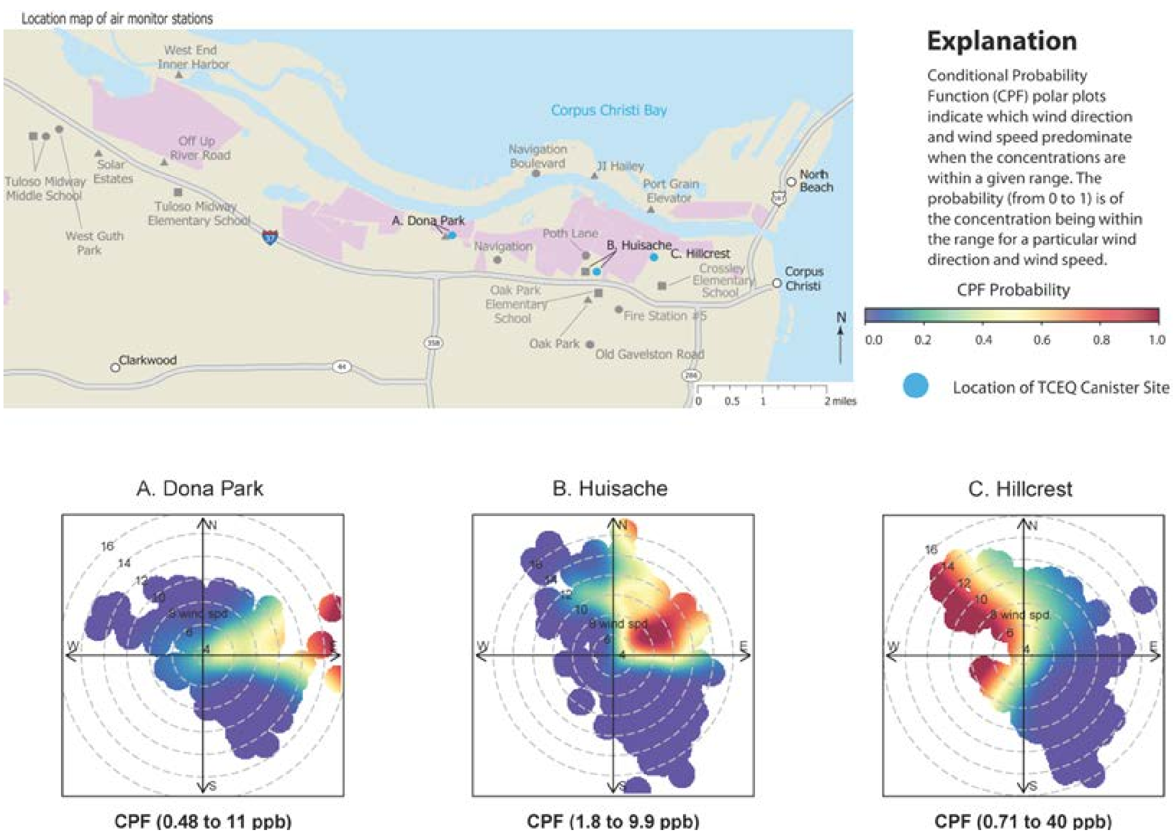
Texas Commission on Environmental Quality. 2014. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through a query performed with the target list "Meteorological Parameters" for dates within the range >=1/1/2005 to <1/1/2011 for Solar Estates Monitor, area. Data downloaded on 3 March 2014.

The University of Texas. 2011. April 25th email from Dr. David Sullivan, The University of Texas at Austin, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing an Excel attachment with the continuous 2010 volatile organic compounds data for the Solar Estates and Oak Park air monitoring sites. Austin, TX.

* Plots show concentration quartiles (each quartile spans 25% of the concentrations). Wind speed is in knots.

Auto GC	automatic gas chromatograph
CPF	conditional probability function
ppb	parts per billion

Figure 23A. TCEQ Canister Top Quartile Benzene Conditional Probability Plots, Corpus Christi, TX*



A. Benzene concentrations at Dona Park were more likely in the top quartile when the winds were from the east.
B. Similar to the Huisache Auto GC data, the Huisache canister benzene concentrations were more likely to be in the top quartile when winds were from the northeast. The northwest winds are not as influential on the CPF, possibly due to time averaging effects or relative quantities of benzene emissions.
C. Westerly winds increased the likelihood that benzene concentrations were in the top quartile at Hillcrest.

Data Sources:

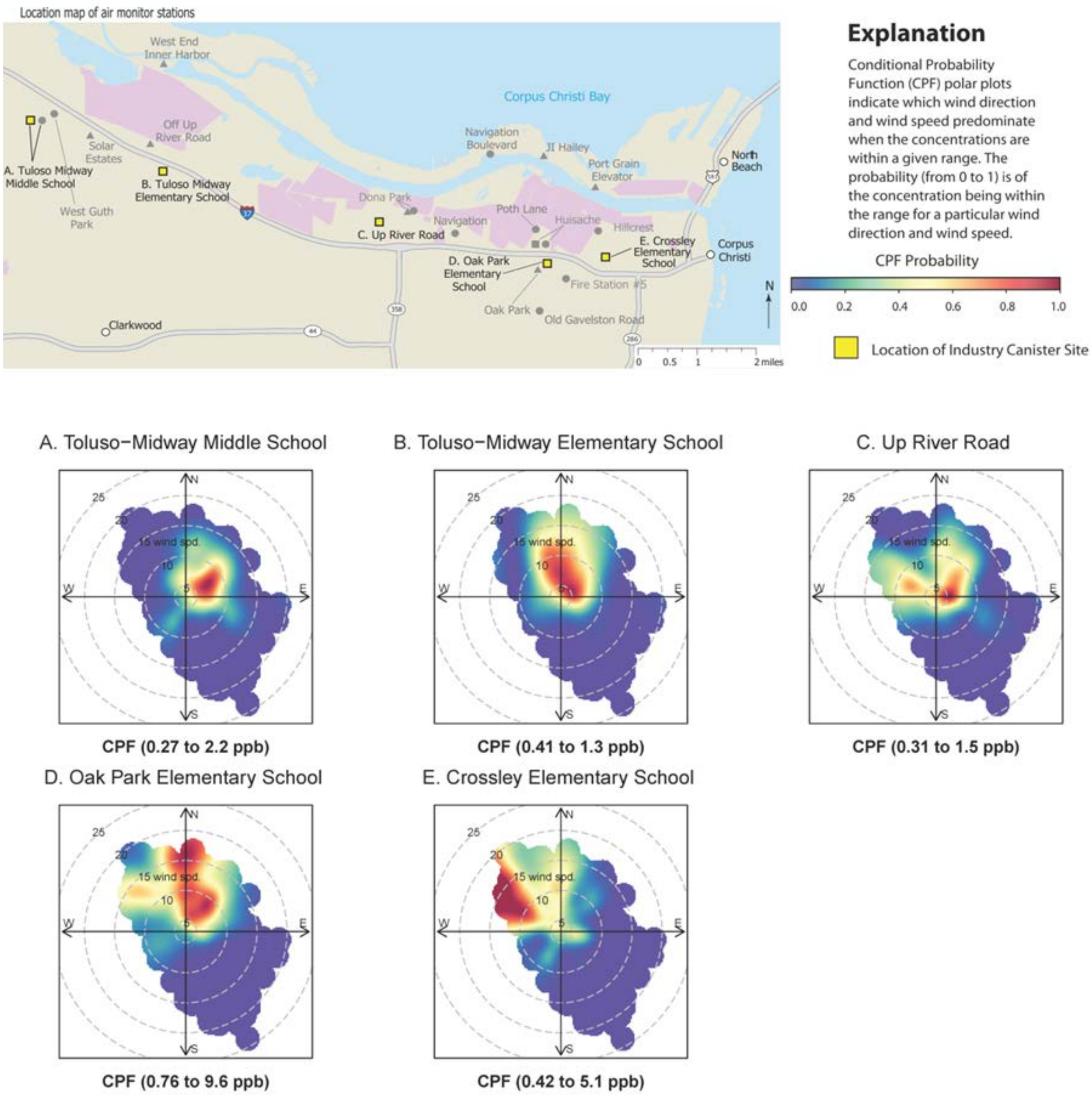
Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through three separate queries performed with the target list "Canister Parameters" group, 24-hour concentrations for dates within the range >=1/1/1990 to <1/1/2011 for monitors in the Corpus Christi area. Data queried on 29 May 2013.

Texas Commission on Environmental Quality. 2014. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through three separate queries performed with the target list "Meteorological Parameters" group, 1-hour values for dates within the range >=1/1/1993 to <1/1/2011 for locations Huisache, Hillcrest, and Dona Park . Data queried on 20 March 2014.

* Plots show the top quartile at each site (a quartile spans 25% of the concentrations). Wind speed is in knots.

CPF conditional probability function
ppb parts per billion
TCEQ Texas Commission on Environmental Quality

Figure 24A. Industry Canister Top Quartile Benzene Conditional Probability Plots, Corpus Christi, TX* (page 1 of 2)



A. Similar to the Solar Estates Auto GC data, Tuloso Midway Middle School had increased probabilities of top quartile benzene concentrations when winds were from the northeast.
B. Tuloso Midway Elementary School had increased probabilities of top quartile benzene concentrations when winds were from the north.
C. Similar to the Dona Park canister data, easterly winds at the Up River Road site slightly increased the probability of top quartile benzene concentrations. Being farther west than Dona Park, the Up River Road site also showed westerly winds slightly increasing the probability of top quartile benzene concentrations.
D. Similar to the Oak Park Auto GC data, northerly winds increased the probability of top quartile benzene concentrations at Oak Park Elementary School.
E. A higher probability of top quartile benzene concentrations at Crossley Elementary School occurred when winds were from the northwest.

Figure 24A. Industry Canister Top Quartile Benzene Conditional Probability Plots, Corpus Christi, TX* (page 2 of 2)

Data Sources:

ToxStrategies, Inc. 2011. September 8th email from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005−2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

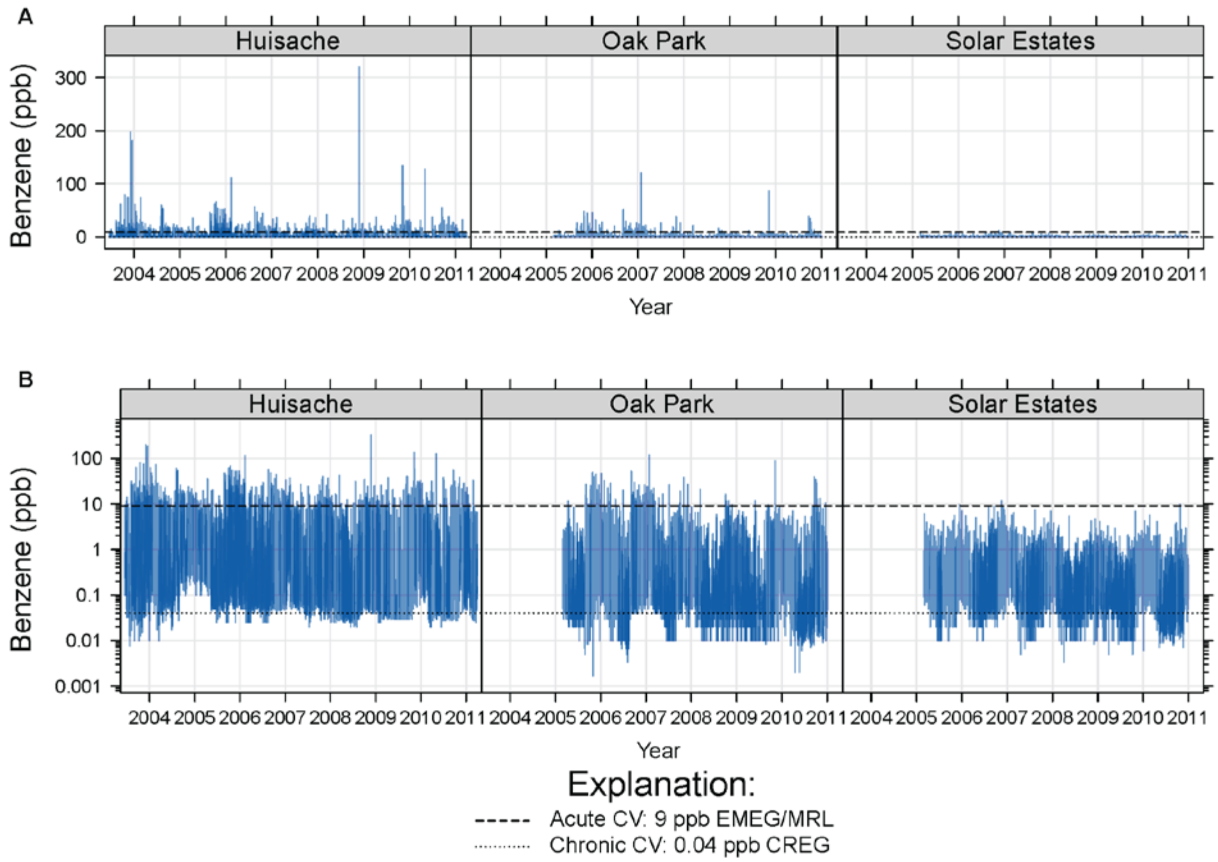
Texas Commission on Environmental Quality. 2014. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through a query performed with the target list “Meteorological Parameters” for dates within the range >=1/1/2005 to <1/1/2011 for Solar Estates Monitor, area. Data downloaded on 3 March 2014.

Texas Commission on Environmental Quality. 2014. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through three separate queries performed with the target list “Meteorological Parameters” group, 1-hour values for dates within the range >=1/1/1993 to <1/1/2011 for locations Huisache, Hillcrest, and Dona Park . Data queried on 20 March 2014.

* Plots show the top quartile at each site (a quartile spans 25% of the concentrations). Wind speed is in knots.

CPF conditional probability function
ppb parts per billion

Figure 25A. Benzene Auto GC Concentration Exceedances above Comparison Values, Corpus Christi, TX*



A. Linear Scale
B. Log-10 Scale

Data Sources:

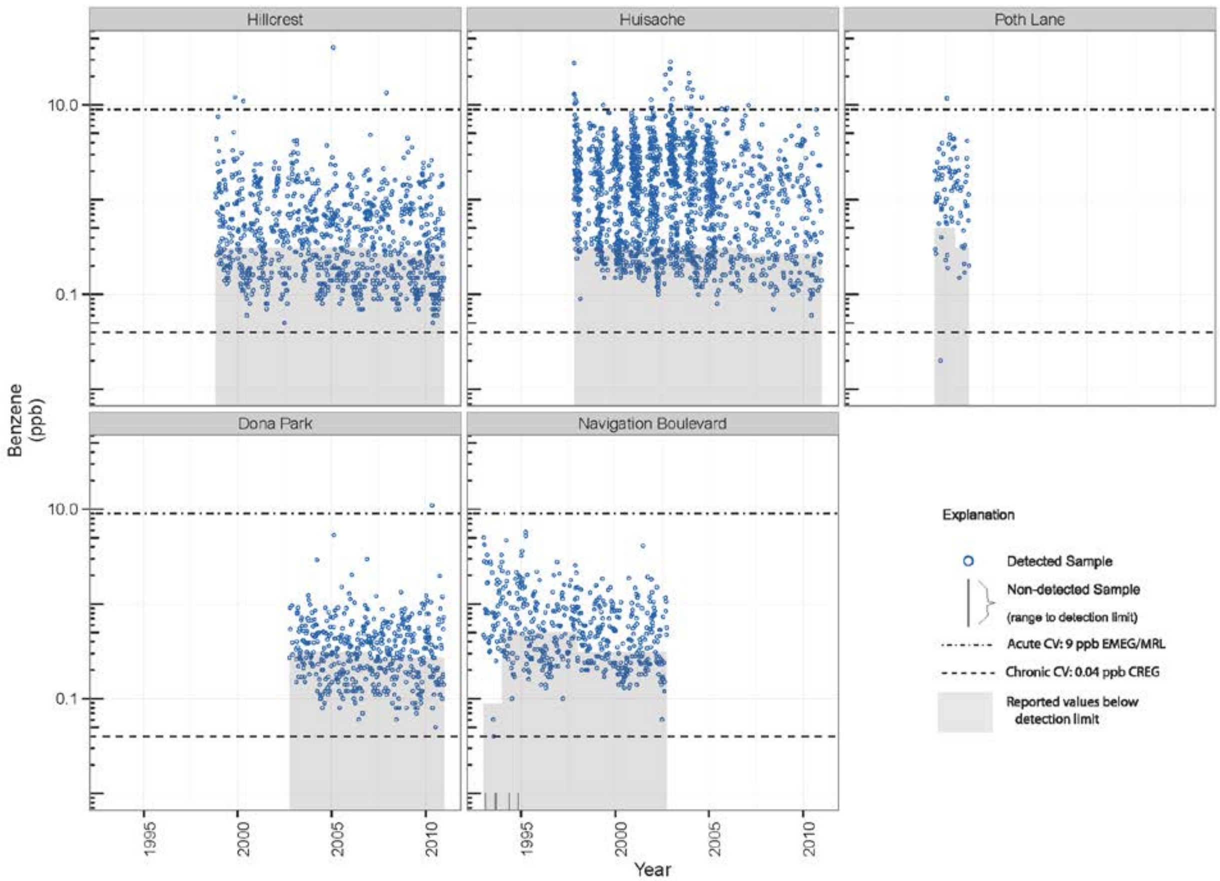
ToxStrategies, Inc. 2011. September 8th email from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005−2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

The University of Texas. 2011. April 25th email from Dr. David Sullivan, The University of Texas at Austin, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing an Excel attachment with the continuous 2010 volatile organic compounds data for the Solar Estates and Oak Park air monitoring sites. Austin, TX.

* The 15-minute benzene readings at Huisache were averaged to make the data comparable to the 1-hour benzene reading at Oak Park and Solar Estates.

Auto GC	automatic gas chromatograph
CREG	cancer risk evaluation guide
CV	comparison value
EMEG/MRL	environmental media evaluation guide/minimal risk level
ppb	parts per billion

Figure 26A. TCEQ Benzene Canister Sampling Data, Corpus Christi, TX*

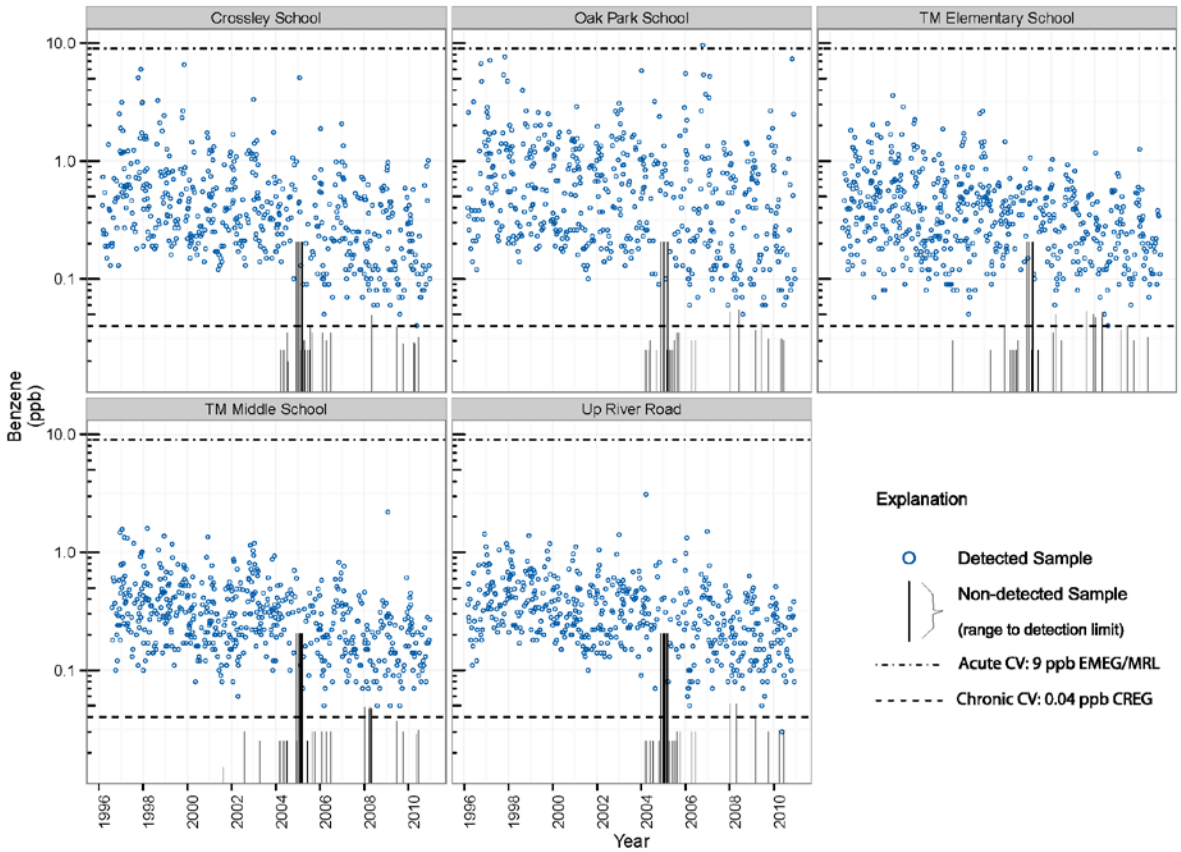


Data Source: Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through three separate queries performed with the target list “Canister Parameters” group, 24-hour concentrations for dates within the range >=1/1/1990 to <1/1/2011 for monitors in the Corpus Christi area. Data queried on 29 May 2013.

* For the TCEQ data, the detection limit is a value such that it is high enough to have a 99% confidence that it does not include zero. TCEQ reports values less than the detection limit, and uses these data in summary statistical calculations, but individually, the results should be qualified as uncertain.

CREG	cancer risk evaluation guide
CV	comparison value
EMEG/MRL	environmental media evaluation guide/minimal risk level
ppb	parts per billion
TCEQ	Texas Commission on Environmental Quality

Figure 27A. Industry Benzene Canister Sampling Data, Corpus Christi, TX*

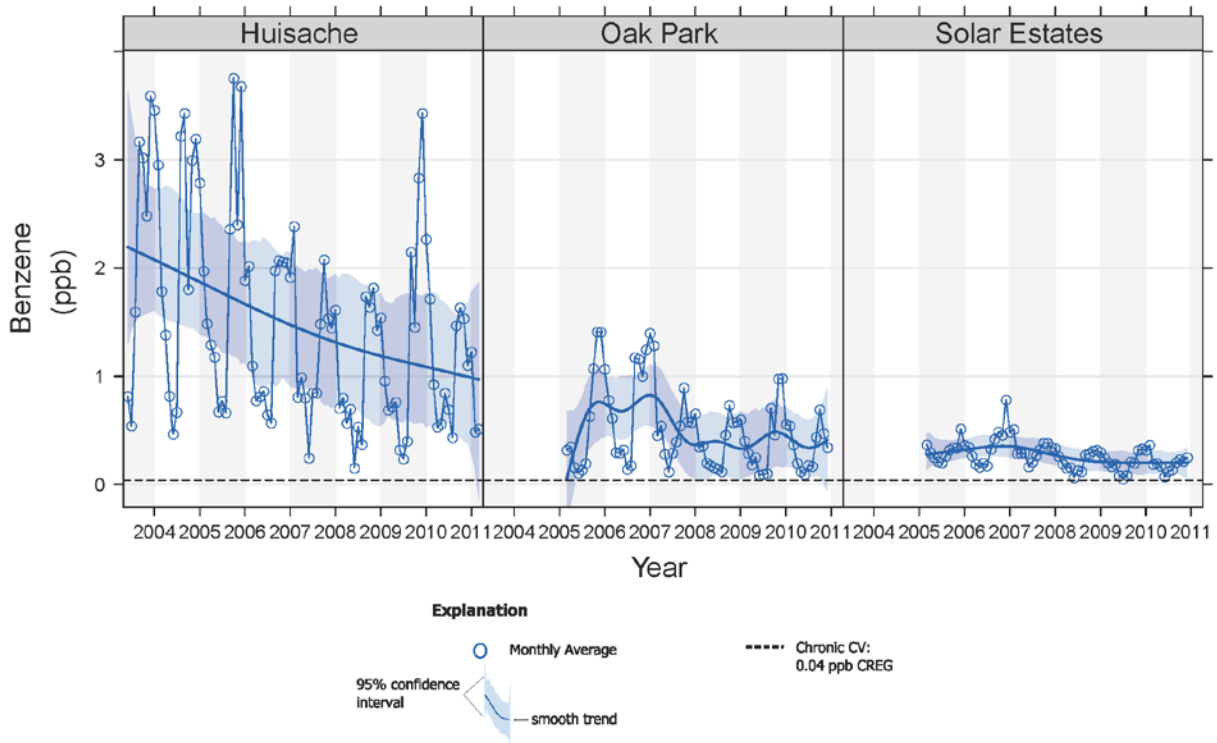


Data Source: ToxStrategies, Inc. 2011. September 8th email from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005−2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

* For the industry data, censored data are identified by a vertical line showing the range from zero to the detection limit.

CREG	cancer risk evaluation guide
CV	comparison value
EMEG/MRL	environmental media evaluation guide/minimal risk level
ppb	parts per billion

Figure 28A. Monthly Average Benzene Auto GC Concentrations, Corpus Christi, TX*



Data Sources:

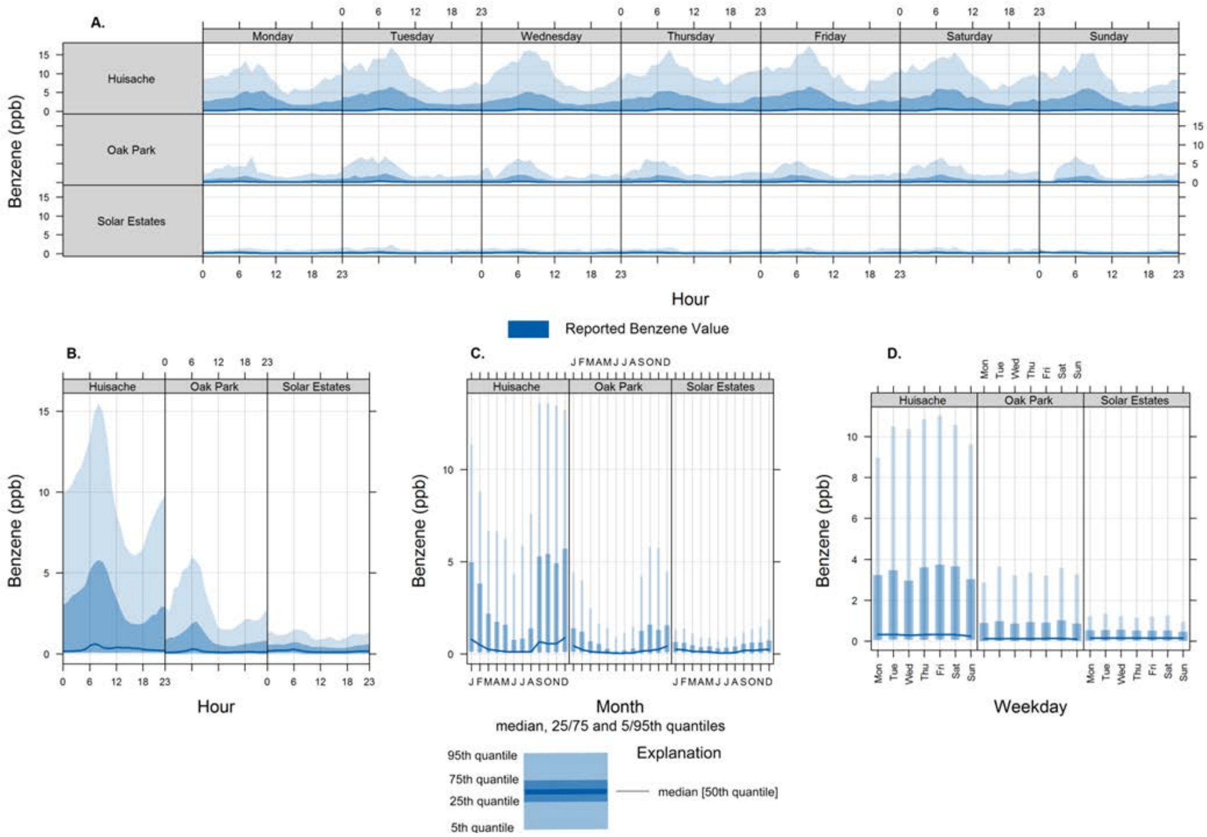
ToxStrategies, Inc. 2011. September 8th email from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005–2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

The University of Texas. 2011. April 25th email from Dr. David Sullivan, The University of Texas at Austin, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing an Excel attachment with the continuous 2010 volatile organic compounds data for the Solar Estates and Oak Park air monitoring sites. Austin, TX.

* Huisache Auto GC values were averaged by month using ROS to make them comparable to other two Auto GC sites. Trend uncertainty was estimated using the block bootstrap (R=200) option in smoothTrend function. Seasonal effects were not removed from this trend. Data were available for Huisache from 2003-2010, and 2005-2010 for Oak Park and Solar Estates.

Auto GC	automatic gas chromatograph
CREG	cancer risk evaluation guide
CV	comparison value
ppb	parts per billion

Figure 29A. Temporal Variations in Auto GC Benzene Data, Corpus Christi, TX*



A. Hourly benzene concentrations by day of the week.
B. Hourly benzene concentrations.
C. Monthly benzene concentrations.
D. Weekday benzene concentrations.

Data Sources:

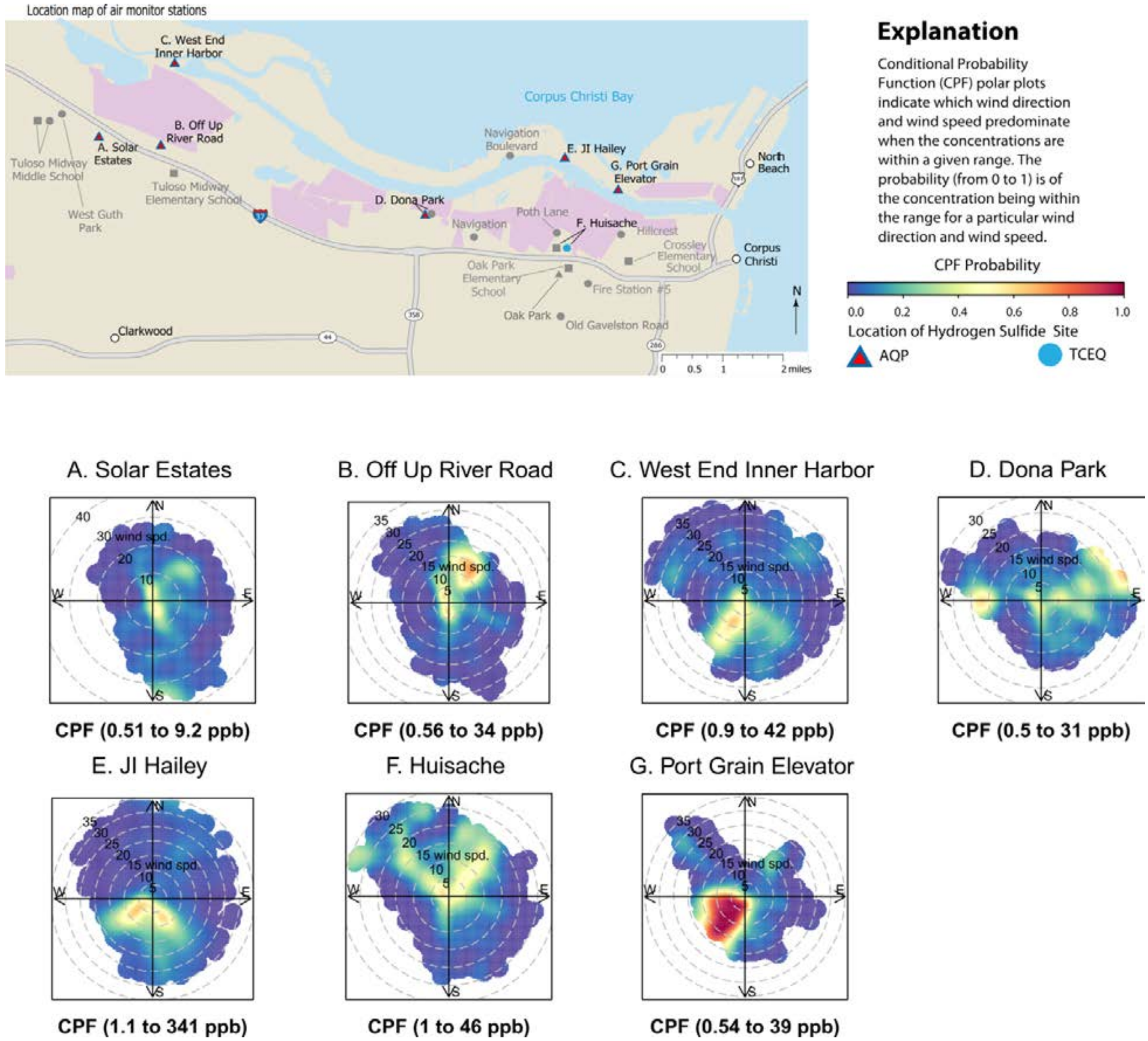
ToxStrategies, Inc. 2011. September 8th email from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005−2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

The University of Texas. 2011. April 25th email from Dr. David Sullivan, The University of Texas at Austin, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing an Excel attachment with the continuous 2010 volatile organic compounds data for the Solar Estates and Oak Park air monitoring sites. Austin, TX.

* The benzene data for Oak Park and Solar Estates shown are the reported values given by the Auto GC instrument. Huisache 15-minute Auto GC measurements were averaged by hour to make data comparable to other Auto GC sites. Quantiles are a percent of the total amount – that is, the amount of the data less than the quantile percent level.

Auto GC	automatic gas chromatograph
JFMAMJJASOND	January, February, March, April, May, June, July, August, September, October, November December
ppb	parts per billion

Figure 30A. Hydrogen Sulfide Top Quintile Conditional Probability Plots, Corpus Christi, TX* (page 1 of 2)



A. Solar Estates had the lowest top quintile of hydrogen sulfide concentrations, with only a slight increase in probability of concentrations being in this range when the winds were from the northeast.

B. At Off Up River Road, increased probabilities of top quintile concentrations occurred when winds were from the north through the northeast, at relatively higher speeds. This could be an indication of a buoyant plume or plumes or taller stack emissions brought down to ground level by turbulent conditions [Carslaw 2014].

C. Obvious trends appeared with hydrogen sulfide at West End Inner Harbor, which had higher probabilities of hydrogen sulfide concentrations in the top quintile when winds were from the south-southwest. There was some slight increase in probability when the winds were from the southeast.

D. Dona Park had higher probabilities of top quintile hydrogen sulfide concentrations when the winds were from the northeast and a small increase in probability when the winds were from the west.

E. JI Hailey hydrogen sulfide data showed that when winds were from the southeast or southwest, the probabilities of top quintile concentrations were elevated. Also, the JI Hailey site had the highest hydrogen sulfide concentrations for the 2006–2010 period.

Figure 30A. Hydrogen Sulfide Top Quintile Conditional Probability Plots, Corpus Christi, TX* (page 2 of 2)

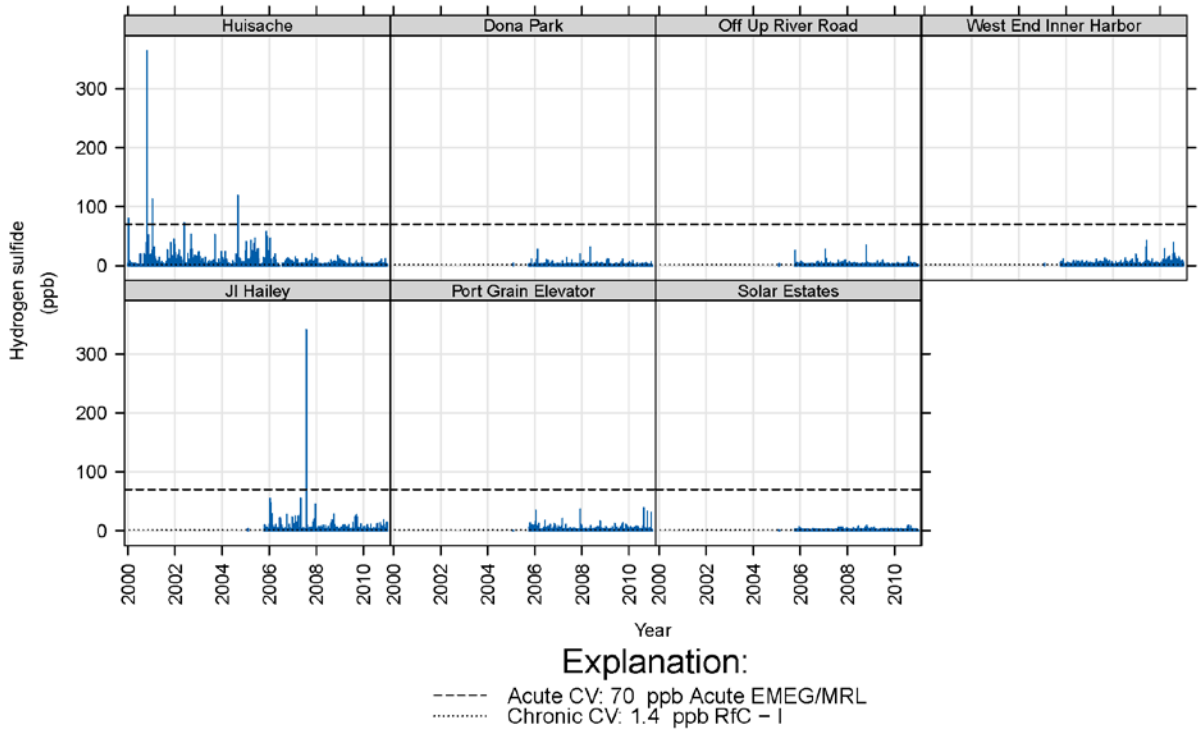
F. Huisache had higher probabilities of top quintile hydrogen sulfide concentrations when the winds were from the northeast or northwest. Huisache is approximately 1.37 miles south of JI Hailey, and their polar plots suggest strong sources of hydrogen sulfide at locations between the two monitors (i.e., their polar plots are inverses of each other). The plots also show the same sources affect Port Grain Elevator (located approximately 1.27 miles northeast of Huisache and 0.91 southeast of JI Hailey).
G. An increased probability of hydrogen sulfide concentrations being in the top quintile occurred when winds were from the southwest through west at Port Grain Elevator.

Data Sources:
Carslaw DC. 2014. The openair manual. 10th edition. Kings London: College of London. Available online: http://www.openair-project.org/PDF/OpenAir_Manual.pdf.
Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through queries on hourly hydrogen sulfide and sulfur dioxide measurements for dates within the range >=1/1/1980 to <1/1/2011 (separate queries for each parameter by decade) for monitors in the Corpus Christi area. Data downloaded on 28 August 2013.
Texas Commission on Environmental Quality. 2014. Texas Commission on Environmental Quality. 2014 Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through queries on Meteorological Parameters for Tuloso Midway Middle School, Solar Estates, Off Up River Road, West End Inner Harbor, Dona Park, JI Hailey, Huisache, and Port Grain Elevator. Data downloaded on 20 March 2014 and 27 June 2014.

* Plots show the top quintile at each site (a quintile spans 20% of the concentrations). Wind speed is in knots.

CPF conditional probability function
ppb parts per billion

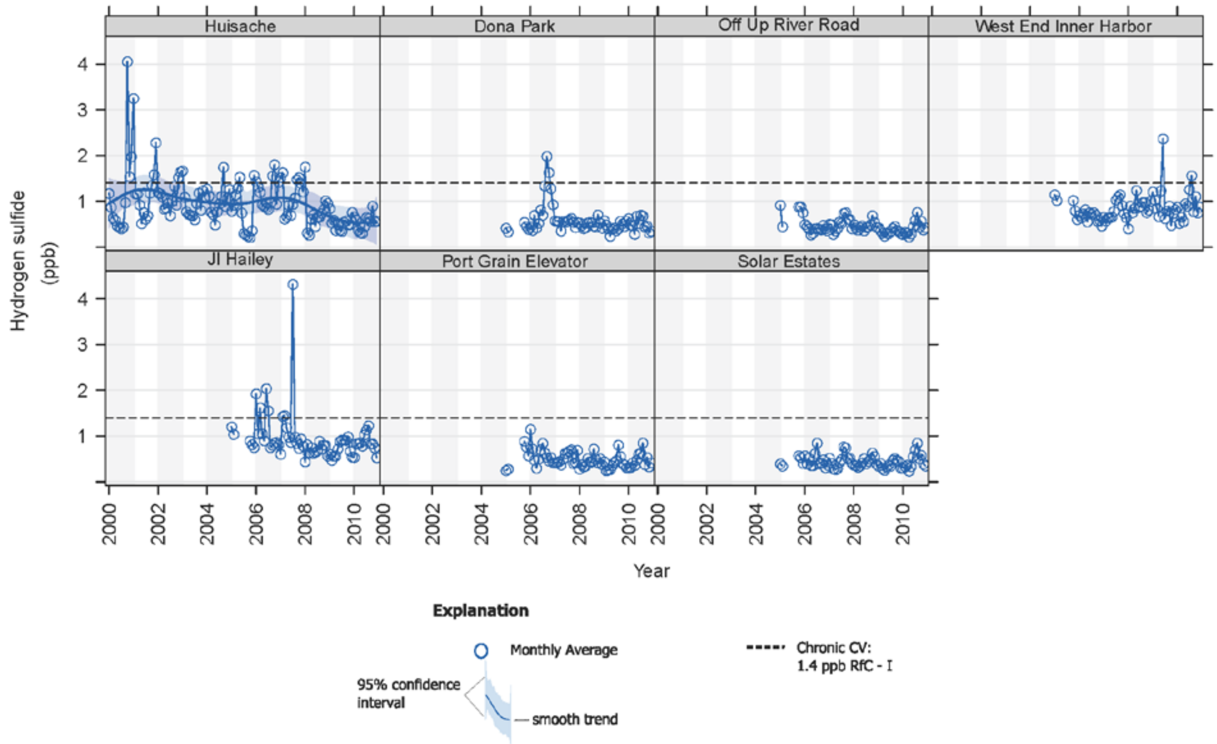
Figure 31A. Hourly Hydrogen Sulfide Measurements (2000–2010), Corpus Christi, TX



Data Source: Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through queries on hourly hydrogen sulfide and sulfur dioxide measurements for dates within the range >=1/1/1980 to <1/1/2011 (separate queries for each parameter by decade) for monitors in the Corpus Christi area. Data downloaded on 28 August 2013.

CV	comparison value
EMEG/MRL	environmental media evaluation guide/minimal risk level
ppb	parts per billion
RfC – I	reference concentration – Integrated Risk Information System

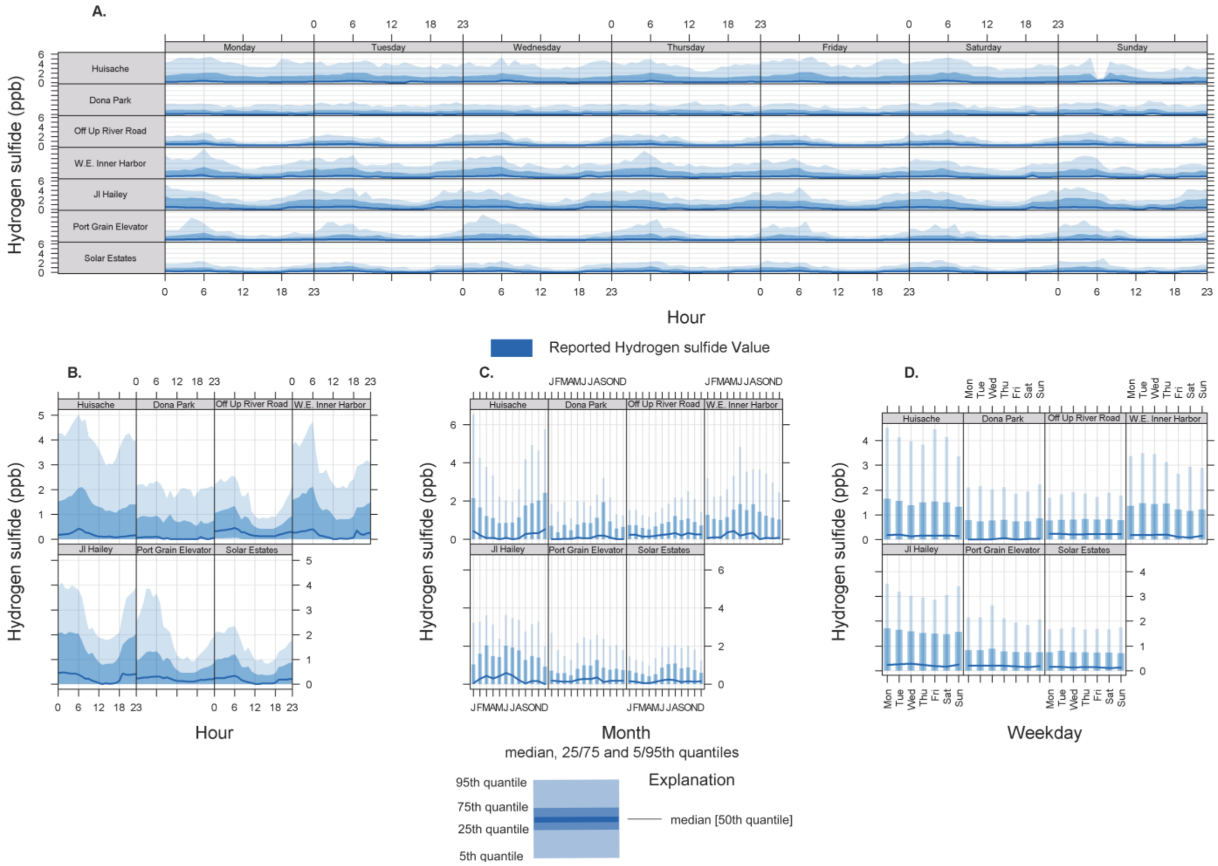
Figure 32A. Monthly Hydrogen Sulfide Measurements (2000–2010), Corpus Christi, TX



Data Source: Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through queries on hourly hydrogen sulfide and sulfur dioxide measurements for dates within the range >=1/1/1980 to <1/1/2011 (separate queries for each parameter by decade) for monitors in the Corpus Christi area. Data downloaded on 28 August 2013.

CV	comparison value
ppb	parts per billion
RfC – I	reference concentration – Integrated Risk Information System

Figure 33A. Temporal Variations in Hydrogen Sulfide Measurements, Corpus Christi, TX*



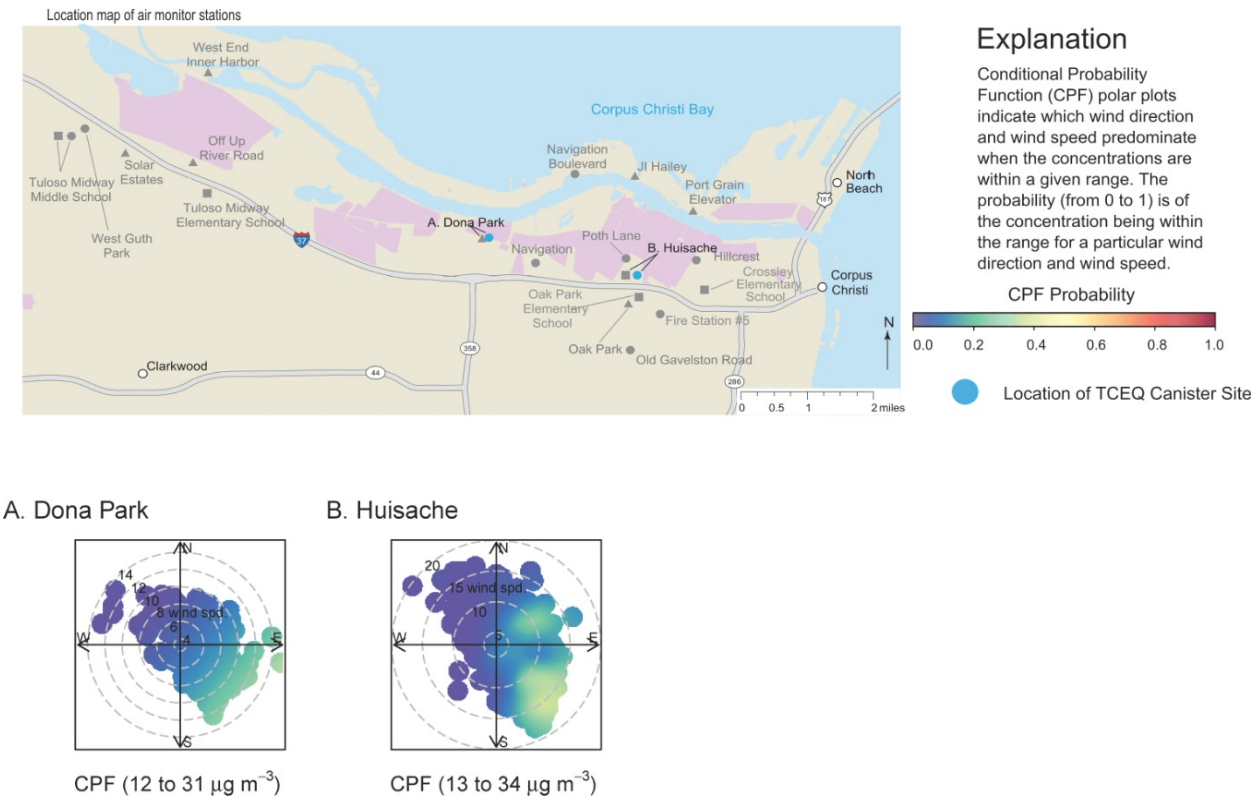
A. Hour and Weekday hydrogen sulfide concentrations.
B. Hourly hydrogen sulfide concentrations.
C. Monthly hydrogen sulfide concentrations.
D. Weekday hydrogen sulfide concentrations.

Data Source: Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through queries on hourly hydrogen sulfide and sulfur dioxide measurements for dates within the range >=1/1/1980 to <1/1/2011 (separate queries for each parameter by decade) for monitors in the Corpus Christi area. Data downloaded on 28 August 2013.

*Quantiles are a percent of the total amount – that is, the amount of the data less than the quantile percent level.

JFMAMJJASOND	January, February, March, April, May, June, July, August, September, October, November, December
ppb	parts per billion
W.E. Inner Harbor	West End Inner Harbor

Figure 34A. $PM_{2.5}$ Top Quartile Conditional Probability Plots, Corpus Christi, TX*



Data Sources:

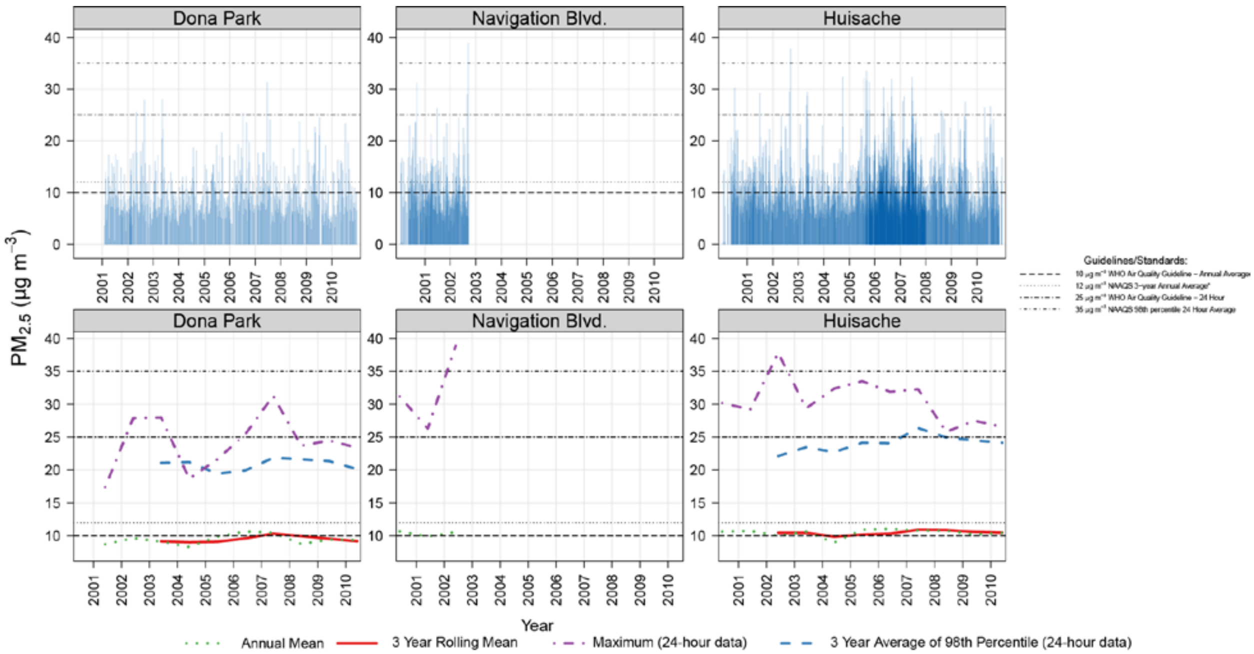
Texas Commission on Environmental Quality. 2012. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through a query performed with the target list "Meteorological Parameters" for dates within the range >=1/1/2000 to <1/1/2011 for monitors in the Corpus Christi, area. Data downloaded on 15 and 16 October 2012.

Texas Commission on Environmental Quality. 2014. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through a query performed for Parameter Pm2.5 - Local Conditions, 24-hour concentrations, for dates within the range >=1/1/1980 to <1/1/2011 at the Dona Park, Huisache, and Navigation stationary air monitors. Data downloaded on 23 June 2014.

* Plots show the top quartile at each site (a quartile spans 25% of the concentrations). Wind speed is in knots.

CPF	conditional probability function
$\mu g\ m^{-3}$	micrograms per cubic meter
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
TCEQ	Texas Commission on Environmental Quality

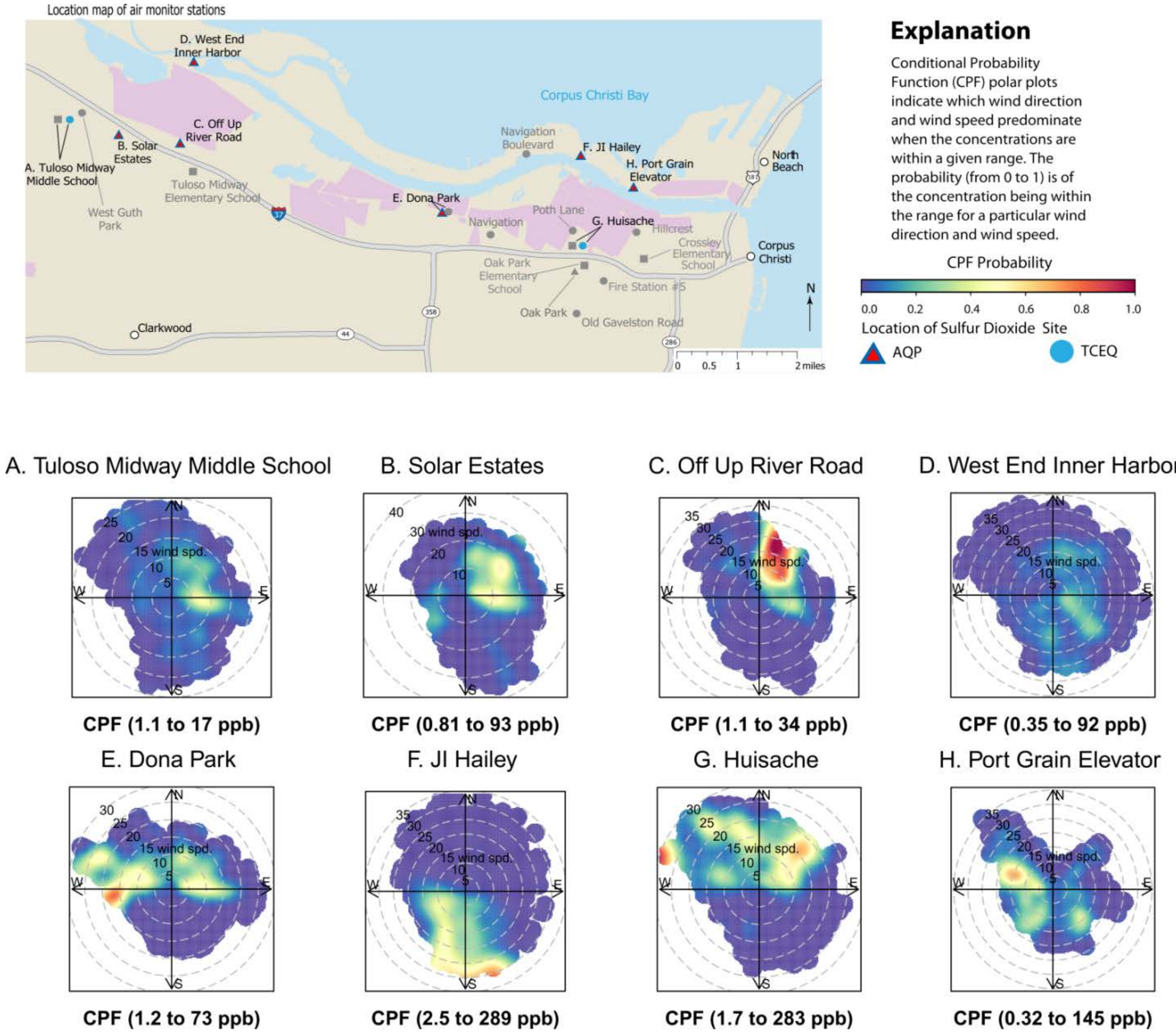
Figure 35A. Daily $PM_{2.5}$ Measurements and Statistics, Corpus Christi, TX



Data Source: Texas Commission on Environmental Quality. 2014. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through a query performed for Parameter Pm2.5 - Local Conditions, 24-hour concentrations, for dates within the range >=1/1/1980 to <1/1/2011 at the Dona Park, Huisache, and Navigation stationary air monitors. Data downloaded on 23 June 2014.

CV health-based comparison value
μg m^{-3} micrograms per cubic meter
NAAQS National Ambient Air Quality Standard
$PM_{2.5}$ particulate matter less than 2.5 microns in diameter
WHO World Health Organization

Figure 36A. Sulfur Dioxide Top Decile Conditional Probability Plots, Corpus Christi, TX* (page 1 of 2)



A. Tuloso Midway Middle School had higher probabilities of sulfur dioxide concentrations in the top decile when winds were from the east, with a lesser increase when winds were from the northeast.

B. Solar Estates, located 0.87 miles to the east southeast of the middle school, had higher slightly higher probabilities of sulfur dioxide concentrations in the top decile when winds were from the west, and even higher probabilities when winds were from the north through east-southeast

C. Off Up River Road, located approximately 1.02 miles to the east of Solar Estates, had increased probabilities of sulfur dioxide concentrations in the top decile when winds were from the northwest. This result would be expected given the CPF polar plot for Solar Estates. Increased probabilities also existed when the winds were from the north-northeast.

D. West End Inner Harbor is approximately 1.43 miles north of the Off Up River Road site. This site did not show very clear patterns, although this could be because the sulfur dioxide data were censored in the top decile, dampening any measureable effects, or because the site was more distant from potential sources than were the other sites.

E. When winds were from the east or west, Dona Park showed increased probabilities of sulfur dioxide concentrations in the top decile .

Figure 36A. Sulfur Dioxide Top Decile Conditional Probability Plots, Corpus Christi, TX* (page 2 of 2)

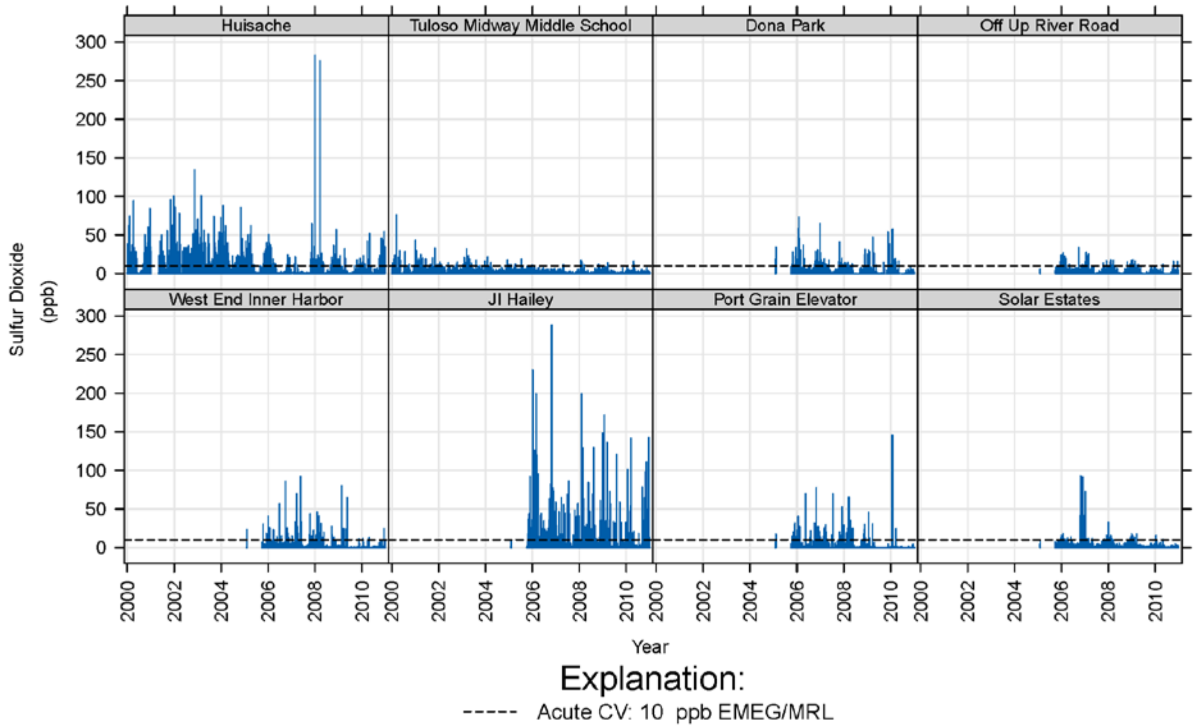
F. Toward the west end of Refinery Row, JI Hailey had increased probabilities of sulfur dioxide concentrations in the top decile when winds were from the west, south by southeast, south, and south by southwest.
G. Huisache showed increased probabilities of sulfur dioxide concentrations in the top decile when winds were from northeast, but also increased probabilities when winds were from any northerly direction.
H. Port Grain Elevator had elevated probabilities of sulfur dioxide concentrations in the top decile when winds were from the west by northwest, southwest, and southeast.

Data Sources:
Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through queries on hourly hydrogen sulfide and sulfur dioxide measurements for dates within the range >=1/1/1980 to <1/1/2011 (separate queries for each parameter by decade) for monitors in the Corpus Christi area. Data downloaded on 28 August 2013.
Texas Commission on Environmental Quality. 2014 Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through queries on Meteorological Parameters for Tuloso Midway Middle School, Solar Estates, Off Up River Road, West End Inner Harbor, Dona Park, JI Hailey, Huisache, and Port Grain Elevator. Data downloaded on 20 March 2014 and June 27 2014.

* Plots show the top decile at each site (a decile spans 10% of the concentrations). Wind speed is in knots.

CPF conditional probability function
ppb parts per billion

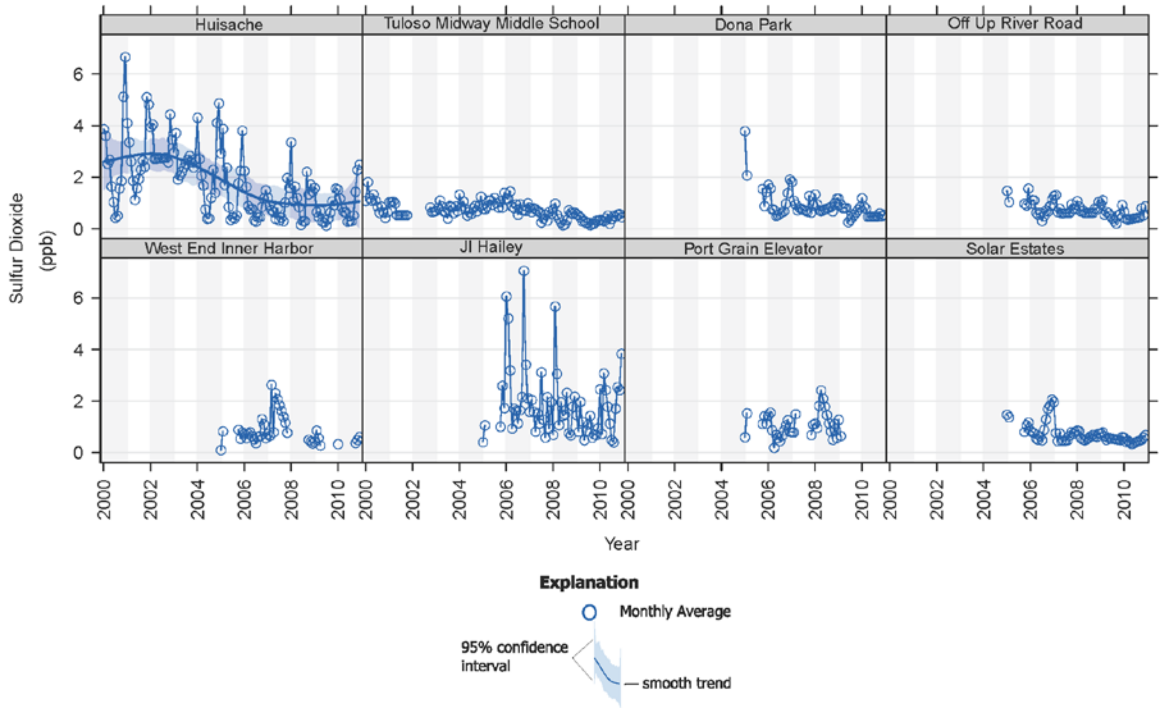
Figure 37A. Hourly Sulfur Dioxide Measurements (2000–2010), Corpus Christi, TX



Data Source: Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through queries on hourly hydrogen sulfide and sulfur dioxide measurements for dates within the range >=1/1/1980 to <1/1/2011 (separate queries for each parameter by decade) for monitors in the Corpus Christi area. Data downloaded on 28 August 2013.

CV	comparison value
EMEG/MRL	environmental media evaluation guide/minimal risk level
ppb	parts per billion

Figure 38A. Monthly Sulfur Dioxide Measurements (2000–2010), Corpus Christi, TX*

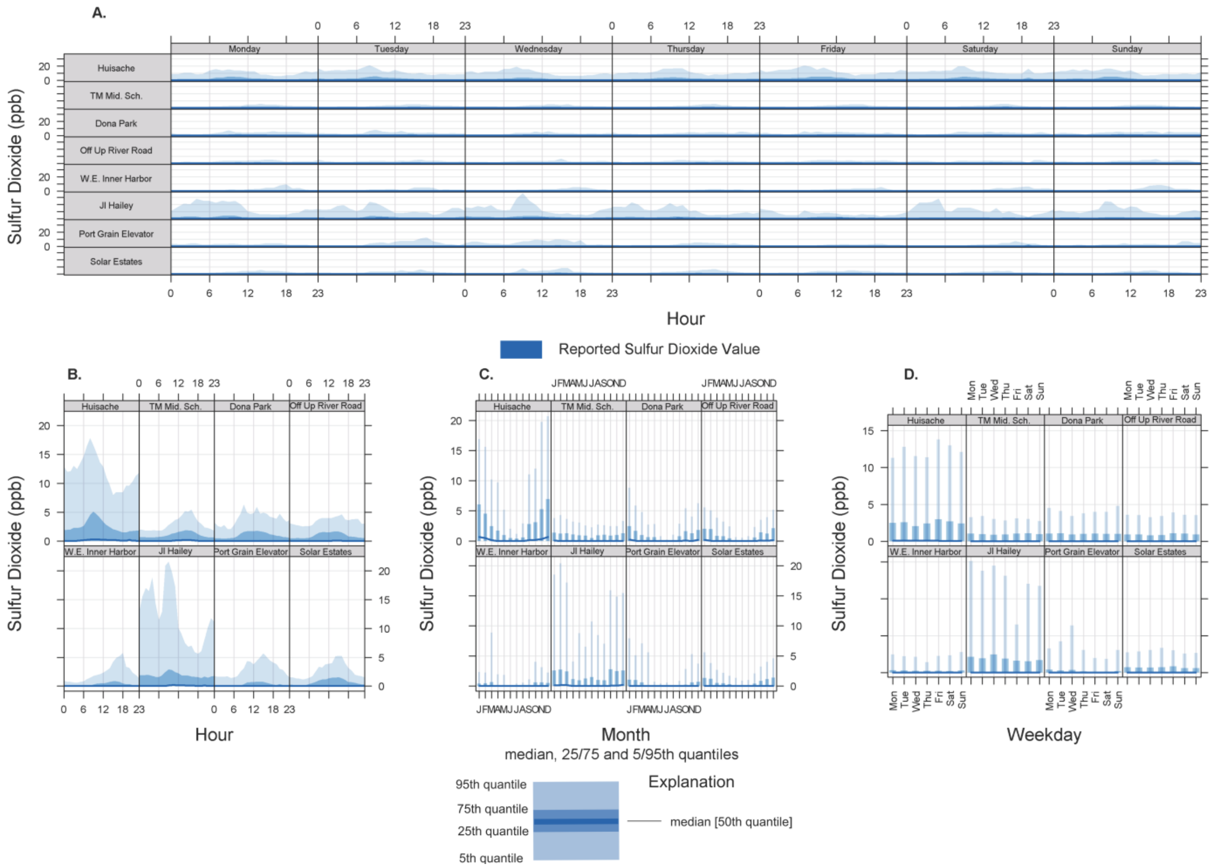


Data Source: Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through queries on hourly hydrogen sulfide and sulfur dioxide measurements for dates within the range >=1/1/1980 to <1/1/2011 (separate queries for each parameter by decade) for monitors in the Corpus Christi area. Data downloaded on 28 August 2013.

* Data for Dona Park, Off Up River Road, West End Inner Harbor, JI Hailey, Port Grain Elevator and Solar Estates were only available for 2005–2010. Months with censoring rates greater than 80% or data availability less than 50% (or both) are excluded. Seasonal effects were not removed from this trend. Trend uncertainty was estimated using block bootstrap (R=200) option in smoothTrend function.

ppb parts per billion

Figure 39A. Temporal Variations in Sulfur Dioxide Measurements, Corpus Christi, TX*

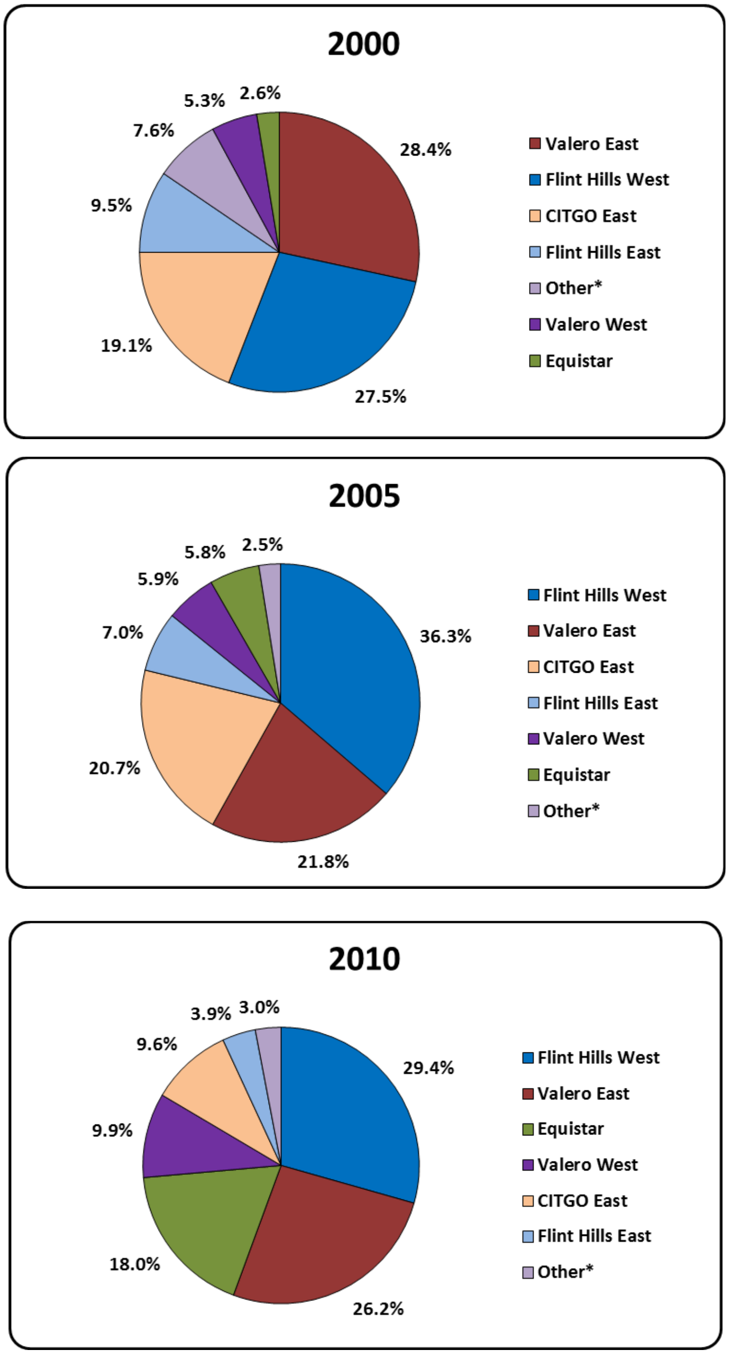


Data Source: Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through queries on hourly hydrogen sulfide and sulfur dioxide measurements for dates within the range >=1/1/1980 to <1/1/2011 (separate queries for each parameter by decade) for monitors in the Corpus Christi area. Data downloaded on 28 August 2013.

*Quantiles are a percent of the total amount – that is, the amount of the data less than the quantile percent level.

JFMAMJJASOND	January, February, March, April, May, June, July, August, September, October, November, December
ppb	parts per billion
TM Mid. Sch.	Tuloso Midway Middle School
W.E. Inner Harbor	West End Inner Harbor

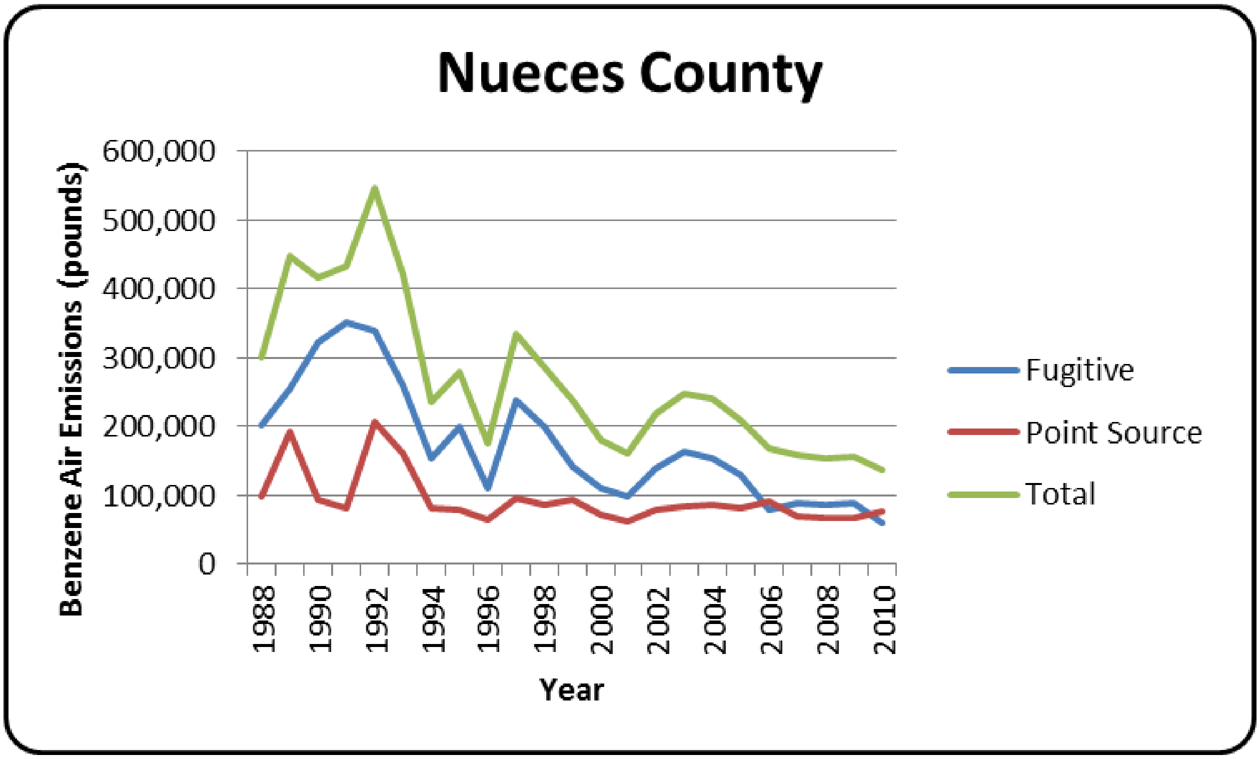
Figure 40A. Percent Each Facility Contributed Total Benzene Air Emissions in Nueces County for 2000, 2005 and 2010



Data Source: US Environmental Protection Agency. 2012. Toxics Release Inventory (TRI) Explorer. Releases: facility report: air emissions (in pounds) for facilities in all industries in the US. Facility data downloaded for benzene for the years 2000, 2005 and 2010. TRI data updates as of 12 March 2012. Data downloaded from www.epa.gov/tri on 18 April 2012 and 6 September 2012.

* The category "Other" is the combined total benzene air emissions of CITGO Deep Sea Terminal, CITGO West and Ticona Polymers. Note that Ticona Polymers is outside the Refinery Row area.

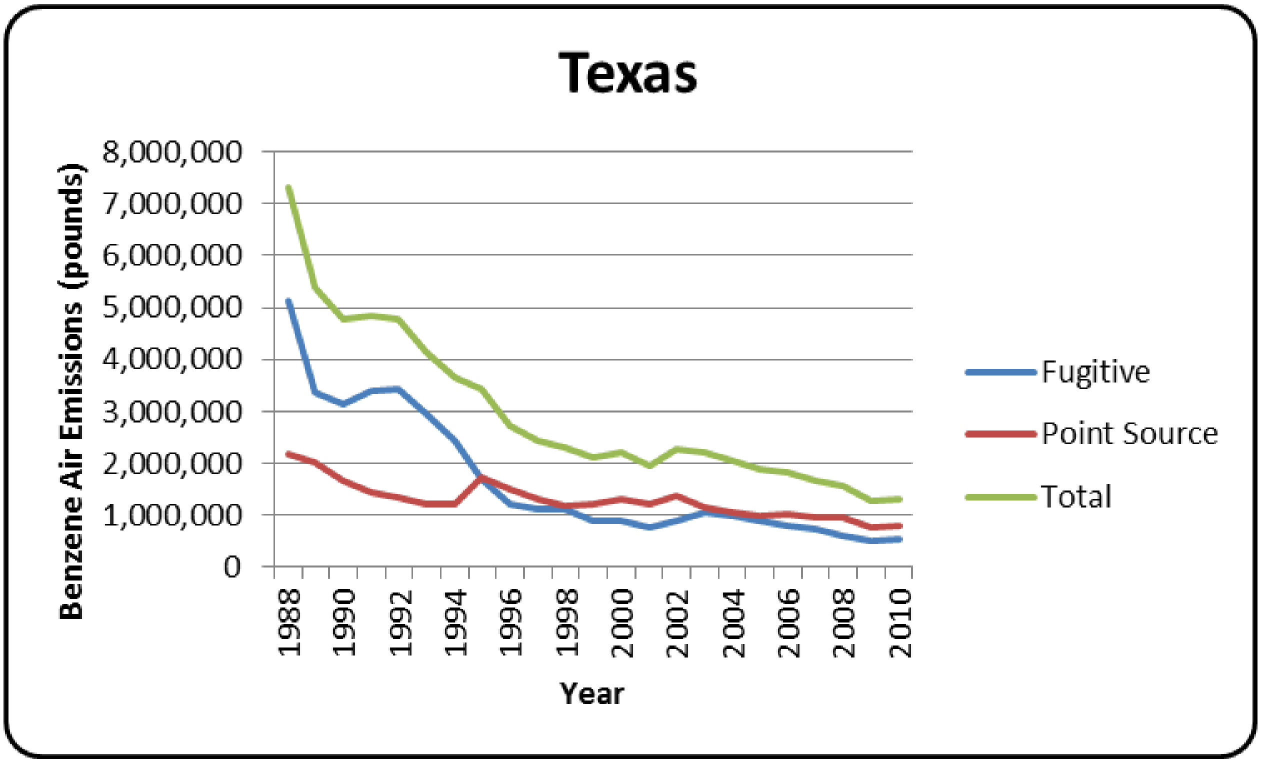
Figure 41A. TRI Reported Benzene Air Emissions for Nueces County



Data Source: US Environmental Protection Agency. 2012. Toxics Release Inventory (TRI) Explorer. Releases: trend report: benzene air emissions (in pounds) for facilities in all industries, 1988–2010. Trend report searches for Nueces County, the state of Texas and the US. TRI data updates as of 12 March 2012. Data downloaded from www.epa.gov/tri on 6 September 2012.

TRI Toxics Release Inventory

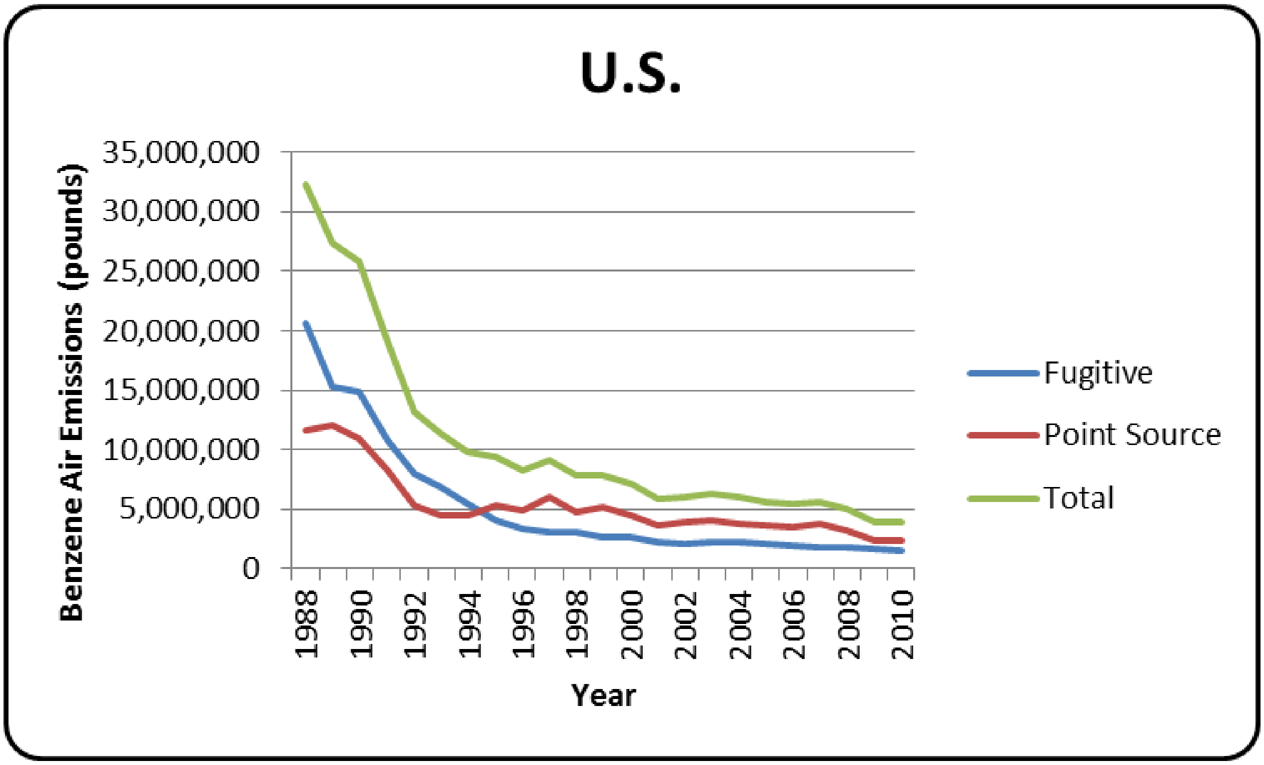
Figure 42A. TRI Reported Benzene Air Emissions for the State of Texas



Data Source: US Environmental Protection Agency. 2012. Toxics Release Inventory (TRI) Explorer. Releases: trend report: benzene air emissions (in pounds) for facilities in all industries, 1988–2010. Trend report searches for Nueces County, the state of Texas and the US. TRI data updates as of 12 March 2012. Data downloaded from www.epa.gov/tri on 6 September 2012.

TRI Toxics Release Inventory

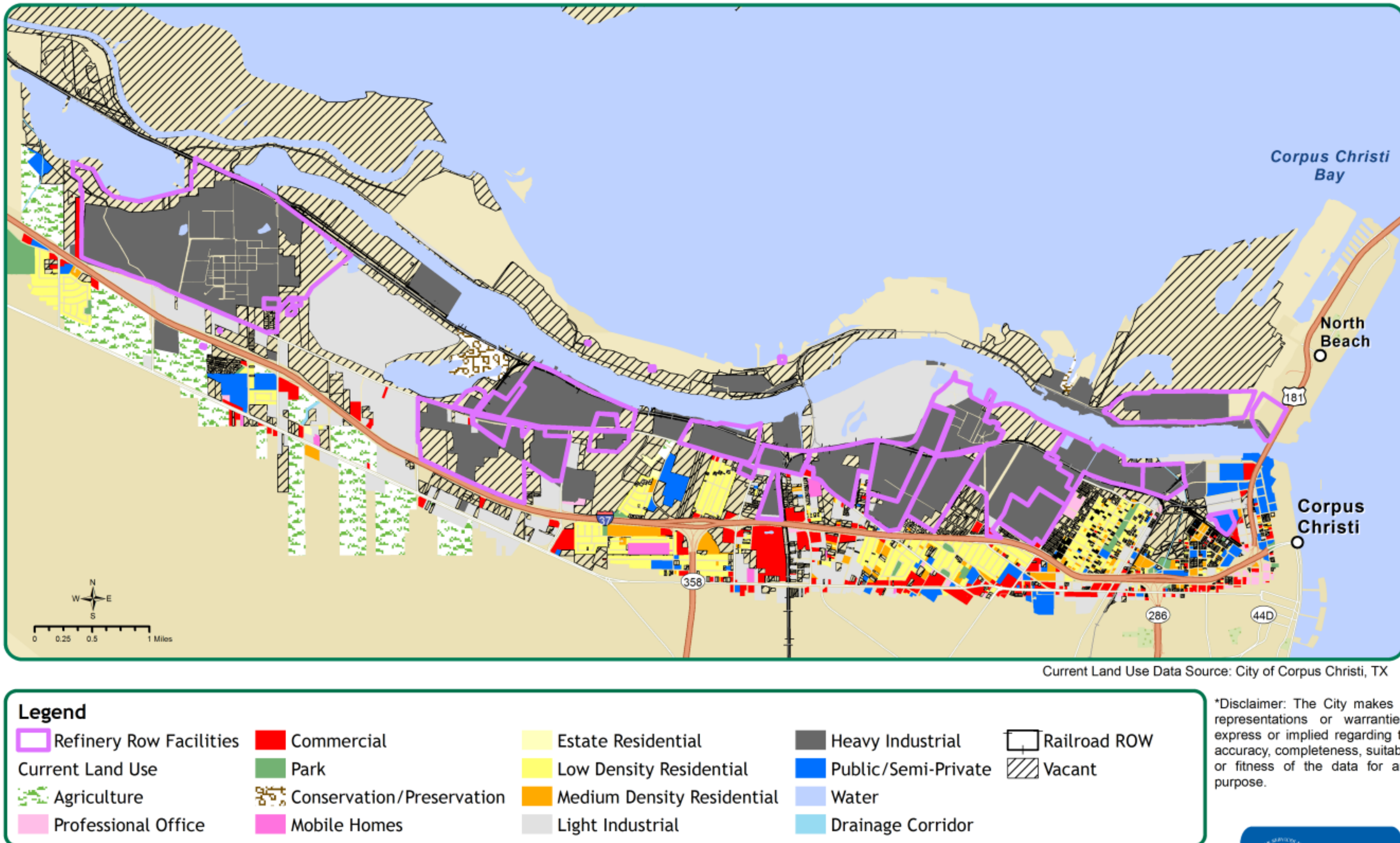
Figure 43A. TRI Reported Benzene Air Emissions for the United States



Data Source: US Environmental Protection Agency. 2012. Toxics Release Inventory (TRI) Explorer. Releases: trend report: benzene air emissions (in pounds) for facilities in all industries, 1988–2010. Trend report searches for Nueces County, the state of Texas and the US. TRI data updates as of 12 March 2012. Data downloaded from www.epa.gov/tri on 6 September 2012.

TRI Toxics Release Inventory

Figure 44A. Refinery Row Land Use, Corpus Christi, TX



*Disclaimer: The City makes no representations or warranties, express or implied regarding the accuracy, completeness, suitability or fitness of the data for any purpose.

Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations

igure 45A. Corpus Christi Refinery Row Social Vulnerability Index—Overall (Total) Vulnerability

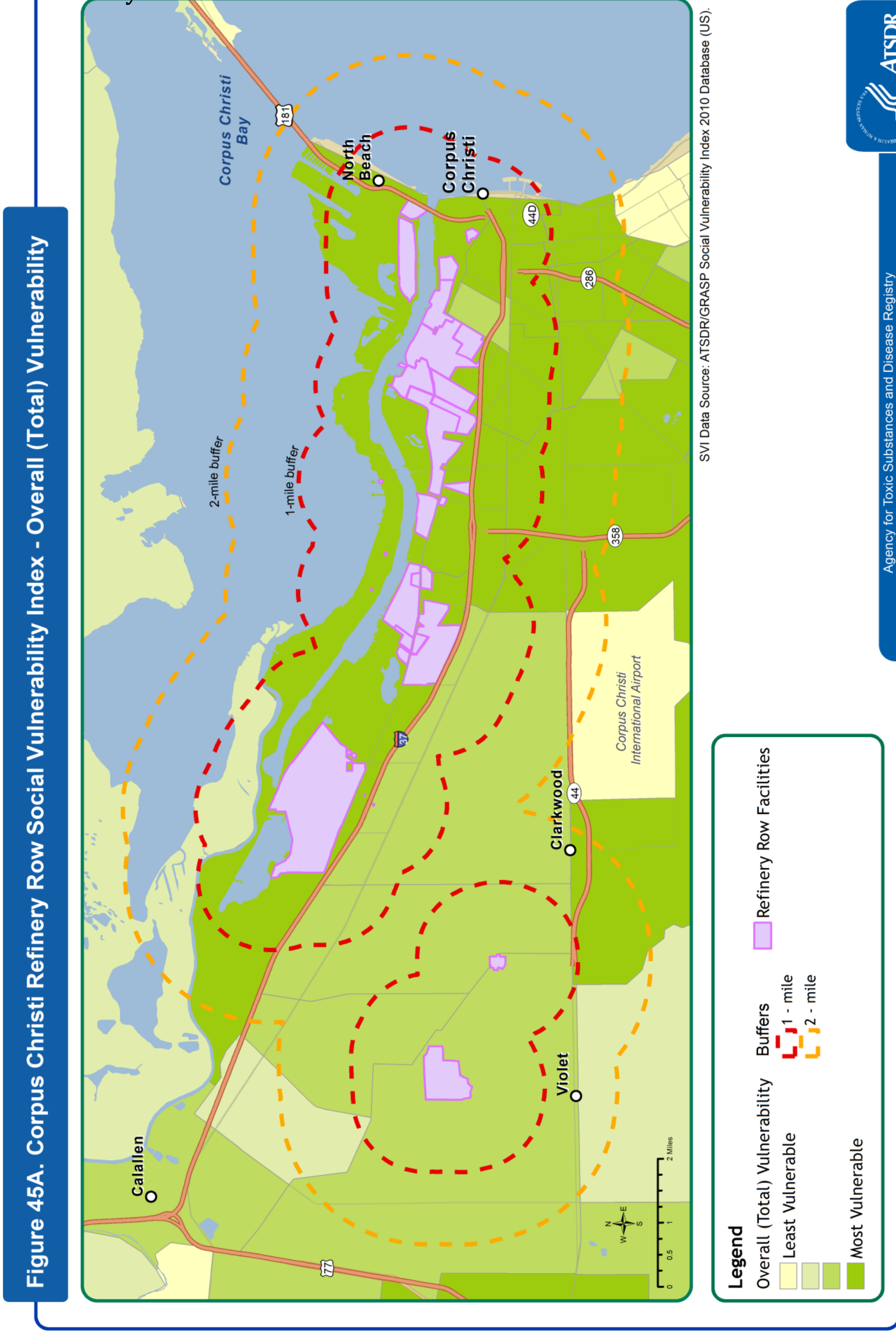
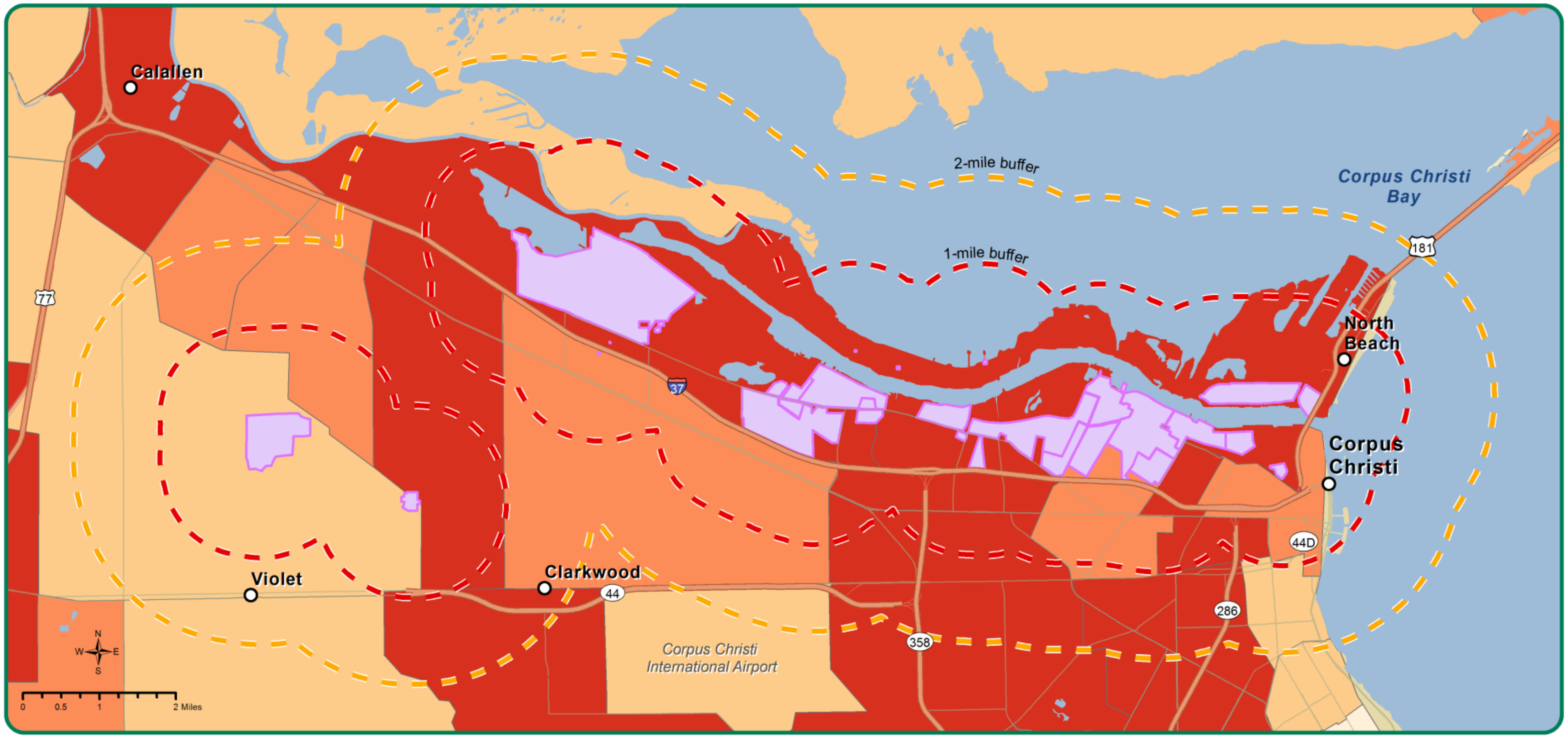


Figure 46A. Corpus Christi Refinery Row Social Vulnerability Index - Household Composition



SVI Data Source: ATSDR/GRASP Social Vulnerability Index 2010 Database (US).

Legend

Household Composition: Least Vulnerable, Most Vulnerable

Buffers: 1 - mile, 2 - mile

Refinery Row Facilities

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Figure 47A. Corpus Christi Refinery Row Social Vulnerability Index - Housing and Transportation

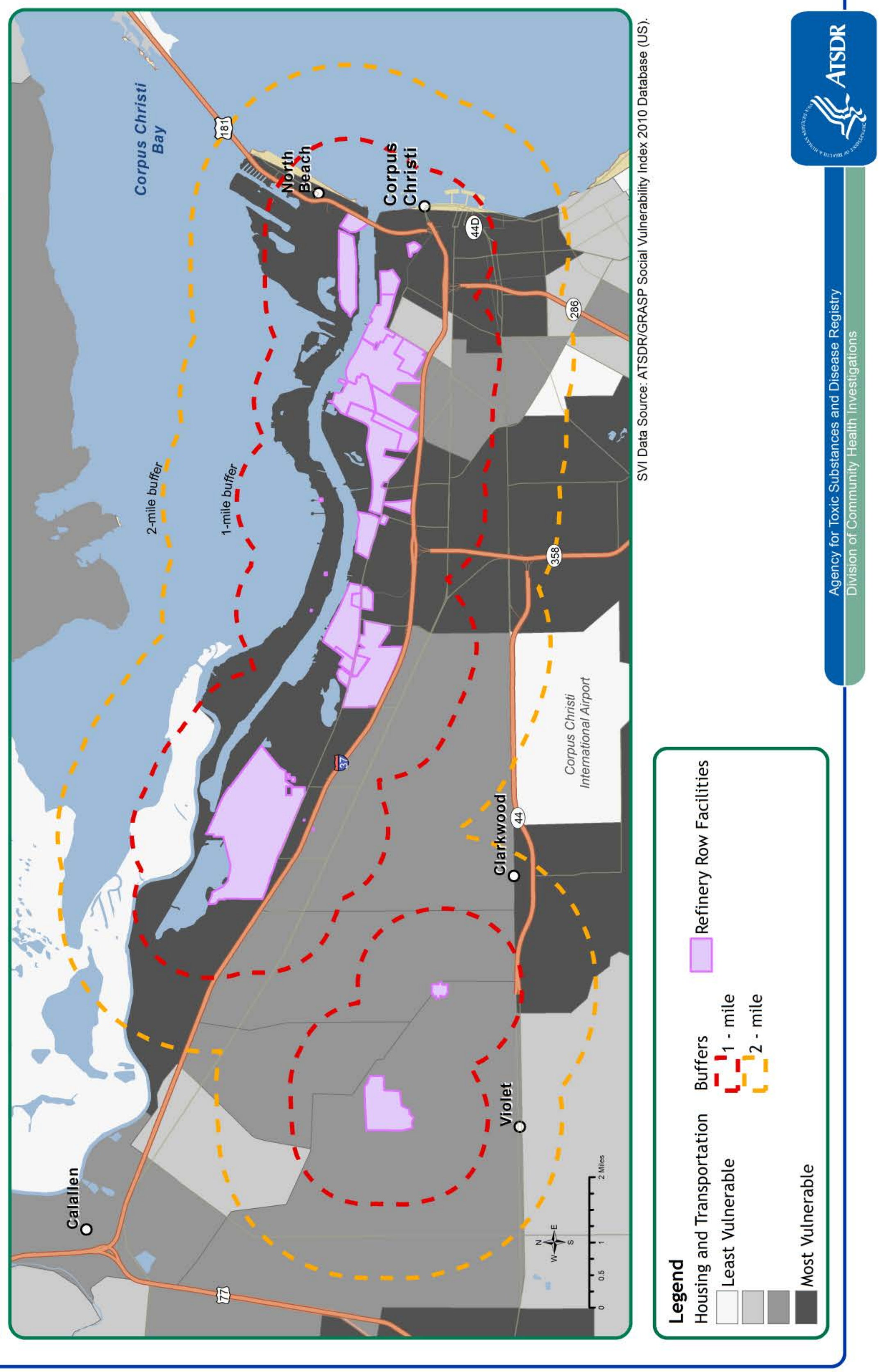
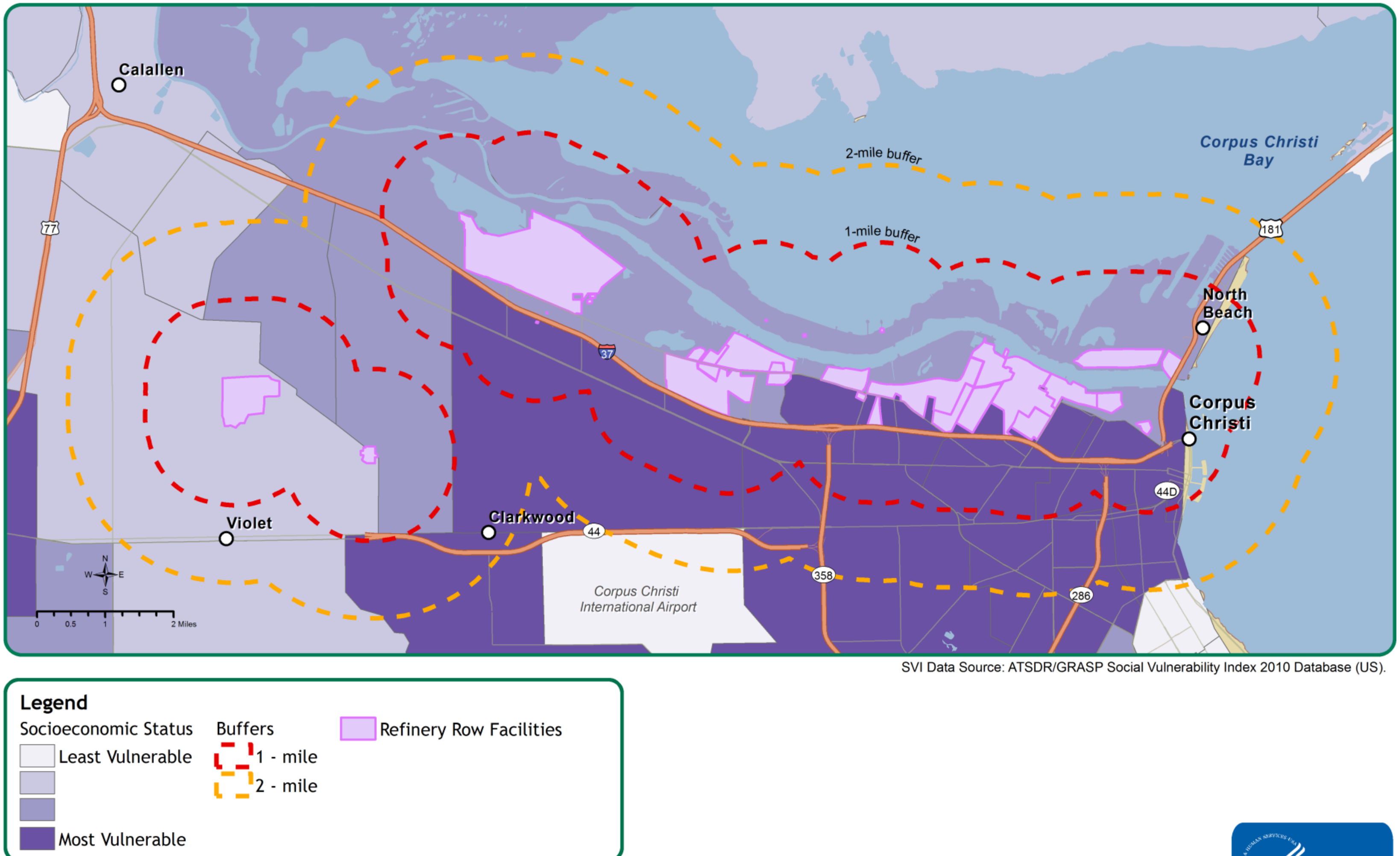


Figure 48A. Corpus Christi Refinery Row Social Vulnerability Index - Socioeconomic Status



SVI Data Source: ATSDR/GRASP Social Vulnerability Index 2010 Database (US).

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Figure 49A. Corpus Christi Refinery Row Social Vulnerability Index - Minority Status and Language

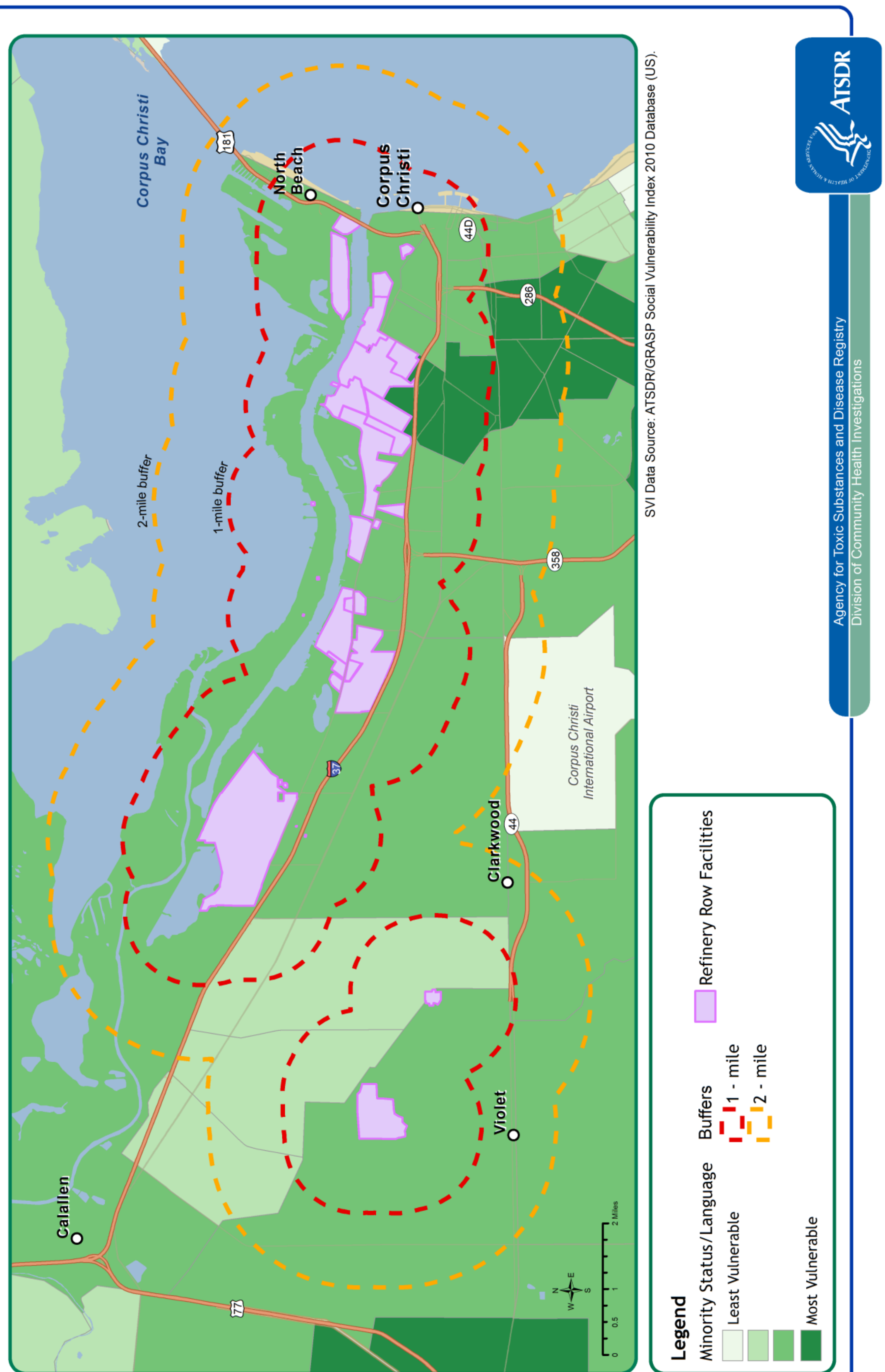
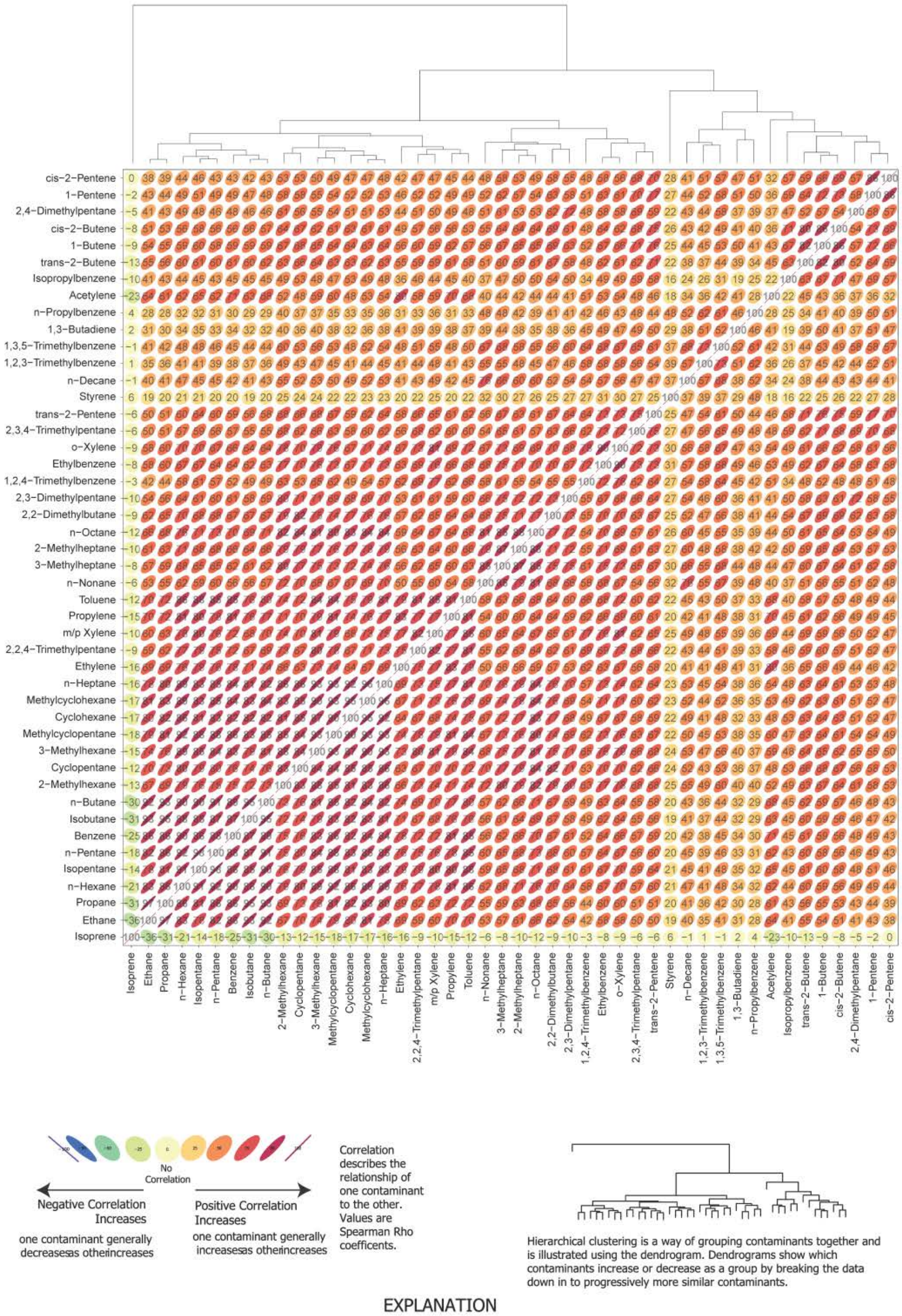


Figure 50A. Correlation Matrix of Oak Park Auto GC Data with Hierarchical Clustering, Corpus Christi, TX* (page 1 of 2)



Data sources:

Texas Commission on Environmental Quality. 2010. Data posted to FTP site by Melanie Hotchkiss, TCEQ, and downloaded by John Wilhelmi, Eastern Research Group, Inc. Contains continuous 2005-2009 sulfur compound and volatile organic compound data for both TCEQ and Corpus Christi Air Quality Project air monitoring sites. Austin, TX.

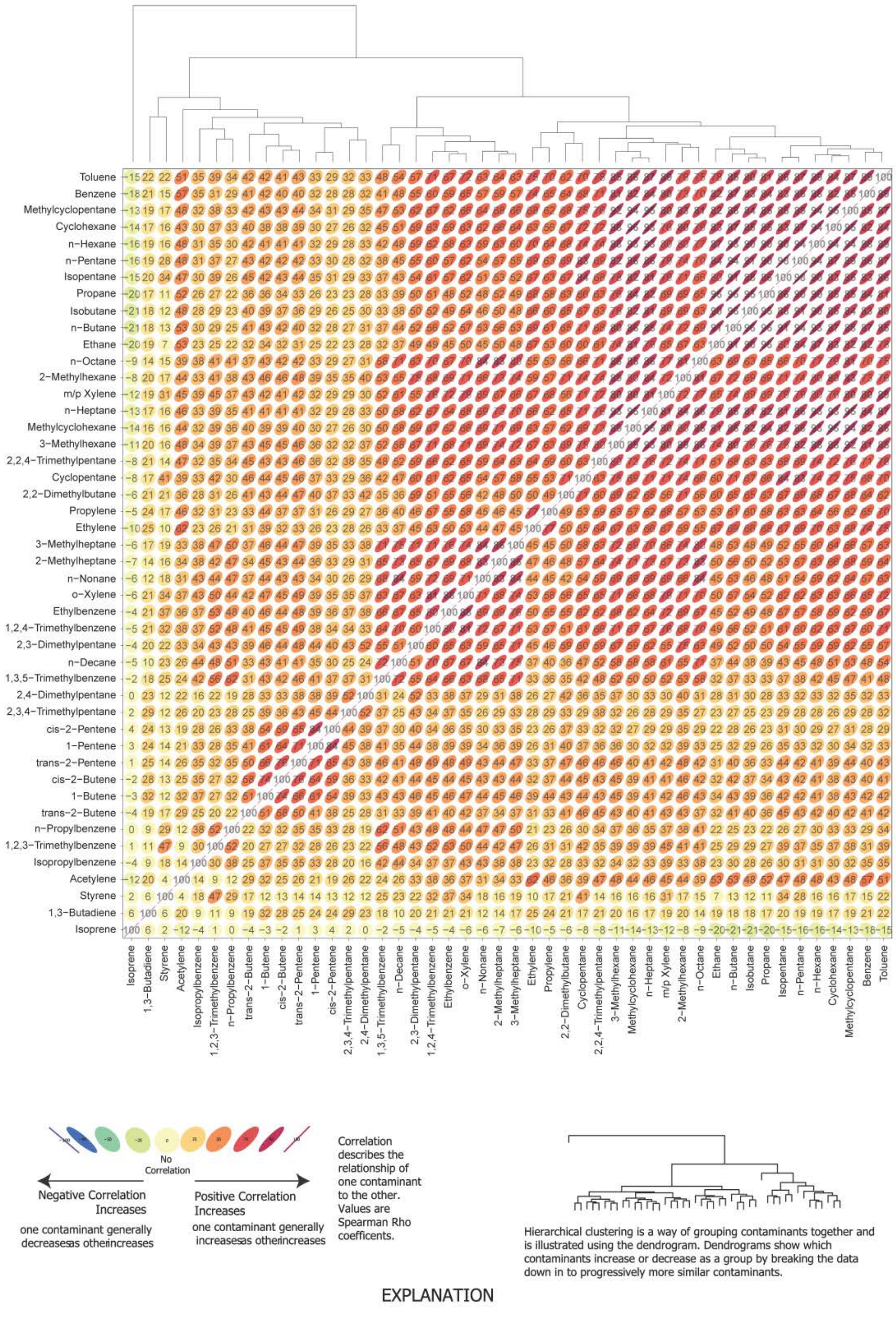
Figure 50A. Correlation Matrix of Oak Park Auto GC Data with Hierarchical Clustering, Corpus Christi, TX* (page 2 of 2)

The University of Texas. 2011. April 25th email from Dr. David Sullivan, The University of Texas at Austin, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing an Excel attachment with the continuous 2010 volatile organic compounds data for the Solar Estates and Oak Park air monitoring sites. Austin, TX.

* This figure shows the correlation of the different chemicals measured by the Auto GC to each other. Chemicals that increase or decrease together are plotted nearer to each other using hierarchical clustering. Thinness of the shape shows the degree of association (with no correlation as a circle and perfect correlation as a line). The color of the shape becomes darker red with positive correlation and yellow with negative correlation. Numerical values are Spearman's Rho correlation coefficient (which ranges from 0 to 100). Data below the detection limit were considered "tied."

Auto GC automatic gas chromatograph

Figure 51A. Correlation Matrix of Solar Estates Auto GC Data with Hierarchical Clustering, Corpus Christi, TX* (page 1 of 2)



Data sources:

Texas Commission on Environmental Quality. 2010. Data posted to FTP site by Melanie Hotchkiss, TCEQ, and downloaded by John Wilhelmi, Eastern Research Group, Inc. Contains continuous 2005-2009 sulfur compound and volatile organic compound data for both TCEQ and Corpus Christi Air Quality Project air monitoring sites. Austin, TX.

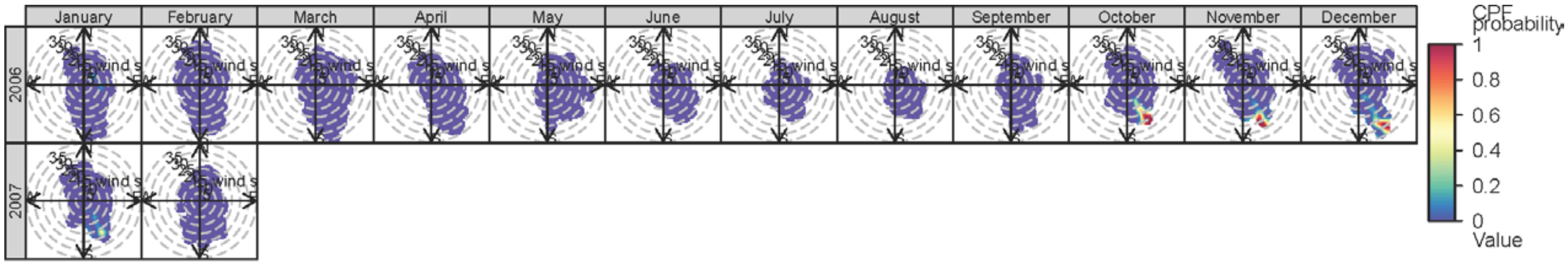
Figure 51A. Correlation Matrix of Solar Estates Auto GC Data with Hierarchical Clustering, Corpus Christi, TX* (page 2 of 2)

The University of Texas. 2011. April 25th email from Dr. David Sullivan, The University of Texas at Austin, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing an Excel attachment with the continuous 2010 volatile organic compounds data for the Solar Estates and Oak Park air monitoring sites. Austin, TX.

* This figure shows the correlation of the different chemicals measured by the Auto GC to each other. Chemicals that increase or decrease together are plotted nearer to each other using hierarchical clustering. Thinness of the shape shows the degree of association (with no correlation as a circle and perfect correlation as a line). The color of the shape becomes darker red with positive correlation and yellow with negative correlation. Numerical values are Spearman's Rho correlation coefficient (which ranges from 0 to 100). Data below the detection limit were considered "tied."

Auto GC automatic gas chromatograph

Figure 52A. Sulfur Dioxide Polar Plots by Year and Month at Solar Estates, Corpus Christi, TX*



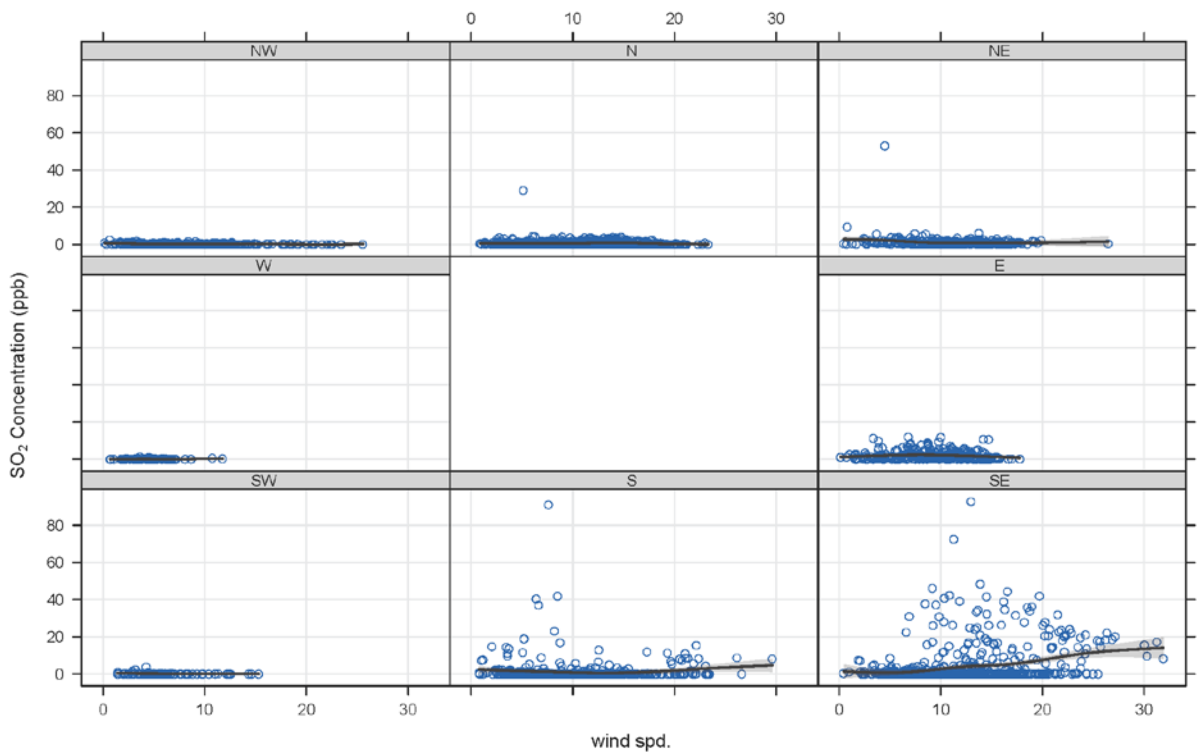
CPF at the 99th percentile (=13)

Data Source: Texas Commission on Environmental Quality. 2012. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through a query performed with the target list "Meteorological Parameters" for dates within the range >=1/1/2000 to <1/1/2011 for monitors in the Corpus Christi area. Data downloaded on 15 and 16 October 2012. Note: Dona Park wind rose data cover 2003 to 2010.

* Polar plots of Solar Estates sulfur dioxide concentrations using conditional probability that level exceeded 99th percentile (greater than 5 ppb). Note: high probabilities of sulfur dioxide over 5 ppb to the southeast during the autumn of 2006 and winter of 2006–2007. Wind speed is in knots

CPF conditional probability function
ppb part per billion

Figure 53A. Relationship of Wind Speed to Sulfur Dioxide Concentrations from 10/1/2006 through 3/1/2007 by Wind Direction at Solar Estates, Corpus Christi, TX*



Data Sources:

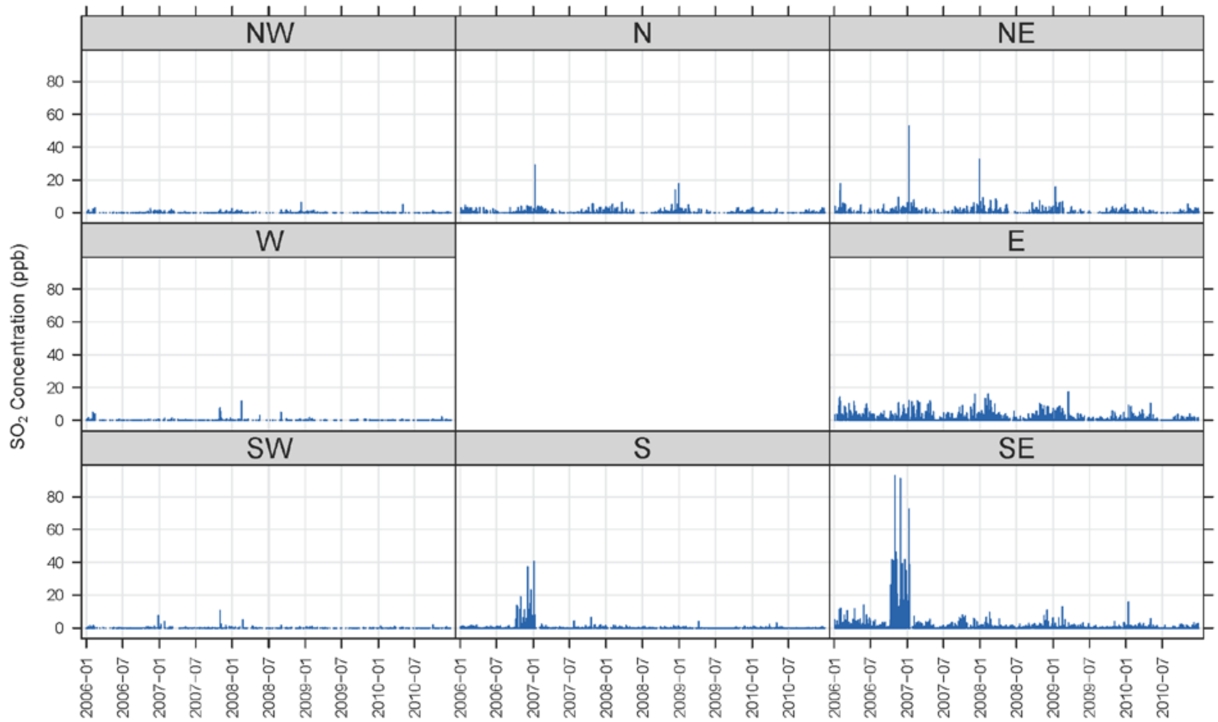
Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through queries on hourly hydrogen sulfide and sulfur dioxide measurements for dates within the range >=1/1/1980 to <1/1/2011 (separate queries for each parameter by decade) for monitors in the Corpus Christi area. Data downloaded on 28 August 2013.

Texas Commission on Environmental Quality. 2014 Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through queries on Meteorological Parameters for Tuloso Midway Middle School, Solar Estates, Off Up River Road, West End Inner Harbor, Dona Park, JI Hailey, Huisache, and Port Grain Elevator. Data downloaded on 20 March 2014 and June 27 2014.

* Line is smooth trend using Generalized Additive Model smooth in openair scatterplot function. Southeasterly winds were associated with higher variance in the sulfur dioxide measurements, and increased wind speeds were associated with higher average concentration of sulfur dioxide. This pattern is inconsistent with low-elevation gaseous emissions The pattern is more consistent with high-elevation buoyant plumes, or distant source(s), or fugitive dust emissions, or with all three [Carslaw 2014].

ppb parts per billion
SO_2 sulfur dioxide

Figure 54A. Sulfur Dioxide Measurements by Wind Direction at Solar Estates, Corpus Christi, TX*



Data Sources:

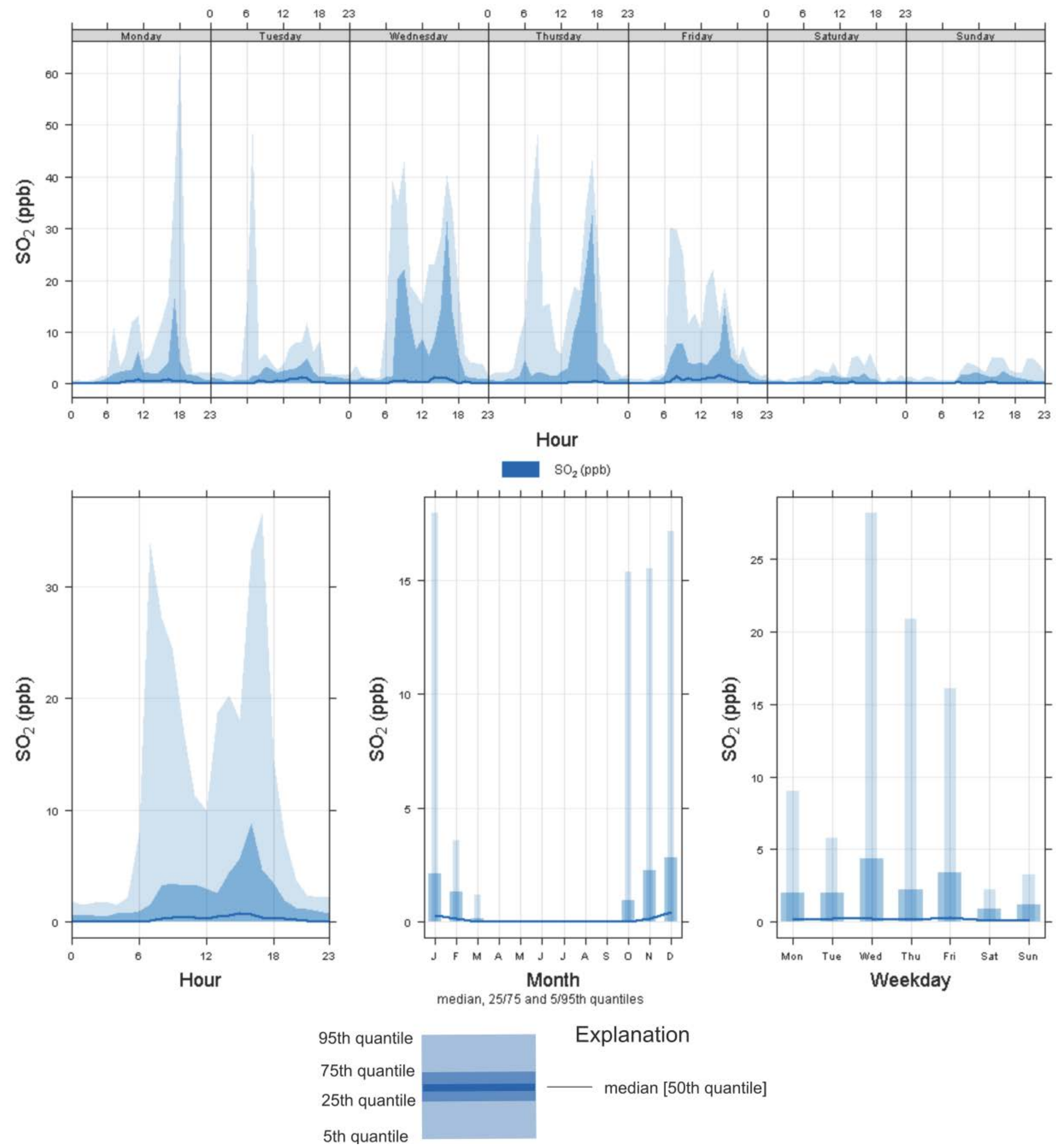
Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through queries on hourly hydrogen sulfide and sulfur dioxide measurements for dates within the range >=1/1/1980 to <1/1/2011 (separate queries for each parameter by decade) for monitors in the Corpus Christi area. Data downloaded on 28 August 2013.

Texas Commission on Environmental Quality. 2014 Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through queries on Meteorological Parameters for Tuloso Midway Middle School, Solar Estates, Off Up River Road, West End Inner Harbor, Dona Park, JI Hailey, Huisache, and Port Grain Elevator. Data downloaded on 20 March 2014 and June 27 2014.

* Higher sulfur dioxide measurements occurred during the fall of 2006 and winter of 2006/2007 when winds were from the south and southeast.

ppb parts per billion
SO_2 sulfur dioxide

Figure 55A. Time Variation of Sulfur Dioxide Measurements at Solar Estates (10/1/2006 through 3/1/2007), Corpus Christi, TX*



Data Sources:

Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through queries on hourly hydrogen sulfide and sulfur dioxide measurements for dates within the range >=1/1/1980 to <1/1/2011 (separate queries for each parameter by decade) for monitors in the Corpus Christi area. Data downloaded on 28 August 2013.

* Quantiles are a percent of the total amount – that is, the amount of the data less than the quantile percent level. Higher sulfur dioxide measurements peaked during weekdays and during mornings and evenings.

ppb parts per billion
SO_2 sulfur dioxide

Figure 56A. Proximity Areas Surrounding Refinery Row, Corpus Christi, TX, for Birth Defect Rates

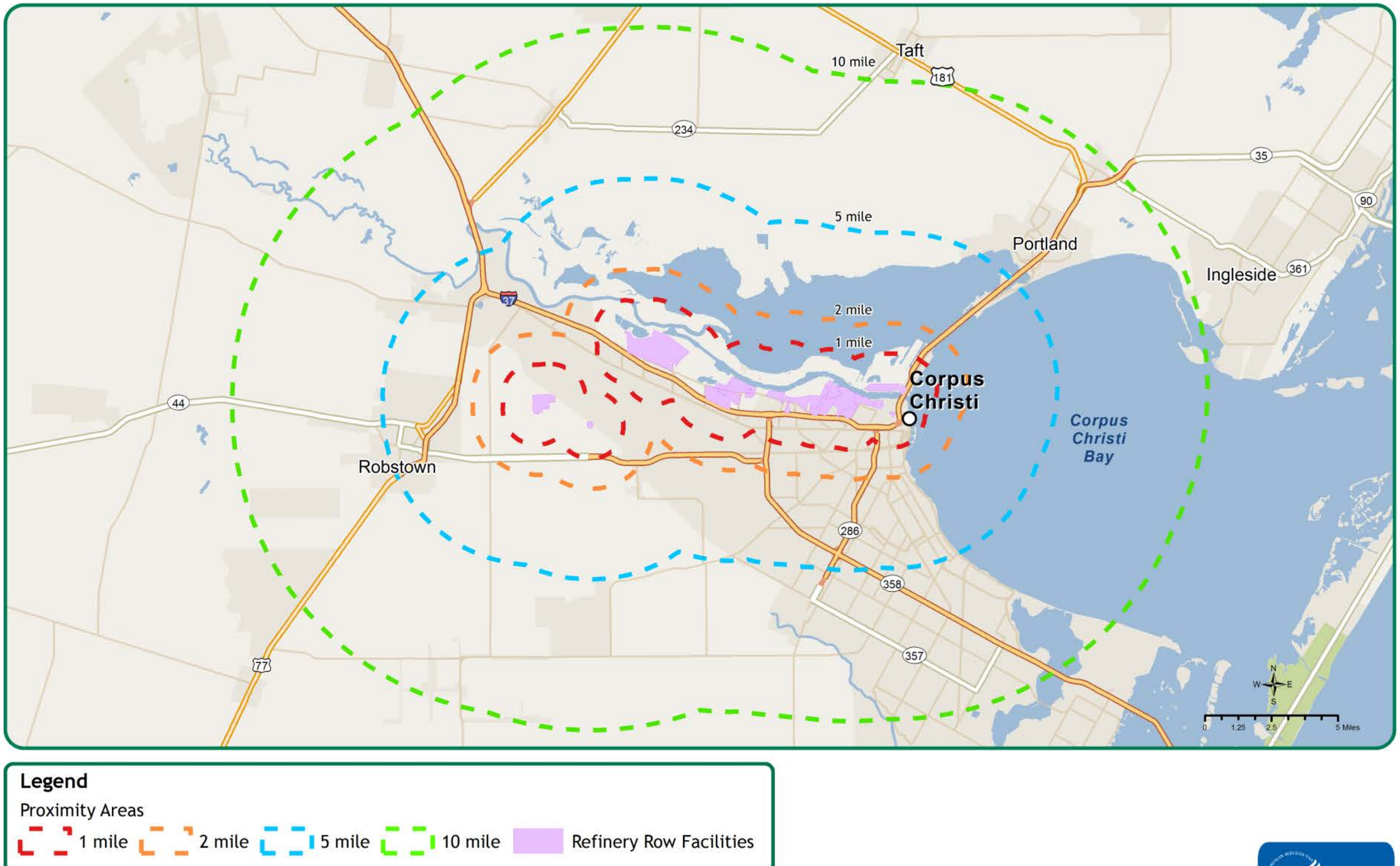


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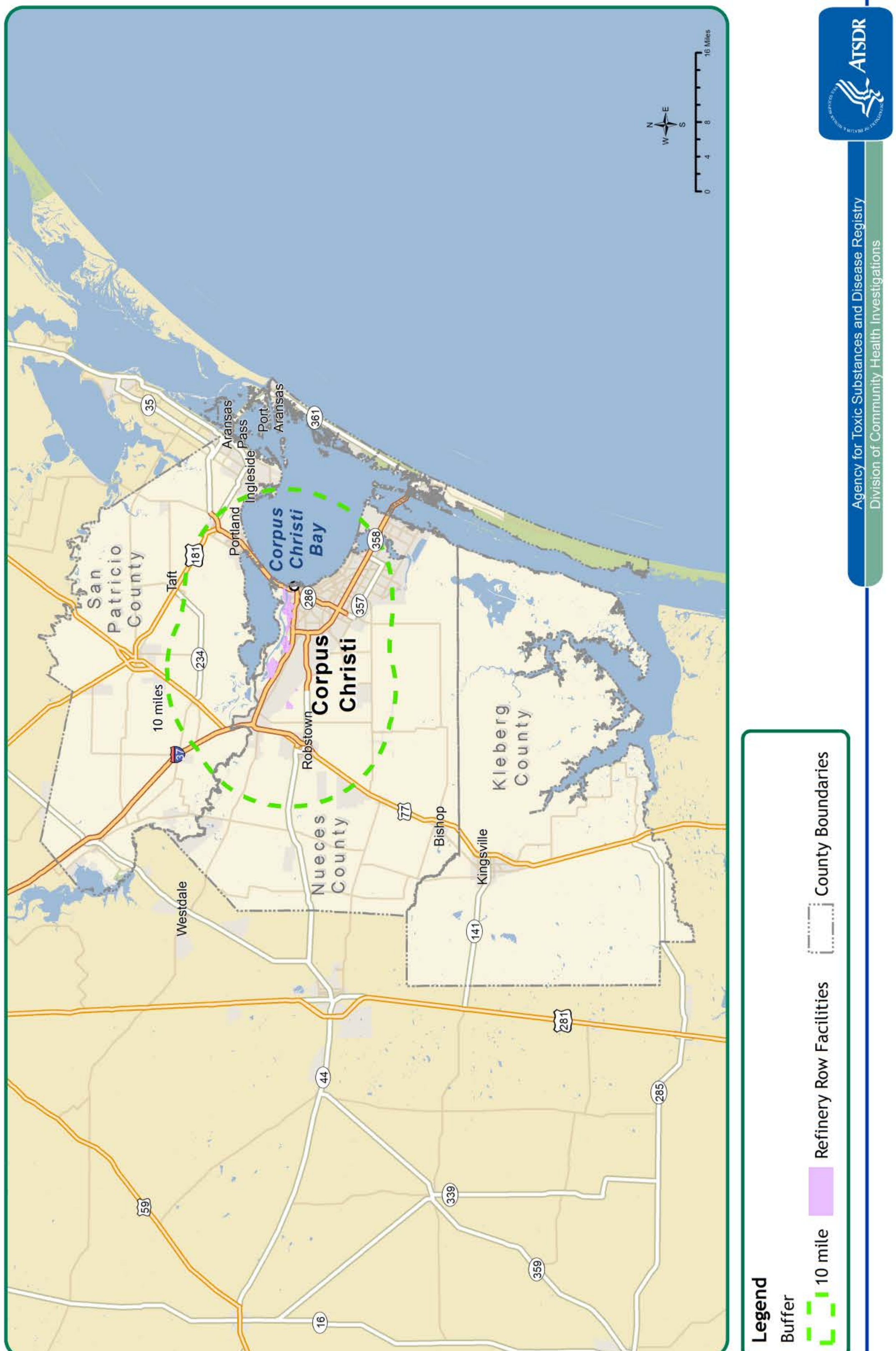
Figure 57A. Tri-county Area, Corpus Christi, TX



Appendix B. Tables

Table 1B. Stationary Air Monitoring Location Descriptions in the Refinery Row Area * (page 1 of 2)

Air Monitor Station Name	*Area Description*	*Network*	*Dates Evaluated*	*Chemicals Evaluated*
Crossley Elementary School	Neighborhood	Industry	1996–2010	canister VOCs
Dona Park	Neighborhood	AQP	2005–2010	continuous H_2S, continuous SO_2, event triggered VOCs
		TCEQ	2001–2010	canister VOCs, metals, $PM_{2.5}$, PM_{10}
Fire Station #5	Neighborhood	TCEQ	1981–1987; 1993–1996	metals, PM_{10}
Hillcrest	Neighborhood	TCEQ	1998–2010	canister VOCs
Huisache †	Neighborhood (past) Industry (current)	Industry	2003–2010	continuous benzene
		TCEQ	1997–2010	canister VOCs, continuous H_2S, continuous SO_2, $PM_{2.5}$
JI Hailey	Industry	AQP	2005–2010	continuous H_2S, continuous SO_2, event triggered VOCs
Navigation	Neighborhood	TCEQ	1985–1987; 1993–2002	canister VOCs, lead, $PM_{2.5}$, PM_{10}
Navigation Boulevard	Industry, Ship Channel	TCEQ	1981-1987	metals
Oak Park	Neighborhood	AQP	2005–2010	continuous VOCs, event triggered VOCs
Oak Park Elementary School	Neighborhood	Industry	1996–2010	canister VOCs
Off Up River Road	Industry	AQP	2005–2010	continuous H_2S, continuous SO_2, event triggered VOCs
Old Galveston Road	Neighborhood	TCEQ	1980–1981	metals
Port Grain Elevator	Industry, Ship Channel	AQP	2005–2010	continuous H_2S, continuous SO_2, event triggered VOCs
Poth Lane †	Neighborhood (past) Industry (current)	TCEQ	1996–1998	canister VOCs
Solar Estates	Neighborhood	AQP	2005–2010	continuous H_2S, continuous SO_2, continuous VOCs, event triggered VOCs
Tuloso Midway Elementary School	Neighborhood	Industry	1996–2010	canister VOCs
Tuloso Midway Middle School	Neighborhood	Industry	1996–2010	canister VOCs
		TCEQ	1984–2010	continuous SO_2
Up River Road	Neighborhood	Industry	1996–2010	canister VOCs
West End Inner Harbor	Industry, Ship Channel	AQP	2005–2010	continuous H_2S, continuous SO_2, event triggered VOCs

* Refer to Figure 8A, Appendix A, for a map of the stationary air monitor locations.

Table 1B. Stationary Air Monitoring Location Descriptions in the Refinery Row Area * (page 2 of 2)

† In the late 1900's, the homes near the Huisache and Poth Lane air monitoring stations were bought out.

AQP Corpus Christi Air Quality Project
H_2S hydrogen sulfide
$PM_{2.5}$ particulate matter less than 2.5 microns in diameter
PM_{10} particulate matter less than 10 microns in diameter
SO_2 sulfur dioxide
TCEQ Texas Commission on Environmental Quality
VOCs volatile organic compounds

Table 2B. Lowest Available Short-term and Long-term Comparison Values (page 1 of 8)

Chemical	Short-term Comparison Value*			Long-term Comparison Value*		
	Value	Units	Source	Value	Units	Source
Volatile Organic Compounds						
1,1,1-Trichloroethane	1,700	ppb	AMCV (final)	940	ppb	AMCV (final)
1,1,2,2-Tetrachloroethane	10	ppb	AMCV (interim)	0.0061	ppb	SL - C
1,1,2-Trichloroethane	100	ppb	AMCV (under review)	0.011	ppb	CREG
1,1-Dichloroethane	1,000	ppb	AMCV (interim)	0.37	ppb	SL - C
1,1-Dichloroethylene	180	ppb	AMCV (final)	50	ppb	RfC - I
1,2,3-Trimethylbenzene (Hemimellitene)	250	ppb	AMCV (interim)	25	ppb	AMCV (interim)
1,2,4-Trimethylbenzene	250	ppb	AMCV (interim)	1.4	ppb	RfC - P
1,2-Dibromoethane	0.5	ppb	AMCV (interim)	0.00022	ppb	CREG
1,2-Dichloroethane	40	ppb	AMCV (interim)	0.0095	ppb	CREG
1,2-Dichloropropane	50	ppb	Acute EMEG/ MRL	0.052	ppb	SL - C
1,3,5-Trimethylbenzene (Mesitylene)	250	ppb	AMCV (interim)	25	ppb	AMCV (interim)
1,3-Butadiene	300	ppb	Acute REL	0.015	ppb	CREG
1-Butanol						
1-Butene	50,000	ppb	AMCV (final)			
1-Hexene And 2-Methyl-1-Pentene	500	ppb	AMCV (interim)	50	ppb	AMCV (interim)
1-Pentene	2,600	ppb	AMCV (final)			
2,2,4-Trimethylpentane (Isooctane)	750	ppb	AMCV (interim)	75	ppb	AMCV (interim)
2,2-Dimethylbutane (Neohexane)	1,000	ppb	AMCV (interim)	100	ppb	AMCV (interim)
2,3,4-Trimethylpentane	750	ppb	AMCV (interim)	75	ppb	AMCV (interim)
2,3-Dimethylbutane	990	ppb	AMCV (interim)	99	ppb	AMCV (interim)
2,3-Dimethylpentane	850	ppb	AMCV (interim)	85	ppb	AMCV (interim)
2,4-Dimethylpentane	850	ppb	AMCV (interim)	85	ppb	AMCV (interim)
2-Butanone (Methyl Ethyl Ketone)	4,400	ppb	Acute REL	1,700	ppb	RfC - I
2-Chloropentane	240	ppb	AMCV (interim)	24	ppb	AMCV (interim)
2-Methyl-1-Pentene	500	ppb	AMCV (interim)	50	ppb	AMCV (interim)
2-Methyl-2-Butene	2,600	ppb	AMCV (interim)			

Table 2B. Lowest Available Short-term and Long-term Comparison Values (page 2 of 8)

Chemical	Short-term Comparison Value*			Long-term Comparison Value*		
	Value	Units	Source	Value	Units	Source
2-Methylheptane	750	ppb	AMCV (interim)	75	ppb	AMCV (interim)
2-Methylhexane (Isoheptane)	750	ppb	AMCV (interim)	75	ppb	AMCV (interim)
2-Methylpentane (Isohexane)	850	ppb	AMCV (under review)	85	ppb	AMCV (under review)
2-Methyl-3-Hexanone	27	ppb	AMCV (interim)	2.7	ppb	AMCV (interim)
3-Methyl-1-Butene	8,000	ppb	AMCV (interim)	800	ppb	AMCV (interim)
3-Methylheptane	750	ppb	AMCV (interim)	75	ppb	AMCV (interim)
3-Methylhexane	750	ppb	AMCV (interim)	75	ppb	AMCV (interim)
3-Methylpentane	1,000	ppb	AMCV (interim)	100	ppb	AMCV (interim)
3-Hexanone	30	ppb	AMCV (interim)	3	ppb	AMCV (interim)
3-Pentanone (Diethyl ketone)	2,000	ppb	AMCV (interim)	200	ppb	AMCV (interim)
4-Methyl-1-Pentene	500	ppb	AMCV (interim)	50	ppb	AMCV (interim)
Acetylene	25,000	ppb	AMCV (interim)	2,500	ppb	AMCV (interim)
Benzene	9	ppb	Acute EMEG/MRL	0.04	ppb	CREG
Bromomethane	30	ppb	AMCV (interim)	3	ppb	AMCV (interim)
Butyl Acetate	7,400	ppb	AMCV (final)	130	ppb	AMCV (final)
Butyraldehyde	250	ppb	AMCV (under review)	25	ppb	AMCV (under review)
Cis-1,3-Dichloropropylene	10	ppb	AMCV (interim)	1	ppb	AMCV (interim)
Carbon Tetrachloride	20	ppb	AMCV (under review)	0.026	ppb	CREG
Chlorobenzene	100	ppb	AMCV (interim)	10	ppb	AMCV (interim)
Chloroform	20	ppb	AMCV (under review)	0.0089	ppb	CREG
Chloroprene (Chloro-1,3-butadiene)				0.00091	ppb	CREG
Cyclohexane	1,000	ppb	AMCV (interim)	100	ppb	AMCV (interim)
Cyclopentane	1,200	ppb	AMCV (interim)	120	ppb	AMCV (interim)
Cyclopentene	2,900	ppb	AMCV (interim)	290	ppb	AMCV (interim)
Ethane			simple asphyxiant†			simple asphyxiant
Ethyl Acetate	4,000	ppb	AMCV (interim)	19	ppb	RfC - P
Ethylbenzene	5,000	ppb	Acute EMEG/MRL	0.22	ppb	SL - C

Table 2B. Lowest Available Short-term and Long-term Comparison Values (page 3 of 8)

Chemical	Short-term Comparison Value*			Long-term Comparison Value*		
	Value	Units	Source	Value	Units	Source
Ethylene	500,000	ppb	AMCV (final)	5,300	ppb	AMCV (final)
Isobutane	33,000	ppb	AMCV (final)	2,400	ppb	AMCV (final)
Isopentane	68,000	ppb	AMCV (final)	8,000	ppb	AMCV (final)
Isoprene	20	ppb	AMCV (under review)	2	ppb	AMCV (under review)
Isopropylbenzene (Cumene)	500	ppb	AMCV (interim)	50	ppb	AMCV (interim)
Methyl Butyl Ketone (2-Hexanone)	10	ppb	AMCV (interim)	1	ppb	AMCV (interim)
Methyl Isobutyl Ketone	200	ppb	AMCV (interim)	20	ppb	AMCV (interim)
Methyl t-Butyl ether	500	ppb	AMCV (interim)	2.6	ppb	SL - C
Methylcyclohexane	4,000	ppb	AMCV (interim)	400	ppb	AMCV (interim)
Methylcyclopentane	750	ppb	AMCV (interim)	75	ppb	AMCV (interim)
Methylene Chloride (Dichloromethane)	600	ppb	Acute EMEG/MRL	29	ppb	CREG
Propane			simple asphyxiant			simple asphyxiant
Propylene			simple asphyxiant	1,700	ppb	Chronic REL
Styrene	5,000	ppb	Acute EMEG/MRL	110	ppb	AMCV (final)
Tetrachloroethylene	200	ppb	Acute EMEG/MRL	0.57	ppb	CREG
Toluene	1,000	ppb	Acute EMEG/MRL	80	ppb	Chronic EMEG/MRL
Trichloroethylene	100	ppb	AMCV (under review)	0.045	ppb	CREG
Trichlorofluoromethane (Freon 11)	5,000	ppb	AMCV (interim)	500	ppb	AMCV (interim)
Vinyl Chloride	500	ppb	Acute EMEG/MRL	0.044	ppb	CREG
a-Pinene	630	ppb	AMCV (interim)	63	ppb	AMCV (interim)
b-Pinene	630	ppb	AMCV (interim)	63	ppb	AMCV (interim)
c-2-Butene	15,000	ppb	AMCV (final)			
c-2-Hexene	500	ppb	AMCV (interim)	50	ppb	AMCV (interim)
c-2-Pentene	2,600	ppb	AMCV (final)			
Dichlorodifluoromethane (Freon 12)	10,000	ppb	AMCV (interim)	20	ppb	RfC - P
Isobutyraldehyde	1,000	ppb	AMCV (interim)	100	ppb	AMCV (interim)
m-Diethylbenzene	460	ppb	AMCV (interim)	46	ppb	AMCV (interim)

Table 2B. Lowest Available Short-term and Long-term Comparison Values (page 4 of 8)

Chemical	***Short-term Comparison Value****			***Long-term Comparison Value****		
	Value	***Units***	***Source***	***Value***	***Units***	***Source***
m-Ethyltoluene	250	ppb	AMCV (interim)	25	ppb	AMCV (interim)
Methyl Chloride (Chloromethane)	500	ppb	AMCV (interim)	50	ppb	AMCV (interim)
n-Butane	92,000	ppb	AMCV (final)	2,400	ppb	AMCV (final)
n-Decane	1750	ppb	AMCV (interim)	175	ppb	AMCV (interim)
Dodecane						
n-Heptane	850	ppb	AMCV (interim)	85	ppb	AMCV (interim)
n-Hexane	1,800	ppb	AMCV (final)	190	ppb	AMCV (final)
n-Nonane	2,000	ppb	AMCV (interim)	3.8	ppb	RfC - P
n-Octane	750	ppb	AMCV (interim)	75	ppb	AMCV (interim)
n-Pentane	68,000	ppb	AMCV (final)	340	ppb	RfC - P
n-Propyl Acetate	2,000	ppb	AMCV (interim)	200	ppb	AMCV (interim)
n-Propylbenzene	500	ppb	AMCV (interim)	50	ppb	AMCV (interim)
n-Undecane	550	ppb	AMCV (interim)	55	ppb	AMCV (interim)
o-Ethyltoluene	250	ppb	AMCV (interim)	25	ppb	AMCV (interim)
o-Xylene	1,700	ppb	AMCV (final)	140	ppb	AMCV (final)
p-Diethylbenzene	460	ppb	AMCV (interim)	46	ppb	AMCV (interim)
p-Ethyltoluene	250	ppb	AMCV (interim)	25	ppb	AMCV (interim)
p-Xylene + m-Xylene	1,700	ppb	AMCV (final)	140	ppb	AMCV (final)
t-2-Butene	15,000	ppb	AMCV (final)			
t-2-Hexene	500	ppb	AMCV (interim)	50	ppb	AMCV (interim)
t-2-Pentene	2,600	ppb	AMCV (final)			
Trans-1-3-Dichloropropylene	10	ppb	AMCV (interim)	1	ppb	AMCV (interim)
Naphthalene	95	ppb	AMCV (interim)	0.014	ppb	SL - C
xylenes (o,m,p)	2,000	ppb	Acute EMEG/MRL	23	ppb	RfC - I
Metals and Particulate Matter						
Ammonium Ion‡	1,200	$\mu g/m^3$	Acute EMEG/MRL	70	$\mu g/m^3$	Chronic EMEG/MRL
Antimony	5	$\mu g/m^3$	AMCV (interim)	0.5	$\mu g/m^3$	AMCV (interim)

Table 2B. Lowest Available Short-term and Long-term Comparison Values (page 5 of 8)

Chemical	Short-term Comparison Value*			Long-term Comparison Value*		
	Value	Units	Source	Value	Units	Source
Arsenic	0.2	µg/m³	Acute REL	0.00023	µg/m³	CREG
Barium	5	µg/m³	AMCV (interim)	0.5	µg/m³	AMCV (interim)
Cadmium	0.03	µg/m³	Acute EMEG/MRL	0.00056	µg/m³	CREG
Chlorine						
Chromium (hexavalent)	0.1	µg/m³	AMCV (under review)	0.000083	µg/m³	CREG
Cobalt	0.2	µg/m³	AMCV (interim)	0.00027	µg/m³	SL - P
Copper	10	µg/m³	AMCV (interim)	1	µg/m³	AMCV (interim)
Lead	0.15	µg/m³	NAAQS 3-month average			
Manganese§	2	µg/m³	AMCV (interim)	0.3	µg/m³	Chronic EMEG/MRL
Mercury	0.6	µg/m³	Acute REL	0.03	µg/m³	Chronic REL
Molybdenum	30	µg/m³	AMCV (interim)	3	µg/m³	AMCV (interim)
Nickel¶	0.2	µg/m³	Acute REL	0.01	µg/m³	SL - I
Selenium	2	µg/m³	AMCV (interim)	0.2	µg/m³	AMCV (interim)
Vanadium (as vanadium pentoxide)	0.5	µg/m³	AMCV (interim)	0.05	µg/m³	AMCV (interim)
Zinc	20	µg/m³	AMCV (interim)	2	µg/m³	AMCV (interim)
$PM_{2.5}$	35	µg/m³	NAAQS	12	µg/m³	NAAQS
PM_{10}	150	µg/m³	NAAQS			
Other						
Hydrogen Sulfide	70	ppb	Acute EMEG/MRL	1.4	ppb	RfC - I
Sulfur Dioxide	10	ppb	Acute EMEG/MRL			
Polycyclic Aromatic Hydrocarbons**						
Acenaphthene	1,000	ng/m³	AMCV (interim)	100	ng/m³	AMCV (interim)
Acenaphthylene	1,000	ng/m³	AMCV (interim)	100	ng/m³	AMCV (interim)
Anthracene	500	ng/m³	AMCV (interim)	50	ng/m³	AMCV (interim)
Benzo (a) Anthracene	500	ng/m³	AMCV (interim)	8.7	ng/m³	SL - C
Benzo (a) Pyrene	30	ng/m³	AMCV (under review)	0.87	ng/m³	SL - C
Benzo (b) Fluoranthene	500	ng/m³	AMCV (interim)	8.7	ng/m³	SL - C

Table 2B. Lowest Available Short-term and Long-term Comparison Values (page 6 of 8)

Chemical	*Short-term Comparison Value**			*Long-term Comparison Value**		
	Value	*Units*	*Source*	*Value*	*Units*	*Source*
Benzo (g,h,i) Perylene	500	ng/m^3	AMCV (interim)	50	ng/m^3	AMCV (interim)
Benzo (k) Fluoranthene	500	ng/m^3	AMCV (interim)	8.7	ng/m^3	SL - C
Chrysene	500	ng/m^3	AMCV (interim)	87	ng/m^3	SL - C
Dibenzo (a,h) Anthracene	500	ng/m^3	AMCV (interim)	0.8	ng/m^3	SL - C
Fluoranthene	500	ng/m^3	AMCV (interim)	50	ng/m^3	AMCV (interim)
Fluorene	10,000	ng/m^3	AMCV (interim)	1,000	ng/m^3	AMCV (interim)
Indeno (1,2,3-cd) Pyrene	500	ng/m^3	AMCV (interim)	8.7	ng/m^3	SL - C
Naphthalene	500,000	ng/m^3	AMCV (interim)	72	ng/m^3	SL - C
Phenanthrene	500	ng/m^3	AMCV (interim)	50	ng/m^3	AMCV (interim)
Pyrene	500	ng/m^3	AMCV (interim)	50	ng/m^3	AMCV (interim)
Carbonyl Compounds						
2,5-Dimethyl-Benzaldehyde	20	ppb	AMCV (interim)	2	ppb	AMCV (interim)
Acetaldehyde	250	ppb	AMCV (under review)	0.61	ppb	SL - I
Acetone	2,500	ppb	AMCV (under review)	250	ppb	AMCV (under review)
Acrolein	3	ppb	Acute EMEG/MRL	0.0087	ppb	RfC - I
Benzaldehyde	20	ppb	AMCV (interim)	2	ppb	AMCV (interim)
Butyraldehyde	250	ppb	AMCV (under review)	25	ppb	AMCV (under review)
Crotonaldehyde	3	ppb	AMCV (interim)	0.3	ppb	AMCV (interim)
Formaldehyde	40	ppb	Acute EMEG/MRL	0.063	ppb	CREG
Furfural				13	ppb	RfC - H
Heptaldehyde	80	ppb	AMCV (interim)	8	ppb	AMCV (interim)
Hexaldehyde	2,000	ppb	AMCV (interim)	200	ppb	AMCV (interim)
Isovaleraldehyde	500	ppb	AMCV (interim)	50	ppb	AMCV (interim)
Methyl Ethyl Ketone (2-Butanone)	20,000	ppb	AMCV (final)	3,000	ppb	AMCV (final)
m-Tolualdehyde	21	ppb	AMCV (interim)	2.1	ppb	AMCV (interim)
o-Tolualdehyde	21	ppb	AMCV (interim)	2.1	ppb	AMCV (interim)
Propionaldehyde	200	ppb	AMCV (under review)	3.4	ppb	RfC - I

Table 2B. Lowest Available Short-term and Long-term Comparison Values (page 7 of 8)

Chemical	Short-term Comparison Value*			Long-term Comparison Value*		
	Value	Units	Source	Value	Units	Source
p-Tolualdehyde	21	ppb	AMCV (interim)	2.1	ppb	AMCV (interim)
Valeraldehyde	500	ppb	AMCV (interim)	50	ppb	AMCV (interim)

Data Sources:

Agency for Toxic Substances and Disease Registry. 2013. Updated comparison value tables - March 2013. Comparison value spreadsheet provided via email by AnnMarie DePasquale, ATSDR, to agency staff on March 8, 2013. Atlanta: US Department of Health and Human Services.

California Environmental Protection Agency. 2014. All OEHHA acute, 8-hour and chronic reference exposure levels (chRELs) as of January 2014. Office of Environmental Health Hazard Assessment (OEHHA). Sacramento, CA. Available at: http://www.oehha.ca.gov/air/allrels.html.

Texas Commission on Environmental Quality. 2013. Air toxics, air monitoring comparison values (AMCV). Excel table last modified September 2013. Available at: http://www.tceq.texas.gov/toxicology/AirToxics.html#list.

US Environmental Protection Agency. 2013. Regional screening level (RSL) residential air supporting table November 2013. Available at: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm.

US Environmental Protection Agency. 2012. National ambient air quality standards (NAAQS) as of October 2011. Office of Air and Radiation. Research Triangle Park, NC. Webpage last updated 14 December 2012. Available at: http://www.epa.gov/air/criteria.html.

* The lowest short-term comparison value and lowest long-term comparison value are reported for each chemical. Blank table cells indicate that a comparison value was not available from the sources reviewed by ATSDR.

† A simple asphyxiant displaces air, lowering the partial pressure of oxygen and causing hypoxia at sufficiently high concentrations.

‡ Both the short-term and long-term comparison values provided are for ammonia.

§ The long-term comparison value provided for manganese is ATSDR's chronic EMEG/MRL of 0.3 $\mu g/m^3$, even though the U.S. EPA RfC of 0.05 $\mu g/m^3$ is lower. In 2012, after a reassessment of available studies, ATSDR's chronic EMEG/MRL was changed from 0.04 $\mu g/m^3$ to 0.3 $\mu g/m^3$. U.S. EPA's RfC for manganese was last revised in 1993. ATSDR consider its manganese chronic EMEG/MRL protective of public health for long-term air exposures, and therefore, does not use the U.S. EPA RfC to screen the Corpus Christi air data.

¶ The long-term comparison value provided is for nickel refinery dust.

** Polycyclic aromatic hydrocarbons (PAHs) are a subset of semi-volatile organic compounds (SVOCs). ATSDR provided comparison values for only those SVOCs detected in at least one mobile monitoring event air sample.

AMCV air monitoring comparison value
CREG cancer risk evaluation guide
EMEG environmental media evaluation guide
$\mu g/m^3$ micrograms per cubic meter
MRL minimal risk level
NAAQS national ambient air quality standards

Table 2B. Lowest Available Short-term and Long-term Comparison Values (page 8 of 8)

ng/m^3	nanograms per cubic meter
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
PM_{10}	particulate matter less than 10 microns in diameter
ppb	parts per billion
REL	reference exposure level
RfC – H	reference concentration – Health Effects Assessment Summary Tables
RfC – I	reference concentration – Integrated Risk Information System
RfC – P	reference concentration – Provisional Peer Reviewed Toxicity Values electronic library
SL – C	carcinogenic target screening risk level – California Environmental Protection Agency
SL – I	carcinogenic target screening risk level – Integrated Risk Information System
SL – P	carcinogenic target screening risk level – Provisional Peer Reviewed Toxicity Values electronic library

Table 3B. Auto GC Initial Data Screening Results (page 1 of 2)

Chemical	Auto GC Data			Is Maximum Level above Long-term CV?
	Maximum Level (ppb)	Location	Date	
Acetylene	56.4	Oak Park	12/23/2005	No
Benzene	1,014	Huisache	11/26/2008	Yes
1,3-Butadiene	35.7	Solar Estates	9/27/2009	Yes
n-Butane	681	Oak Park	5/30/2009	No
1-Butene	15.4	Oak Park	2/13/2007	---
c-2-Butene	12.5	Solar Estates	1/13/2006	---
t-2-Butene	9.55	Oak Park	5/27/2005	---
Cyclohexane	87.4	Oak Park	9/19/2010	No
Cyclopentane	45.6	Oak Park	11/19/2005	No
n-Decane	5.14	Oak Park	4/13/2006	No
2,2-Dimethylbutane (Neohexane)	63.4	Oak Park	11/19/2005	No
2,3-Dimethylpentane	13.6	Oak Park	9/19/2010	No
2,4-Dimethylpentane	6.33	Oak Park	1/23/2007	No
Ethane	380	Oak Park	1/10/2007	---
Ethylbenzene	5.42	Oak Park	6/1/2006	Yes
Ethylene	200	Solar Estates	4/15/2010	No
n-Heptane	75.8	Oak Park	9/19/2010	No
n-Hexane	196	Oak Park	9/19/2010	Yes
Isobutane	378	Oak Park	12/2/2007	No
Isopentane	682	Oak Park	5/16/2007	No
Isoprene	2.33	Oak Park	8/13/2010	Yes
Isopropylbenzene (Cumene)	88.7	Solar Estates	1/27/2007	Yes
Methylcyclohexane	92.4	Oak Park	9/19/2010	No
Methylcyclopentane	99.6	Oak Park	9/19/2010	Yes
2-Methylheptane	19.6	Oak Park	9/19/2010	No
3-Methylheptane	12.6	Oak Park	9/19/2010	No
3-Methylhexane	39.2	Oak Park	9/19/2010	No
2-Methylhexane (Isoheptane)	32.5	Oak Park	9/19/2010	No
n-Nonane	7.8	Solar Estates	10/7/2010	Yes
n-Octane	21.9	Oak Park	9/19/2010	No
n-Pentane	501	Oak Park	5/16/2007	Yes
1-Pentene	5.74	Solar Estates	8/12/2007	---
t-2-Pentene	21.9	Oak Park	3/3/2007	---

Table 3B. Auto GC Initial Data Screening Results (page 2 of 2)

Chemical	Auto GC Data			Is Maximum Level above Long-term CV?
	Maximum Level (ppb)	Location	Date	
c-2-Pentene	7.71	Oak Park	3/3/2007	---
Propane	805	Oak Park	12/2/2007	---
n-Propylbenzene	8.46	Oak Park	11/3/2006	No
Propylene	118	Oak Park	7/6/2006	No
Styrene	62.2	Oak Park	8/8/2005	No
Toluene	136	Solar Estates	3/6/2007	Yes
1,2,4-Trimethylbenzene	10.5	Oak Park	5/18/2008	Yes
1,2,3-Trimethylbenzene (Hemimellitene)	3.26	Oak Park	6/1/2006	No
1,3,5-Trimethylbenzene (Mesitylene)	4.12	Oak Park	6/1/2006	No
2,3,4-Trimethylpentane	9.1	Solar Estates	6/1/2006	No
2,2,4-Trimethylpentane (Isooctane)	34.4	Solar Estates	6/1/2006	No
o-Xylene	20	Solar Estates	1/27/2007	No
p-Xylene + m-Xylene	32.7	Solar Estates	1/31/2006	No

Data sources:

Texas Commission on Environmental Quality. 2010. Data posted to FTP site by Melanie Hotchkiss, TCEQ, and downloaded by John Wilhelmi, Eastern Research Group, Inc. Contains continuous 2005-2009 sulfur compound and volatile organic compound data for both TCEQ and Corpus Christi Air Quality Project air monitoring sites. Austin, TX.

The University of Texas. 2011. April 25th email from Dr. David Sullivan, The University of Texas at Austin, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing an Excel attachment with the continuous 2010 volatile organic compounds data for the Solar Estates and Oak Park air monitoring sites. Austin, TX.

ToxStrategies, Inc. 2011. September 8th email from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005−2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

--- No long-term comparison value is available.

Auto GC automatic gas chromatograph
CV health-based comparison value
ppb parts per billion

Table 4B. TCEQ Canisters Initial Data Screening Results (page 1 of 3)

Chemical	*TCEQ Canister Data*			*Is Maximum Level above Long-term CV?*
	Maximum Level (ppb)	*Location*	*Date*	
Acetylene	29.62	Huisache	11/10/2000	No
Benzene	40.32	Hillcrest	02/03/2005	Yes
Bromomethane	0.77	Navigation	02/28/1998	No
1,3-Butadiene	2.93	Dona Park	10/17/2010	Yes
n-Butane	576.7	Huisache	11/17/2000	No
2-Butanone (Methyl Ethyl Ketone)	11.41	Huisache	03/14/2004	No
1-Butene	66.24	Huisache	10/20/1998	---
c-2-Butene	26.7	Huisache	12/30/2000	---
t-2-Butene	36.91	Huisache	12/30/2000	---
Butyl Acetate	0.16	Huisache	07/15/2005	No
Butyraldehyde	1.24	Huisache	01/05/2005	No
Carbon Tetrachloride	4.96	Navigation	09/24/1996	Yes
Chlorobenzene	2.48	Navigation	12/06/1997	No
Chloroform	0.69	Navigation	02/28/1998	Yes
2-Chloropentane	12.04	Navigation	11/03/1993	No
Chloroprene	0.06	Huisache	05/09/2004	Yes
Cis-1,3-Dichloropropylene	0.05	Huisache	12/12/2003	No
Cyclohexane	259.8	Hillcrest	10/19/1999	Yes
Cyclopentane	9.33	Huisache	11/17/2000	No
Cyclopentene	3.06	Huisache	01/22/2004	No
n-Decane	1.98	Huisache	03/03/1998	No
1,2-Dibromoethane	0.18	Hillcrest	12/10/2010	Yes
Dichlorodifluoromethane (Freon 12)	0.97	Huisache	12/12/2003	No
1,1-Dichloroethane	0.67	Navigation	02/28/1998	Yes
1,2-Dichloroethane	0.67	Navigation	06/24/1993	Yes
1,1-Dichloroethylene	0.68	Navigation	02/28/1998	No
1,2-Dichloropropane	0.95	Navigation	01/09/1995	Yes
m-Diethylbenzene	0.58	Huisache	01/29/2003	No
p-Diethylbenzene	2	Huisache	01/29/2003	No
2,3-Dimethylbutane	8.75	Huisache	01/29/2003	No
2,2-Dimethylbutane (Neohexane)	14.08	Navigation	01/15/1995	No
2,3-Dimethylpentane	6.18	Huisache	11/22/1997	No
2,4-Dimethylpentane	4.68	Huisache	12/06/1997	No
Ethane	558.3	Huisache	11/17/2000	---
Ethylbenzene	9.21	Huisache	01/29/2003	Yes
Ethylene	87.2	Navigation	11/26/1999	No

Table 4B. TCEQ Canisters Initial Data Screening Results (page 2 of 3)

Chemical	TCEQ Canister Data			Is Maximum Level above Long-term CV?
	Maximum Level (ppb)	Location	Date	
m-Ethyltoluene	9.56	Huisache	01/29/2003	No
o-Ethyltoluene	3.19	Huisache	01/29/2003	No
p-Ethyltoluene	3.36	Huisache	01/29/2003	No
n-Heptane	12.29	Huisache	11/17/2000	No
n-Hexane	44.58	Huisache	11/17/2000	No
3-Hexanone	0.76	Hillcrest	04/29/2006	No
c-2-Hexene	1.26	Huisache	01/22/2004	No
t-2-Hexene	1.99	Huisache	01/22/2004	No
1-Hexene And 2-Methyl-1-Pentene	2.83	Huisache	01/22/2004	No
Isobutane	297.6	Huisache	11/17/2000	No
Isobutyraldehyde	2.46	Dona Park	01/06/2005	No
Isopentane	264.1	Huisache	11/17/2000	No
Isoprene	1.37	Navigation	02/28/1998	No
Isopropylbenzene (Cumene)	4.14	Hillcrest	12/19/1998	No
3-Methyl-1-Butene	8.14	Huisache	01/21/2004	No
2-Methyl-1-Pentene	2.65	Poth Lane	09/26/1998	No
4-Methyl-1-Pentene	1.88	Navigation	03/28/1995	No
2-Methyl-2-Butene	39.18	Huisache	01/22/2004	---
2-Methyl-3-Hexanone	0.9	Hillcrest	04/29/2006	No
Methyl Butyl Ketone (MBK) (2-Hexanone)	1.31	Hillcrest	04/29/2006	Yes
Methyl Chloride (Chloromethane)	2.78	Dona Park	09/09/2008	No
Methyl Isobutyl Ketone	0.8	Hillcrest	04/29/2006	No
Methyl t-Butyl ether	33.65	Huisache	01/29/2003	Yes
Methylcyclohexane	15.64	Huisache	10/30/1997	No
Methylcyclopentane	17.15	Huisache	11/17/2000	No
Methylene Chloride (Dichloromethane)	93.08	Hillcrest	06/23/2008	Yes
2-Methylheptane	3.28	Huisache	11/17/2000	No
3-Methylheptane	3.64	Huisache	01/29/2003	No
3-Methylhexane	19.17	Huisache	11/22/1997	No
2-Methylhexane (Isoheptane)	19.1	Huisache	11/22/1997	No
3-Methylpentane	24.34	Huisache	11/17/2000	No
2-Methylpentane (Isohexane)	45.21	Huisache	11/17/2000	No
n-Nonane	1.67	Hillcrest	12/19/1998	No
n-Octane	3.44	Huisache	11/17/2000	No
n-Pentane	238.2	Huisache	11/17/2000	No
3-Pentanone (Diethyl ketone)	0.06	Hillcrest	05/03/2004	No

Table 4B. TCEQ Canisters Initial Data Screening Results (page 3 of 3)

Chemical	TCEQ Canister Data			Is Maximum Level above Long-term CV?
	Maximum Level (ppb)	Location	Date	
1-Pentene	21.5	Huisache	01/21/2004	---
t-2-Pentene	31.07	Huisache	01/21/2004	---
c-2-Pentene	15.85	Huisache	01/21/2004	---
a-Pinene	0.19	Navigation	08/07/1995	No
b-Pinene	0.06	Navigation	01/16/1996	No
Propane	689.8	Huisache	11/17/2000	---
n-Propylbenzene	1.83	Hillcrest	12/19/1998	No
Propylene	167.2	Huisache	01/21/2001	No
Styrene	9.35	Huisache	11/16/1997	No
1,1,2,2-Tetrachloroethane	0.07	Huisache	01/25/2004	Yes
Tetrachloroethylene	1.88	Hillcrest	06/23/2008	Yes
Toluene	49.66	Huisache	03/30/1999	No
Trans-1-3-Dichloropropylene	0.04	Huisache	12/12/2003	No
1,1,1-Trichloroethane	116.4	Huisache	01/17/2001	No
1,1,2-Trichloroethane	0.68	Navigation	02/28/1998	Yes
Trichloroethylene	12.76	Navigation	03/26/1993	Yes
Trichlorofluoromethane (Freon 11)	1.37	Navigation	05/26/1994	No
1,2,4-Trimethylbenzene	15.75	Huisache	01/29/2003	Yes
1,2,3-Trimethylbenzene (Hemimellitene)	3.03	Huisache	01/29/2003	No
1,3,5-Trimethylbenzene (Mesitylene)	3.67	Huisache	01/29/2003	No
2,3,4-Trimethylpentane	8.62	Hillcrest	12/19/1998	No
2,2,4-Trimethylpentane (Isooctane)	21.46	Hillcrest	12/19/1998	No
n-Undecane	8.74	Huisache	01/17/2001	No
Vinyl Chloride	0.72	Navigation	02/28/1998	Yes
o-Xylene	61.58	Poth Lane	08/27/1998	No
p-Xylene + m-Xylene	37.1	Huisache	01/29/2003	No

Data source: Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) web interface. Data downloaded from TAMIS through three separate queries performed with the target list 'Canister Parameters' group, 24-hour concentrations for dates within the range >=1/1/1990 to <1/1/2011 for monitors in the Corpus Christi area. Data queried on 29 May 2013.

--- No long-term comparison value is available.

CV health-based comparison value
ppb parts per billion
TCEQ Texas Commission on Environmental Quality

Table 5B. Industry Canisters Initial Data Screening Results

Chemical	Industry Canister Data			Is Maximum Level above Long-term CV?
	Maximum Level (ppb)	Location	Date	
Benzaldehyde	3.57	Crossley Elementary School	07/20/2003	Yes
Benzene	9.58	Oak Park Elementary School	10/20/2006	Yes
1,3-Butadiene	5.74	Tuloso Midway Elementary School	09/15/2008	Yes
1-Butanol	61.4	Crossley Elementary School	06/11/1999	---
Butyraldehyde	5.87	Crossley Elementary School	07/28/1998	No
Carbon Tetrachloride	1.39	Crossley Elementary School	03/28/2003	Yes
Cis-1,3-Dichloropropylene	0.5	Tuloso Midway Middle School	04/16/1997	No
Cyclohexane	13.9	Oak Park Elementary School	12/21/2001	No
1,1-Dichloroethane	0.51	Tuloso Midway Middle School	04/16/1997	Yes
1,2-Dichloroethane	0.65	Tuloso Midway Middle School	04/16/1997	Yes
1,1-Dichloroethylene	0.53	Crossley Elementary School	09/02/1998	No
Ethylbenzene	2.2	Up River Road	01/05/1998	Yes
Ethylene	20.4	Crossley Elementary School	12/11/2004	No
n-Hexane	13.1	Crossley Elementary School	11/30/1997	No
Methyl Chloride (Chloromethane)	5.04	Crossley Elementary School	07/08/2003	No
Methyl t-Butyl ether	28.8	Up River Road	01/19/2001	Yes
Naphthalene	0.72	Tuloso Midway Middle School	12/23/1996	Yes
Propylene	27.3	Up River Road	09/29/2002	No
Styrene	5.12	Tuloso Midway Middle School	08/23/2001	No
Tetrachloroethylene	8.57	Tuloso Midway Middle School	07/04/1998	Yes
Toluene	861	Oak Park Elementary School	11/02/2000	Yes
Trans-1-3-Dichloropropylene	0.42	Tuloso Midway Middle School	04/16/1997	No
1,1,1-Trichloroethane	0.59	Tuloso Midway Middle School	04/16/1997	No
Trichloroethylene	0.59	Tuloso Midway Middle School	04/16/1997	Yes
1,2,4-Trimethylbenzene	1.96	Crossley Elementary School	09/17/2002	Yes
o-Xylene	25.3	Crossley Elementary School	10/10/2001	No
p-Xylene + m-Xylene	9.54	Crossley Elementary School	10/10/2001	No

Data source: ToxStrategies, Inc. 2011. September 8th email from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005−2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

--- No long-term comparison value is available.

CV health-based comparison value
ppb parts per billion

Table 6B. AQP Triggered Canisters Initial Screening Results (page 1 of 2)

Chemical	*AQP Triggered Canister Data*				*Number of Detections above Short-term CV*
	Location	*Total Number of AQP Triggered Values Reported**	*Maximum Level Detected (ppb)*	*Date of Maximum Level Detected*	
Benzene	Dona Park	66	60.55	12/15/2009	1
	JI Hailey	82	407.25	3/6/2007	18
	Oak Park	10	33.27	1/4/2006	1
	Off Up River Road	9	31.19	1/13/2008	2
	Port Grain Elevator	58	196.01	5/10/2007	12
	West End Inner Harbor	35	113.21	5/18/2006	6
Carbon Tetrachloride	Port Grain Elevator	13	47.62	2/16/2010	1
	West End Inner Harbor	14	34.43	7/19/2008	1
1,2-Dibromoethane	Port Grain Elevator	13	4.78	3/3/2010	10
Dodecane	Dona Park	4	0.97	12/30/2008	---
	JI Hailey	3	1.81	6/12/2008	
	Port Grain Elevator	13	1.92	2/14/2010	
	West End Inner Harbor	2	0.93	1/14/2009	
Isoprene	JI Hailey	59	77.89	5/13/2007	1
	West End Inner Harbor	29	76.17	5/18/2006	1
Propane	Dona Park	66	525.04	11/16/2010	---
	JI Hailey	82	4,148.93	4/2/2007	
	Oak Park	10	128.98	12/18/2005	
	Off Up River Road	9	2,049.93	1/13/2008	
	Port Grain Elevator	58	1,901.21	11/9/2008	
	Solar Estates	6	37.77	1/10/2006	
	West End Inner Harbor	35	722.3	3/13/2010	
Propylene	Dona Park	66	16.5	10/31/2007	---
	JI Hailey	82	24.66	12/1/2010	
	Oak Park	10	12.93	12/18/2005	
	Off Up River Road	9	4.65	11/3/2007	
	Port Grain Elevator	58	31.02	11/30/2005	
	Solar Estates	6	1.87	12/31/2005	
	West End Inner Harbor	35	64.1	3/13/2010	

Data Sources:

The University of Texas. 2011. March 9th email from Dr. David Sullivan, The University of Texas at Austin, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing an Excel attachment with the event-triggered data and 2010 H_2S and SO_2 data for the Corpus Christi site. Austin, TX.

Table 6B. AQP Triggered Canisters Initial Screening Results (page 2 of 2)

The University of Texas. 2013. November 5th email from Dr. David Sullivan, The University of Texas at Austin, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing an Excel attachment with the CCAQP, event-triggered VOC data for Port Grain Elevator station. Austin, TX.

--- No short-term comparison value is available.

CV health-based comparison value
ppb part per billion

Table 7B. Mobile Monitoring Initial Data Screening Results (page 1 of 3)

Chemical	*Mobile Monitoring Data*				*Number (and Percent) of Samples above Short-term CV*
	Monitor Type	*Total Number of Values Reported**	*Maximum Level Detected (ppb)*	*Date of Maximum Level Detected*	
Benzene	Auto GC - Continuous Average	763	190	2/26/2001	164 (21%)
	Auto GC - High 1-hr Average	763	440	2/26/2001	264 (5%)
	Auto GC - Maximum	763	760	2/26/2001	374 (49%)
	Canister[†]	798	370,000	7/31/2000	266 (33%)
	Real-time GCMS	8	20	2/2/2003	2 (25%)
Carbon Tetrachloride	Canister	480	130	2/28/2001	4 (0.83%)
Chloroform	Canister	480	110	5/31/2000	2 (0.42%)
Chloroprene	Canister	196	0.83	11/17/2003	---
	Real-time GCMS	69	14.9	2/25/2002	
1,2-Dibromoethane	Canister	292	0.87	3/5/2007	2 (0.68%)
Ethane	Auto GC - Continuous Average	222	78	11/15/2004	---
	Auto GC - High 1-hr Average	222	140	4/1/2008	
	Auto GC - Maximum	222	200	3/4/2007	
	Canister	298	3,700	3/6/2007	
Furfural	Canister	18	0.038	2/4/2003	---
Isoprene	Auto GC - Continuous Average	82	80.63	11/15/2004	6 (7.3%)
	Auto GC - High 1-hr Average	82	130	11/15/2004	8 (9.8%)
	Auto GC - Maximum	82	330	11/15/2004	13 (16%)
	Canister	485	99	2/26/2002	1 (0.21%)
Propane	Auto GC - Continuous Average	222	230.21	4/1/2008	---
	Auto GC - High 1-hr Average	222	510	3/2/2007	
	Auto GC - Maximum	222	1,500	3/2/2007	
	Canister	297	710	3/6/2007	
Propylene	Auto GC - Continuous Average	222	110	3/30/2008	---
	Auto GC - High 1-hr Average	222	140	3/30/2008	
	Auto GC - Maximum	222	180	3/30/2008	
	Canister	297	140	3/30/2008	
Toluene	Auto GC - Maximum	744	1,000	3/2/2007	1 (0.13%)
	Canister	775	1,300	5/31/2000	2 (0.26%)

Data Sources:

Texas Natural Resource Conservation Commission. 1996a. Corpus Christi area monitoring network summary of measurements for the period March 1994 – March 1996. Report date 3 June 1996. Austin, TX.

Texas Natural Resource Conservation Commission. 1996b. Toxicological evaluation of the results of the mobile monitoring, volatile organic and sulfur compounds, February 4-9, 1996. Report date 12 June 1996. Austin, TX.

Table 7B. Mobile Monitoring Initial Data Screening Results (page 2 of 3)

Texas Natural Resource Conservation Commission. 1997. Toxicological evaluation of results of mobile monitoring for sulfur compounds, VOCs, carbon monoxide, respirable particulate matter, and metals, Corpus Christi, Nueces County, February 1-7, 1997, Report date 20 May 1997. Austin, TX.

Texas Natural Resource Conservation Commission. 1998a. Toxicological evaluation of results of mobile monitoring VOCs and sulfur compounds, Corpus Christi, Nueces County, January 31- February 6, 1998. Austin, TX.

Texas Natural Resource Conservation Commission. 1998b. Toxicological evaluation of results of mobile monitoring VOCs, Corpus Christi, Nueces County, November 20 - 22, 1998. Austin, TX.

Texas Natural Resource Conservation Commission. 1999. Toxicological evaluation of results of mobile monitoring VOCs, Corpus Christi, Nueces County, January 9 - 13, 1999. Austin, TX

Texas Natural Resource Conservation Commission. 2000a. Toxicological evaluation of results of mobile monitoring volatile organic compounds and sulfur compounds, Corpus Christi, Nueces County, February 5 – 11, 2000. Report date 16 June 2000. Austin, TX.

Texas Natural Resource Conservation Commission. 2000b. Toxicological evaluation of results of ambient air sampling for benzene and other VOCs, hydrocarbon seep at Elementis Chromium, and Amerada Hess Recovery Wells in Oak Park Neighborhood (Cenizo Street), Corpus Christi, Nueces County. Report date 1 March 2000. Austin, TX.

Texas Natural Resource Conservation Commission. 2000c. Toxicological evaluation of results of ambient air sampling for benzene and other VOCs, Corpus Christi, Nueces County, April 27 - 30, 2000. Austin, TX.

Texas Natural Resource Conservation Commission. 2000d. Toxicological evaluation of air sampling results, benzene and other volatile organic compounds (VOCs), hydrocarbon seep and remediation activities at Elementis Chromium, recovery wells at Coastal Refining and Marketing – East and West Plants, Corpus Christi, Nueces County, July 31, 2000. Report date 9 November 2000. Austin, TX.

Texas Natural Resource Conservation Commission. 2001. Toxicological evaluation of mobile monitoring results for VOCs, H_2S, and SO_2, Corpus Christi and Three Rivers TX, February 24 - March 1, 2001. Austin, TX.

Texas Commission on Environmental Quality. 2002. Results from Corpus Christi mobile laboratory VOC sampling trip, February 23 – March 1, 2002. Austin, TX.

Texas Commission on Environmental Quality. 2003. Results from Corpus Christi mobile laboratory sampling trip, February 1 – 6, 2003. Austin, TX.

Texas Commission on Environmental Quality. 2003. Results from Corpus Christi mobile laboratory sampling trip, November 15 – 20, 2003. Austin, TX.

Texas Commission on Environmental Quality. 2004. Results from Corpus Christi mobile laboratory sampling trip, November 14-19, 2004. Austin, TX.

Texas Commission on Environmental Quality. 2006. Region 14 VOC survey project, August 18-24, 2006. Report date 25 October 2006. Austin, TX.

Texas Commission on Environmental Quality. 2007. Corpus Christi monitoring project, March 1-8, 2007. Report date 14 September 2007. Austin, TX.

[TCEQ] Texas Commission on Environmental Quality. 2008. Corpus Christi monitoring project, March 29-April 4, 2008 and April 21, 2008. 18 Dec 2008. Austin, TX.

* "Total number of Values Reported" refers to the total number of samples in the ATSDR database of extracted chemical concentrations data from the Mobile Monitoring reports. Some of these samples were listed as "ND", "<mdl", etc. If there was a numeric value or a data qualifier, it was counted as a sample.

† The durations for the canister samples varied across reports. Most of the canister samples were 3 hour canisters, but some were 1 hour and some were 30 minute.

--- No short-term comparison value is available.

Auto GC	automated gas chromatograph
CV	health-based comparison value

Table 7B. Mobile Monitoring Initial Data Screening Results (page 3 of 3)

hr	hour
ppb	parts per billion
GCMS	gas chromatography/mass spectroscopy

Table 8B. Metals and Particulate Matter Initial Data Results (page 1 of 2)

Chemical	Metals and Particulate Matter Data			Is Maximum Level above Long-term CV?
	Maximum Level ($\mu g/m^3$)	Location	Date	
Ammonium Ion*	4.1	Dona Park	08/30/2002	No
Antimony	0.0668	Dona Park	02/07/2002	No
Arsenic	0.00278	Dona Park	08/02/2005	Yes
Barium	0.37354	Dona Park	04/18/2008	No
Cadmium	0.06106	Dona Park	04/13/2009	Yes
Chlorine†	2.73493	Dona Park	05/06/2007	---
Chromium‡	0.02368	Dona Park	11/16/2010	Yes
Cobalt	0.00112	Dona Park	05/10/2005	Yes
Copper	0.05913	Dona Park	11/03/2009	No
Lead	0.17449	Dona Park	04/13/2009	---
Manganese	0.035	Dona Park	06/23/2007	No
Mercury	0.00524	Dona Park	10/31/2005	No
Molybdenum	0.00627	Dona Park	02/14/2002	No
Nickel§	0.0168	Dona Park	02/01/2002	Yes
Selenium	0.00393	Dona Park	05/28/2005; 04/17/2006	No
Vanadium¶	0.02199	Dona Park	04/29/2006	No
Zinc	0.77228	Dona Park	04/13/2009	No
$PM_{2.5}$	38.9	Navigation	09/14/2002	Yes
PM_{10}	102	Navigation	07/04/1998	---

Data Sources:

Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) web interface. Data downloaded from TAMIS through a query performed with the target list 'PM2.5-parameters' group, 24-hour concentrations, for dates within the range >=1/1/1990 to <1/1/2011 at the Dona Park stationary air monitor. Data downloaded on 26 January 2013.

Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through a query performed for Pm10 Total 0-10um Stp and Pm10 - Lc, 24-hour concentrations, for dates within the range >=1/1/1984 to <1/1/2011 at the Dona Park, Fire Station #5, and Navigation stationary air monitors. Data downloaded on November 19, 2013.

Texas Commission on Environmental Quality. 2014. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through a query performed for Parameter Pm2.5 - Local Conditions, 24-hour concentrations, for dates within the range >=1/1/1980 to <1/1/2011 at the Dona Park, Huisache, and Navigation stationary air monitors. Data downloaded on 23 June 2014.

* Screened against the long-term comparison value available for ammonia.

† Although comparison values exist for chlorine in its gaseous (vapor) phase, no comparison values exist for chlorine as a particulate.

‡ Screened against the long-term comparison value available for hexavalent chromium.

§ Screened against the long-term comparison value available for nickel refinery dust.

¶ Screened against the long-term comparison value available for vanadium pentoxide.

--- No long-term comparison value is available.

Table 8B. Metals and Particulate Matter Initial Data Results (page 2 of 2)

CV	health-based comparison value
$\mu g/m^3$	micrograms per cubic meter
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
PM_{10}	particulate matter less than 10 microns in diameter

Table 9B. Metals – 1980s Stationary Air Monitor Initial Data Results

Chemical	Metals – 1980's Stationary Air Monitor Data			Is Maximum Level above Long-term CV?
	Maximum Level ($\mu g/m^3$)	Location	Date	
Antimony	0.095	Old Galveston Road	09/18/1980	No
Arsenic	0.093	West Guth Park	09/12/1980	Yes
Barium	6.335	Navigation Blvd	08/26/1981	Yes
Cadmium	0.175	Fire Station #5	12/18/1981	Yes
Chromium*	0.731	Navigation Blvd	05/28/1981	Yes
Cobalt	NA	NA	NA	Yes†
Copper	0.572	West Guth Park	01/22/1981	No
Lead	3.03	Old Galveston Road	09/30/1980	---
Manganese	0.074	Navigation Blvd	09/13/1981	No
Molybdenum	0.04	Old Galveston Road	09/18/1980	No
Nickel‡	0.05	West Guth Park	08/19/1980	Yes
Selenium	NA	NA	NA	No†
Vanadium§	0.123	Fire Station #5	07/27/1981	Yes
Zinc	1.804	Navigation Blvd	11/30/1981	No

Data Source: Texas Commission on Environmental Quality. 2014. Texas Air Monitoring Information System (TAMIS) web interface. Data downloaded from TAMIS through a query performed with the target list 'TSP-parameters' group, 24-hour concentrations, for dates within the range >=1/1/1980 to <1/1/2011 at the Fire Station #5, Navigation Boulevard, Old Galveston Road, and West Guth Park stationary air monitors. The query included the Navigation monitor for TSP/lead speciation. Data downloaded on 13 January 2014.

* Screened against the long-term comparison value available for hexavalent chromium.
† Cobalt and selenium were analyzed for, but not detected. The reporting limit of 0.03 $\mu g/m^3$ is above cobalt's long-term comparison value but not selenium's.
‡ Screened against the long-term comparison value available for nickel refinery dust.
§ Screened against the long-term comparison value available for vanadium pentoxide.
--- No long-term comparison value is available.

CV health-based comparison value
$\mu g/m^3$ micrograms per cubic meter
NA not available

Table 10B. Sulfur Compounds – Mobile Monitoring Screening Results (page 1 of 2)

Chemical	***Sulfur Compounds – Mobile Monitoring Data***				***Number (and Percent) of Samples above Short-term CV***
	Type of Sample	***Total Number of Values Reported****	***Maximum Level Detected (ppb)***	***Date of Maximum Level Detected***	
Hydrogen Sulfide	5-minute Average (July 1993 & Dec 1995)	785	243	7/12/1993	118 (15%)
	Peak Concentration (July 1993 - Mar 2008)	1,099	1,870	2/28/2001	241 (22%)
	30-minute Average (Feb 1994 - Mar 2008)	321	1,086	2/2/1997	43 (13%)
	Impinger Sample (Feb 1996 - Mar 2008)	38	2,000	2/2/1997	26 (68%)
	Auto - GC Maximum (Feb 2002)	117	233	2/23/2002	16 (14%)
	Auto – GC Continuous Average (Feb 1994 - Feb 2001)	237	504	2/27/2001	11 (4.6%)
Sulfur Dioxide	5-minute Average (July 1993 & Dec 1995)	805	1,665	7/13/1993	391 (49%)
	Peak Concentration (Feb 1993 - Mar 2008)	1,109	6,745	7/13/1993	524 (47%)
	30-minute Average (Feb 1994 - Mar 2008)	308	1,010	2/23/1994	133 (43%)
	Auto - GC Maximum (Dec 1995 – Feb 1996)	38	1,800	12/3/1995	18 (47%)
	Auto - GC High 1-hr Average (Dec 1995 – Feb 1996)	38	440	12/3/1995	13 (34%)
	Auto – GC Continuous Average (Dec 1995 – Feb 1996)	38	73	12/3/1995	11 (29%)

Data sources:

Texas Natural Resource Conservation Commission. 1994. Corpus Christi mobile laboratory trip, February 19-25, 1994; RTGC and Composite Sampling. Austin, TX.

Texas Natural Resource Conservation Commission. 1995. Valero, Citgo, and Koch Refineries sampling trip for SO_2 and H_2S, December 8-12, 1995. Austin, TX.

Texas Natural Resource Conservation Commission. 1996. Corpus Christi area monitoring network summary of measurements for the period March 1994 – March 1996. Report date 3 June 1996. Austin, TX.

Texas Natural Resource Conservation Commission. 1996. Toxicological evaluation of the results of the mobile monitoring, volatile organic and sulfur compounds, February 4-9, 1996. Report date 12 June 1996. Austin, TX.

Texas Natural Resource Conservation Commission. 1997. Toxicological evaluation of results of mobile monitoring for sulfur compounds, VOCs, carbon monoxide, respirable particulate matter, and metals, Corpus Christi, Nueces County, February 1-7, 1997. Report date 20 May 1997. Austin, TX.

Texas Natural Resource Conservation Commission. 1998. Toxicological evaluation of results of mobile monitoring VOCs and sulfur compounds, Corpus Christi, Nueces County, January 31- February 6, 1998. Austin, TX.

Texas Natural Resource Conservation Commission. 1998. Toxicological evaluation of results of mobile monitoring VOCs, Corpus Christi, Nueces County, December 11 - 15 , 1998. Austin, TX.

Table 10B. Sulfur Compounds – Mobile Monitoring Screening Results (page 2 of 2)

Texas Natural Resource Conservation Commission. 2000. Toxicological evaluation of results of mobile monitoring volatile organic compounds and sulfur compounds, Corpus Christi, Nueces County, February 5 – 11, 2000. Report date 16 June 2000. Austin, TX.

Texas Natural Resource Conservation Commission. 2001. Toxicological evaluation of mobile monitoring results for VOCs, H2S, and SO2, Corpus Christi and Three Rivers TX, February 24 - March 1, 2001. Austin, TX.

Texas Commission on Environmental Quality. 2002. Results from Corpus Christi mobile laboratory VOC sampling trip, February 23 – March 1, 2002. Austin, TX.

Texas Commission on Environmental Quality. 2003. Results from Corpus Christi mobile laboratory sampling trip, February 1 – 6, 2003. Austin, TX.

Texas Commission on Environmental Quality. 2003. Results from Corpus Christi mobile laboratory sampling trip, November 15 – 20, 2003. Austin, TX.

Texas Commission on Environmental Quality. 2004. Results from Corpus Christi mobile laboratory sampling trip, November 14-19, 2004. Austin, TX.

Texas Commission on Environmental Quality. 2007. Corpus Christi monitoring project, March 1-8, 2007. Report date 14 September 2007. Austin, TX.

[TCEQ] Texas Commission on Environmental Quality. 2008. Corpus Christi monitoring project, March 29-April 4, 2008 and April 21, 2008. 18 Dec 2008. Austin, TX.

* "Total number of Values Reported" refers to the total number of samples in the ATSDR database of extracted chemical concentrations data from the Mobile Monitoring reports. Some of these samples were listed as "ND", "<mdl", etc. If there was a numeric value or a data qualifier, it was counted as a sample.

Auto GC	automated gas chromatograph
CV	health-based comparison value
ppb	parts per billion

Table 11B. Auto GC (2005–2010) Refined Data Screening Results (page 1 of 4)

*Chemical**	*Location*	*Auto GC Data (2005–2010)*									*Is this Chemical of Potential Concern?*
		Total Number of Samples	*Number (and Percent) of Samples above DL*	*Maximum*			*Mean*				
				Level (ppb)	*Number (and Percent) of Samples above Short-term CV*	*Number (and Percent) of Samples above Long-term CV*	*Level (LCL–UCL) (ppb)*	*Mean above Long-term CV*†	*LCL above Long-term CV*†	*UCL above Long-term CV*†	
Benzene	Oak Park	44,044	38,899 (88)	120.15	222 (0.5)	34,840 (79)	0.5 (0.455-0.545)	✓	✓	✓	Yes
	Solar Estates	41,150	37,330 (91)	11.66	3 (0.0073)	34,553 (84)	0.269 (0.256-0.282)	✓	✓	✓	
	Huisache‡	190,455	189,590 (99)	1,014.02	5,199 (2.7)	169,033 (89)	1.31 (1.20- 1.42)	✓	✓	✓	
	Huisache§	49,224	48,947(99)	329.67	3,374 (6.9)	47,259 (96)	2.21 (2.204-2.39)	✓	✓	✓	
	Huisache¶	195,270	194,405 (99.6)	1,014.02	5,346 (2.7)	173,848 (89)	1.34 (1.23-1.45)	✓	✓	✓	
1,3-Butadiene	Oak Park	44,061	37,440 (85)	15.609	0 (0)	31,216 (71)	0.0485 (0.0456-0.0515)	✓	✓	✓	Yes
	Solar Estates	41,992	31,853 (76)	35.73	0 (0)	26,483 (63)	0.0536 (0.045-0.0622)	✓	✓	✓	
Ethylbenzene	Oak Park	44,043	33,631 (76)	5.42	0 (0)	1,694 (3.8)	0.0546 (0.0515-0.0576)				No
	Solar Estates	40,904	27,752 (68)	3.81	0 (0)	794 (1.9)	0.0462 (0.0442-0.0482)				
n-Hexane	Oak Park	44,044	38,455 (87)	196.289	0 (0)	1 (0.0023)	0.493 (0.45-0.536)				No
	Solar Estates	41,170	36,185 (88)	47.33	0 (0)	0 (0)	0.33 (0.314-0.345)				
Isoprene	Oak Park	38,833	30,325 (78)	2.329	0 (0)	1 (0.0026)	0.086 (0.0806-0.0914)				No
	Solar Estates	41,868	25,340 (61)	2.01	0 (0)	1 (0.0024)	0.0413 (0.039-0.0436)				

Table 11B. Auto GC (2005–2010) Refined Data Screening Results (page 2 of 4)

Chemical*	Location	Auto GC Data (2005–2010)									Is this Chemical of Potential Concern?
		Total Number of Samples	Number (and Percent) of Samples above DL	Maximum			Mean				
				Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV†	LCL above Long-term CV†	UCL above Long-term CV†	
Isopropylbenzene	Oak Park	44,040	12,040 (27)	53.99	0 (0)	1 (0.0023)	0.0358 (0.0307-0.0409)				No
	Solar Estates	40,859	11,759 (29)	88.69	0 (0)	1 (0.0024)	0.0258 (0.0202-0.0314)				
Methylcyclo-pentane	Oak Park	44,043	33,305 (76)	99.65	0 (0)	1 (0.0023)	0.224 (0.205-0.242)				No
	Solar Estates	40,738	30,890 (76)	15.47	0 (0)	0 (0)	0.179 (0.171-0.187)				
n-Nonane	Oak Park	44,041	27,392 (62)	7.209	0 (0)	10 (0.023)	0.0413 (0.0377-0.0448)				No
	Solar Estates	40,838	27,530 (67)	7.799	0 (0)	7 (0.017)	0.0631 (0.0586-0.0676)				
n-Pentane	Oak Park	44,066	44,055 (100)	501.38	0 (0)	3 (0.0068)	1.52 (1.37-1.66)				No
	Solar Estates	41,916	41,879 (100)	100.89	0 (0)	0 (0)	0.923 (0.88-0.965)				
1-Pentene	Oak Park	39,801	33,270 (84)	4.29	0 (0)	NA	0.0428 (0.0405-0.0452)	NA	NA	NA	Yes
	Solar Estates	40,707	20,718 (51)	5.74	0 (0)	NA	0.0305 (0.0294-0.0317)	NA	NA	NA	
c-2-Pentene	Oak Park	39,803	29,888 (75)	7.71	0 (0)	NA	0.0387 (0.0364-0.0411)	NA	NA	NA	Yes
	Solar Estates	41,536	14,752 (36)	1.43	0 (0)	NA	0.0287 (0.0278-0.0296)	NA	NA	NA	
t-2-Pentene	Oak Park	39,808	37,397 (94)	21.94	0 (0)	NA	0.0753 (0.0702-0.0805)	NA	NA	NA	Yes
	Solar Estates	41,966	23,374 (56)	3.21	0 (0)	NA	0.043 (0.0409-0.0451)	NA	NA	NA	

Table 11B. Auto GC (2005–2010) Refined Data Screening Results (page 3 of 4)

Chemical*	Location	Auto GC Data (2005–2010)									Is this Chemical of Potential Concern?
		Total Number of Samples	Number (and Percent) of Samples above DL	Maximum			Mean				
				Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV†	LCL above Long-term CV†	UCL above Long-term CV†	
Toluene	Oak Park	44,045	43,914 (100)	69.3	0 (0)	0 (0)	0.612 (0.571-0.654)				No
	Solar Estates	41,115	40,526 (99)	136.32	0 (0)	1 (0.0024)	0.319 (0.3-0.337)				
1,2,4-Trimethylbenzene	Oak Park	43,931	38,224 (87)	10.49	0 (0)	20 (0.046)	0.0634 (0.0599-0.0668)				No
	Solar Estates	39,818	32,721 (82)	3.74	0 (0)	16 (0.04)	0.0511 (0.0487-0.0535)				

Data sources:

Texas Commission on Environmental Quality. 2010. Data posted to FTP site by Melanie Hotchkiss, TCEQ, and downloaded by John Wilhelmi, Eastern Research Group, Inc. Contains continuous 2005-2009 sulfur compound and volatile organic compound data for both TCEQ and Corpus Christi Air Quality Project air monitoring sites. Austin, TX.

The University of Texas. 2011. April 25th email from Dr. David Sullivan, The University of Texas at Austin, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing an Excel attachment with the continuous 2010 volatile organic compounds data for the Solar Estates and Oak Park air monitoring sites. Austin, TX.

ToxStrategies, Inc. 2011. September 8th email from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005–2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

* Information for the chemicals 1-butene, c-2-butene, t-2-butene, ethane, and propane are not included in this table because ATSDR did not complete a public health evaluation of these chemicals in this document. See Appendix I for clarification.

† Blank cells indicate value is below the long-term comparison value.

✓ A check mark indicates value is above the long-term comparison value.

‡ The Huisache air monitoring station operated between 2003 and 2010. The benzene data presented in this row are for March 2005 through the end of 2010. ATSDR used this time frame because the Oak Park and Solar Estates air monitoring stations were not operating until March 2005. ATSDR wanted to keep the time periods the same.

§ The Huisache air monitoring station operated between 2003 and 2010. The benzene data presented in this row are pre-2005 data.

¶ The Huisache air monitoring station operated between 2003 and 2010. The benzene data presented in this row are for 2005–2010.

Table 11B. Auto GC (2005–2010) Refined Data Screening Results (page 4 of 4)

Auto GC	automatic gas chromatograph
CV	health-based comparison value
DL	detection limit
LCL	lower confidence limit
NA	not applicable
ppb	parts per billion
UCL	upper confidence limit

Table 12B. TCEQ Canisters (pre–2005) Refined Data Screening Results (page 1 of 9)

Chemical*	Location	TCEQ Canister Data (pre–2005)				Maximum			Mean				Is this Chemical of Potential Concern prior to 2005?
		Total Number of Samples	Time Period	Method Detection Limits† (ppb)	Number (and Percent) of Samples above MRL*	Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV‡	LCL above Long-term CV‡	UCL above Long-term CV‡	
Benzene	Dona Park	117	10/05/2002 - 12/31/2004	0.31 - .31	117 (100)	2.92	0 (0)	117 (100)	0.42 (0.37-0.49)	✓	✓	✓	Yes
	Hillcrest	452	11/01/1998 - 12/29/2004	0.31 - .31	452 (100)	12.05	2 (0.44)	452 (100)	0.79 (0.69-0.9)	✓	✓	✓	
	Huisache	1,223	10/26/1997 - 12/31/2004	0.31 - 0.5	1,223 (100)	28.54	28 (2.3)	1,223 (100)	2.1 (2-2.3)	✓	✓	✓	
	Navigation	508	01/01/1993 - 09/29/2002	0.08833 - 0.5	502 (99)	5.7	0 (0)	502 (99)	0.72 (0.66-0.79)	✓	✓	✓	
	Poth Lane	84	12/05/1996 - 10/02/1998	0.31 - 0.5	84 (100)	11.71	1 (1.2)	83 (99)	1.6 (1.3-2)	✓	✓	✓	
1,3-Butadiene	Dona Park	117	10/05/2002 - 12/31/2004	0.27 - 0.27	11 (9.4)	0.21	0 (0)	11 (9.4)	----				Yes
	Hillcrest	452	11/01/1998 - 12/29/2004	0.27 - 0.27	55 (12)	1.59	0 (0)	51 (11)	----				
	Huisache	1,223	10/26/1997 - 12/31/2004	0.27 - 0.63	300 (25)	0.81	0 (0)	289 (24)	0.033 (0.029-0.038)	✓	✓	✓	
	Navigation	493	01/01/1993 - 09/29/2002	0.1575 - 0.63	113 (23)	1.57	0 (0)	104 (21)	0.035 (0.025-0.045)	✓	✓	✓	
	Poth Lane	84	12/05/1996 - 10/02/1998	0.27 - 0.63	23 (27)	0.42	0 (0)	21 (25)	0.031 (0.017-0.046)	✓	✓	✓	
Carbon Tetrachloride	Dona Park	117	10/05/2002 - 12/31/2004	0.4 - 0.4	117 (100)	0.16	0 (0)	117 (100)	0.1 (0.099-0.1)	✓	✓	✓	Yes
	Hillcrest	452	11/01/1998 - 12/29/2004	0.4 - 0.4	350 (77)	0.44	0 (0)	342 (76)	0.079 (0.075-0.083)	✓	✓	✓	
	Huisache	1,223	10/26/1997 - 12/31/2004	0.4 - 0.45	998 (82)	0.45	0 (0)	969 (79)	0.079 (0.077-0.081)	✓	✓	✓	
	Navigation	474	01/07/1993 - 09/29/2002	0.4 - 0.45	352 (74)	4.96	0 (0)	348 (73)	0.097 (0.083-0.12)	✓	✓	✓	

Table 12B. TCEQ Canisters (pre–2005) Refined Data Screening Results (page 2 of 9)

Chemical*	Location	TCEQ Canister Data (pre–2005)											Is this Chemical of Potential Concern prior to 2005?
		Total Number of Samples	Time Period	Method Detection Limits† (ppb)	Number (and Percent) of Samples above MRL*	Maximum			Mean				
						Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV‡	LCL above Long-term CV‡	UCL above Long-term CV‡	
Carbon Tetrachloride (continued)	Poth Lane	84	12/05/1996 - 10/02/1998	0.4 - 0.45	77 (92)	0.22	0 (0)	77 (92)	0.093 (0.087-0.1)	✓	✓	✓	Yes
Chloroform	Dona Park	117	10/05/2002 - 12/31/2004	0.21 - 0.21	14 (12)	0.03	0 (0)	14 (12)	----				Yes
	Hillcrest	452	11/01/1998 - 12/29/2004	0.21 - 0.21	31 (6.9)	0.05	0 (0)	31 (6.9)	----				
	Huisache	1,223	10/26/1997 - 12/31/2004	0.21 - 0.64	173 (14)	0.18	0 (0)	173 (14)	----				
	Navigation	509	01/01/1993 - 09/29/2002	0.21 - 0.64	201 (39)	0.69	0 (0)	201 (39)	0.017 (0.014-0.019)	✓	✓	✓	
	Poth Lane	84	12/05/1996 - 10/02/1998	0.21 - 0.64	31 (37)	0.06	0 (0)	31 (37)	0.012 (0.0086-0.015)	✓		✓	
Chloroprene	Dona Park	117	10/05/2002 - 12/31/2004	0.2 - 0.2	0 (0)	ND	NA	NA	----				Yes
	Hillcrest	377	09/29/1999 - 12/29/2004	0.2 - 0.2	0 (0)	ND	NA	NA	----				
	Huisache	978	10/03/1999 - 12/31/2004	0.2 - 0.2	1 (0.1)	0.06	0 (0)	1 (0.1)	----				
	Navigation	161	10/03/1999 - 09/29/2002	0.2 - 0.2	0 (0)	ND	NA	NA	----				
Cyclohexane	Dona Park	117	10/05/2002 - 12/31/2004	0.24 - 0.24	41 (35)	1.47	0 (0)	0 (0)	0.11 (0.077-0.14)				No
	Hillcrest	452	11/01/1998 - 12/29/2004	0.24 - 0.24	259 (57)	259.8	0 (0)	1 (0.22)	1.7 (0.82-3.1)				
	Huisache	1,223	10/26/1997 - 12/31/2004	0.24 - 1.06	887 (73)	28.71	0 (0)	0 (0)	1.2 (1.1-1.4)				
	Navigation	416	10/05/1994 - 09/29/2002	0.24 - 1.06	270 (65)	27.1	0 (0)	0 (0)	0.28 (0.19-0.44)				

Table 12B. TCEQ Canisters (pre–2005) Refined Data Screening Results (page 3 of 9)

Chemical*	Location	TCEQ Canister Data (pre–2005)											Is this Chemical of Potential Concern prior to 2005?
		Total Number of Samples	Time Period	Method Detection Limits† (ppb)	Number (and Percent) of Samples above MRL*	Maximum			Mean				
						Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV‡	LCL above Long-term CV‡	UCL above Long-term CV‡	
Cyclohexane (continued)	Poth Lane	84	12/05/1996 - 10/02/1998	0.24 - 1.06	63 (75)	3.18	0 (0)	0 (0)	0.49 (0.36-0.63)				No
1,2-Dibromoethane	Dona Park	117	10/05/2002 - 12/31/2004	0.2 - 0.2	1 (0.85)	0.01	0 (0)	1 (0.85)	----				Yes
	Hillcrest	293	10/13/2000 - 12/29/2004	0.2 - 0.49	0 (0)	ND	NA	NA	----				
	Huisache	818	10/15/2000 - 12/31/2004	0.2 - 0.49	4 (0.49)	0.06	0 (0)	4 (0.49)	----				
	Navigation	104	11/02/2000 - 09/29/2002	0.2 - 0.49	0 (0)	ND	NA	NA	----				
1,1-Dichloroethane	Dona Park	6	10/05/2002 - 12/31/2004	0.19 - 0.19	0 (0)	ND	NA	NA	----				No
	Hillcrest	301	11/01/1998 - 12/29/2004	0.19 - 0.19	0 (0)	ND	NA	NA	----				
	Huisache	823	10/26/1997 - 12/31/2004	0.16 - 0.19	3 (0.36)	0.08	0 (0)	0 (0)	----				
	Navigation	450	02/01/1994 - 09/29/2002	0.1 - 0.19	8 (1.8)	0.67	0 (0)	1 (0.22)	----				
	Poth Lane	84	12/05/1996 - 10/02/1998	0.16 - 0.19	0 (0)	ND	NA	NA	----				
1,2-Dichloroethane	Dona Park	117	10/05/2002 - 12/31/2004	0.35 - 0.35	9 (7.7)	0.03	0 (0)	9 (7.7)	----				Yes
	Hillcrest	452	11/01/1998 - 12/29/2004	0.35 - 0.35	27 (6)	0.17	0 (0)	27 (6)	----				
	Huisache	1,223	10/26/1997 - 12/31/2004	0.35 - 0.52	56 (4.6)	0.16	0 (0)	56 (4.6)	----				
	Navigation	509	01/01/1993 - 09/29/2002	0.26 - 0.52	79 (16)	0.67	0 (0)	79 (16)	----				
	Poth Lane	84	12/05/1996 - 10/02/1998	0.35 - 0.52	2 (2.4)	0.09	0 (0)	2 (2.4)	----				

Table 12B. TCEQ Canisters (pre–2005) Refined Data Screening Results (page 4 of 9)

Chemical*	Location	TCEQ Canister Data (pre–2005)				Maximum			Mean				Is this Chemical of Potential Concern prior to 2005?
		Total Number of Samples	Time Period	Method Detection Limits† (ppb)	Number (and Percent) of Samples above MRL*	Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV‡	LCL above Long-term CV‡	UCL above Long-term CV‡	
1,2-Dichloropropane	Dona Park	117	10/05/2002 - 12/31/2004	0.17 - 0.17	0 (0)	ND	NA	NA	----				Yes
	Hillcrest	452	11/01/1998 - 12/29/2004	0.17 - 0.17	1 (0.22)	0.02	0 (0)	0 (0)	----				
	Huisache	1,223	10/26/1997 - 12/31/2004	0.17 - 0.25	3 (0.25)	0.07	0 (0)	2 (0.16)	----				
	Navigation	509	01/01/1993 - 09/29/2002	0.08333 - 0.25	4 (0.79)	0.95	0 (0)	4 (0.79)	----				
	Poth Lane	84	12/05/1996 - 10/02/1998	0.17 - 0.25	0 (0)	ND	NA	NA	----				
Ethylbenzene	Dona Park	117	10/05/2002 - 12/31/2004	0.32 - 0.32	66 (56)	0.25	0 (0)	1 (0.85)	0.041 (0.032-0.05)				No
	Hillcrest	452	11/01/1998 - 12/29/2004	0.32 - 0.32	314 (69)	6.65	0 (0)	62 (14)	0.12 (0.092-0.16)				
	Huisache	1,223	10/26/1997 - 12/31/2004	0.32 - 1.07	980 (80)	9.21	0 (0)	293 (24)	0.17 (0.15-0.19)				
	Navigation	509	01/01/1993 - 09/29/2002	0.0825 - 1.07	414 (81)	3.66	0 (0)	95 (19)	0.16 (0.14-0.19)				
	Poth Lane	84	12/05/1996 - 10/02/1998	0.32 - 1.07	77 (92)	0.65	0 (0)	12 (14)	0.12 (0.096-0.14)				
2-Methyl-2-Butene	Dona Park	117	10/05/2002 - 12/31/2004	0.23 - 0.23	18 (15)	0.52	0 (0)	NA	----	NA	NA	NA	Yes
	Hillcrest	452	11/01/1998 - 12/29/2004	0.23 - 0.23	249 (55)	11.34	0 (0)	NA	0.49 (0.38-0.61)	NA	NA	NA	
	Huisache	1,223	10/26/1997 - 12/31/2004	0.23 - 0.4	940 (77)	39.18	0 (0)	NA	0.95 (0.82-1.1)	NA	NA	NA	
	Navigation	416	10/05/1994 - 09/29/2002	0.23 - 0.4	301 (72)	4.92	0 (0)	NA	0.23 (0.2-0.26)	NA	NA	NA	
	Poth Lane	84	12/05/1996 - 10/02/1998	0.23 - 0.4	78 (93)	8.88	0 (0)	NA	0.7 (0.48-1)	NA	NA	NA	

Table 12B. TCEQ Canisters (pre–2005) Refined Data Screening Results (page 5 of 9)

Chemical*	Location	TCEQ Canister Data (pre–2005)											Is this Chemical of Potential Concern prior to 2005?
		Total Number of Samples	Time Period	Method Detection Limits† (ppb)	Number (and Percent) of Samples above MRL*	Maximum			Mean				
						Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV‡	LCL above Long-term CV‡	UCL above Long-term CV‡	
Methyl Butyl Ketone (MBK) (2-Hexanone)	Dona Park	58	01/04/2004 - 12/31/2004	1 - 1	2 (3.4)	0.05	0 (0)	0 (0)	----				No
	Hillcrest	73	01/04/2004 - 12/29/2004	1 - 1	6 (8.2)	0.13	0 (0)	0 (0)	----				
	Huisache	176	01/01/2004 - 12/31/2004	1 - 1	7 (4)	0.03	0 (0)	0 (0)	----				
Methyl t-Butyl ether	Dona Park	117	10/05/2002 - 12/31/2004	1.42 - 1.42	75 (64)	3.27	0 (0)	1 (0.85)	0.079 (0.034-0.15)				No
	Hillcrest	452	11/01/1998 - 12/29/2004	1.42 - 1.42	312 (69)	22.8	0 (0)	21 (4.6)	0.66 (0.53-0.82)				
	Huisache	1,223	10/26/1997 - 12/31/2004	1.42 - 1.42	908 (74)	33.65	0 (0)	36 (2.9)	0.5 (0.41-0.61)				
	Navigation	277	07/03/1997 - 09/29/2002	1.42 - 1.42	178 (64)	4.09	0 (0)	2 (0.72)	0.18 (0.13-0.23)				
	Poth Lane	56	07/03/1997 - 10/02/1998	1.42 - 1.42	32 (57)	10.65	0 (0)	8 (14)	1.1 (0.56-1.7)				
Methylene Chloride (Dichloromethane)	Dona Park	117	10/05/2002 - 12/31/2004	0.14 - 0.14	26 (22)	0.17	0 (0)	0 (0)	0.022 (0.015-0.031)				No
	Hillcrest	452	11/01/1998 - 12/29/2004	0.14 - 0.14	57 (13)	0.59	0 (0)	0 (0)	----				
	Huisache	1,223	10/26/1997 - 12/31/2004	0.14 - 0.4	264 (22)	4.88	0 (0)	0 (0)	0.032 (0.025-0.043)				
	Navigation	509	01/01/1993 - 09/29/2002	0.14 - 0.4	144 (28)	9.16	0 (0)	0 (0)	0.076 (0.044-0.12)				
	Poth Lane	84	12/05/1996 - 10/02/1998	0.14 - 0.4	47 (56)	4.68	0 (0)	0 (0)	0.11 (0.047-0.22)				
1-Pentene	Dona Park	117	10/05/2002 - 12/31/2004	0.6 - 0.6	29 (25)	0.33	0 (0)	NA	0.018 (0.011-0.026)	NA	NA	NA	Yes

Table 12B. TCEQ Canisters (pre–2005) Refined Data Screening Results (page 6 of 9)

Chemical*	Location	TCEQ Canister Data (pre–2005)											Is this Chemical of Potential Concern prior to 2005?
		Total Number of Samples	Time Period	Method Detection Limits† (ppb)	Number (and Percent) of Samples above MRL*	Maximum			Mean				
						Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV‡	LCL above Long-term CV‡	UCL above Long-term CV‡	
1-Pentene (continued)	Hillcrest	452	11/01/1998 - 12/29/2004	0.6 - 0.6	263 (58)	3.52	0 (0)	NA	0.2 (0.17-0.24)	NA	NA	NA	Yes
	Huisache	1,223	10/26/1997 - 12/31/2004	0.31 - 0.6	943 (77)	21.5	0 (0)	NA	0.48 (0.42-0.56)	NA	NA	NA	
	Navigation	416	10/05/1994 - 09/29/2002	0.31 - 0.6	248 (60)	1.31	0 (0)	NA	0.11 (0.094-0.13)	NA	NA	NA	
	Poth Lane	84	12/05/1996 - 10/02/1998	0.31 - 0.6	64 (76)	3.65	0 (0)	NA	0.33 (0.25-0.44)	NA	NA	NA	
c-2-Pentene	Dona Park	117	10/05/2002 - 12/31/2004	0.25 - 0.25	7 (6)	0.26	0 (0)	NA	----	NA	NA	NA	Yes
	Hillcrest	452	11/01/1998 - 12/29/2004	0.25 - 0.25	169 (37)	4.05	0 (0)	NA	0.18 (0.15-0.23)	NA	NA	NA	
	Huisache	1,223	10/26/1997 - 12/31/2004	0.25 - 0.4	772 (63)	15.85	0 (0)	NA	0.38 (0.33-0.43)	NA	NA	NA	
	Navigation	416	10/05/1994 - 09/29/2002	0.25 - 0.4	235 (56)	4.91	0 (0)	NA	0.13 (0.1-0.16)	NA	NA	NA	
	Poth Lane	84	12/05/1996 - 10/02/1998	0.25 - 0.4	73 (87)	3.74	0 (0)	NA	0.28 (0.2-0.41)	NA	NA	NA	
t-2-Pentene	Dona Park	117	10/05/2002 - 12/31/2004	0.76 - 0.76	19 (16)	0.44	0 (0)	NA	----	NA	NA	NA	Yes
	Hillcrest	452	11/01/1998 - 12/29/2004	0.76 - 0.76	244 (54)	8.7	0 (0)	NA	0.36 (0.29-0.44)	NA	NA	NA	
	Huisache	1,223	10/26/1997 - 12/31/2004	0.76 - 0.76	917 (75)	31.07	0 (0)	NA	0.73 (0.64-0.84)	NA	NA	NA	
	Navigation	416	10/05/1994 - 09/29/2002	0.08 - 0.76	287 (69)	2.99	0 (0)	NA	0.18 (0.15-0.2)	NA	NA	NA	
	Poth Lane	84	12/05/1996 - 10/02/1998	0.14 - 0.76	77 (92)	6.74	0 (0)	NA	0.54 (0.38-0.74)	NA	NA	NA	
1,1,2,2-Tetrachloroethane	Dona Park	117	10/05/2002 - 12/31/2004	0.2 - 0.2	2 (1.7)	0.06	0 (0)	2 (1.7)	----				Yes

Table 12B. TCEQ Canisters (pre–2005) Refined Data Screening Results (page 7 of 9)

Chemical*	Location	TCEQ Canister Data (pre–2005)											Is this Chemical of Potential Concern prior to 2005?
						Maximum			Mean				
		Total Number of Samples	Time Period	Method Detection Limits† (ppb)	Number (and Percent) of Samples above MRL*	Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV‡	LCL above Long-term CV‡	UCL above Long-term CV‡	
1,1,2,2-Tetrachloroethane (continued)	Hillcrest	293	10/13/2000 - 12/29/2004	0.2 - 0.2	0 (0)	ND	NA	NA	----				Yes
	Huisache	818	10/15/2000 - 12/31/2004	0.2 - 0.2	4 (0.49)	0.07	0 (0)	4 (0.49)	----				
	Navigation	104	11/02/2000 - 09/29/2002	0.2 - 0.2	0 (0)	ND	NA	NA	----				
Tetrachloroethylene	Dona Park	116	10/05/2002 - 12/31/2004	0.24 - 0.24	11 (9.5)	0.1	0 (0)	0 (0)	----				No
	Hillcrest	450	11/01/1998 - 12/29/2004	0.24 - 0.24	40 (8.9)	0.19	0 (0)	0 (0)	----				
	Huisache	1,221	10/26/1997 - 12/31/2004	0.24 - 0.61	130 (11)	0.24	0 (0)	0 (0)	----				
	Navigation	509	01/01/1993 - 09/29/2002	0.24 - 0.61	165 (32)	0.61	0 (0)	1 (0.2)	0.022 (0.018-0.026)				
	Poth Lane	84	12/05/1996 - 10/02/1998	0.24 - 0.61	20 (24)	0.15	0 (0)	0 (0)	0.0099 (0.0058-0.015)				
1,1,2-Trichloroethane	Dona Park	117	10/05/2002 - 12/31/2004	0.21 - 0.21	0 (0)	ND	NA	NA	----				Yes
	Hillcrest	452	11/01/1998 - 12/29/2004	0.21 - 0.21	0 (0)	ND	NA	NA	----				
	Huisache	1,223	10/26/1997 - 12/31/2004	0.18 - 0.21	3 (0.25)	0.07	0 (0)	3 (0.25)	----				
	Navigation	387	04/03/1995 - 09/29/2002	0.18 - 0.21	1 (0.26)	0.68	0 (0)	1 (0.26)	----				
	Poth Lane	84	12/05/1996 - 10/02/1998	0.18 - 0.21	0 (0)	ND	NA	NA	----				
Trichloroethylene	Dona Park	117	10/05/2002 - 12/31/2004	0.29 - 0.29	2 (1.7)	0.05	0 (0)	1 (0.85)	----				Yes
	Hillcrest	452	11/01/1998 - 12/29/2004	0.29 - 0.29	17 (3.8)	0.11	0 (0)	7 (1.5)	----				

Table 12B. TCEQ Canisters (pre–2005) Refined Data Screening Results (page 8 of 9)

Chemical*	Location	TCEQ Canister Data (pre–2005)											Is this Chemical of Potential Concern prior to 2005?
		Total Number of Samples	Time Period	Method Detection Limits† (ppb)	Number (and Percent) of Samples above MRL*	Maximum			Mean				
						Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV‡	LCL above Long-term CV‡	UCL above Long-term CV‡	
Trichloroethylene (continued)	Huisache	1,222	10/26/1997 - 12/31/2004	0.29 - 0.6	98 (8)	4.15	0 (0)	45 (3.7)	----				Yes
	Navigation	509	01/01/1993 - 09/29/2002	0.29 - 0.6	143 (28)	12.76	0 (0)	53 (10)	0.055 (0.022-0.11)	✓		✓	
	Poth Lane	84	12/05/1996 - 10/02/1998	0.29 - 0.6	14 (17)	0.09	0 (0)	3 (3.6)	----				
1,2,4-Trimethylbenzene	Dona Park	117	10/05/2002 - 12/31/2004	0.31 - 0.31	48 (41)	0.19	0 (0)	0 (0)	0.025 (0.019-0.032)				No
	Hillcrest	452	11/01/1998 - 12/29/2004	0.31 - 0.31	272 (60)	8.36	0 (0)	2 (0.44)	0.13 (0.01-0.18)				
	Huisache	1,223	10/26/1997 - 12/31/2004	0.31 - 1.42	895 (73)	15.75	0 (0)	13 (1.1)	0.16 (0.14-0.2)				
	Navigation	416	10/05/1994 - 09/29/2002	0.31 - 1.42	299 (72)	1.56	0 (0)	1 (0.24)	0.13 (0.11-0.15)				
	Poth Lane	84	12/05/1996 - 10/02/1998	0.31 - 1.42	76 (90)	1.04	0 (0)	0 (0)	0.15 (0.12-0.18)				
Vinyl Chloride	Dona Park	117	10/05/2002 - 12/31/2004	0.17 - 0.17	1 (0.85)	0.02	0 (0)	0 (0)	----				Yes
	Hillcrest	452	11/01/1998 - 12/29/2004	0.17 - 0.17	3 (0.66)	0.01	0 (0)	0 (0)	----				
	Huisache	1,223	10/26/1997 - 12/31/2004	0.17 - 0.45	17 (1.4)	0.67	0 (0)	10 (0.82)	----				
	Navigation	509	01/01/1993 - 09/29/2002	0.17 - 0.45	23 (4.5)	0.72	0 (0)	6 (1.2)	----				
	Poth Lane	84	12/05/1996 - 10/02/1998	0.17 - 0.45	9 (11)	0.11	0 (0)	5(6)	----				

Data source: Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) web interface. Data downloaded from TAMIS through three separate queries performed with the target list 'Canister Parameters' group, 24-hour concentrations for dates within the range >=1/1/1990 to <1/1/2011 for monitors in the Corpus Christi area. Data queried on 29 May 2013.

Table 12B. TCEQ Canisters (pre–2005) Refined Data Screening Results (page 9 of 9)

* Information for the chemicals 1-butene, c-2-butene, t-2-butene, ethane, and propane are not included in this table because ATSDR did not complete a public health evaluation of these chemicals in this document. See Appendix I for clarification.

† There are two types of data limits: the method detection limit (MDL) and the method reporting limit (MRL). The MRL is 0.01 ppb and is the value below which the instrument is not capable of measuring and reporting a value, and is considered nondetect. Any value less than the MDL but above the MRL represents a value in which there is less than 99% confidence that the value is greater than background (or zero), representing a qualified value.

‡ Blank cells indicate mean, LCL, and UCL values are either below the long-term comparison value, or no mean, LCL, and UCL values could be calculated for comparison.

✓ A check mark indicates value is above the long-term comparison value.

--- A mean, lower confidence limit, and upper confidence limit could not be calculated because the detection rate was ≤20%.

CV health-based comparison value
LCL lower confidence limit
MRL method reporting limit
NA not applicable
ND not detected
ppb parts per billion
UCL upper confidence limit

Table 13B. TCEQ Canisters (2005–2010) Refined Data Screening Results (page 1 of 6)

Chemical*	Location	TCEQ Canister Data (2005–2010)											Is this Chemical of Potential Concern for 2005–2010?
		Total Number of Samples	Time Period	Method Detection Limits† (ppb)	Number (and Percent) of Samples above MRL*	Maximum			Mean				
						Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV‡	LCL above Long-term CV‡	UCL above Long-term CV‡	
Benzene	Dona Park	348	01/06/2005 - 12/28/2010	0.27 - 0.31	348 (100)	10.96	1 (0.29)	348 (100)	0.43 (0.36-0.5)	✓	✓	✓	Yes
	Hillcrest	483	01/04/2005 - 12/28/2010	0.27 - 0.31	483 (100)	40.32	2 (0.41)	483 (100)	0.63 (0.5-0.84)	✓	✓	✓	
	Huisache	438	01/02/2005 - 12/28/2010	0.27 - 0.31	438 (100)	9.86	3 (0.68)	438 (100)	1.4 (1.3-1.5)	✓	✓	✓	
1,3-Butadiene	Dona Park	348	01/06/2005 - 12/28/2010	0.27 - 0.27	38 (11)	2.93	0 (0)	35 (10)	----				Yes
	Hillcrest	483	01/04/2005 - 12/28/2010	0.27 - 0.27	59 (12)	0.14	0 (0)	49 (10)	----				
	Huisache	438	01/02/2005 - 12/28/2010	0.27 - 0.27	96 (22)	0.44	0 (0)	90 (21)	0.017 (0.014-0.021)	✓		✓	
Carbon Tetrachloride	Dona Park	348	01/06/2005 - 12/28/2010	0.27 - 0.4	348 (100)	0.15	0 (0)	348 (100)	0.099 (0.097-0.1)	✓	✓	✓	Yes
	Hillcrest	483	01/04/2005 - 12/28/2010	0.27 - 0.4	483 (100)	0.23	0 (0)	482 (100)	0.097 (0.096-0.099)	✓	✓	✓	
	Huisache	438	01/02/2005 - 12/28/2010	0.27 - 0.4	437 (100)	0.17	0 (0)	436 (100)	0.097 (0.095-0.098)	✓	✓	✓	
Chloroform	Dona Park	348	01/06/2005 - 12/28/2010	0.21 - 0.21	194 (56)	0.04	0 (0)	194 (56)	0.012 (0.011-0.013)	✓	✓	✓	Yes
	Hillcrest	483	01/04/2005 - 12/28/2010	0.21 - 0.21	269 (56)	0.14	0 (0)	269 (56)	0.013 (0.012-0.014)	✓	✓	✓	
	Huisache	438	01/02/2005 - 12/28/2010	0.21 - 0.21	210 (48)	0.05	0 (0)	210 (48)	0.012 (0.011-0.014)	✓	✓	✓	
Chloroprene	Dona Park	57	01/06/2005 - 12/24/2005	0.2 - 0.2	1 (1.8)	0.01	0(0)	1 (1.8)	----				Yes
	Hillcrest	77	01/04/2005 - 12/30/2005	0.2 - 0.2	0 (0)	ND	NA	NA	----				

Table 13B. TCEQ Canisters (2005–2010) Refined Data Screening Results (page 2 of 6)

*Chemical**	*Location*	*TCEQ Canister Data (2005–2010)*											*Is this Chemical of Potential Concern for 2005–2010?*
		Total Number of Samples	*Time Period*	*Method Detection Limits*[†] *(ppb)*	*Number (and Percent) of Samples above MRL**	*Maximum*			*Mean*				
						Level (ppb)	*Number (and Percent) of Samples above Short-term CV*	*Number (and Percent) of Samples above Long-term CV*	*Level (LCL–UCL) (ppb)*	*Mean above Long-term CV*[‡]	*LCL above Long-term CV*[‡]	*UCL above Long-term CV*[‡]	
Chloroprene (continued)	Huisache	150	01/02/2005 - 12/30/2005	0.2 - 0.2	0 (0)	ND	NA	NA	----				Yes
Cyclohexane	Dona Park	348	01/06/2005 - 12/28/2010	0.24 - 0.24	198 (57)	1.63	0 (0)	0 (0)	0.16 (0.14-0.18)				No
	Hillcrest	483	01/04/2005 - 12/28/2010	0.24 - 0.24	239 (49)	14.26	0 (0)	0 (0)	0.25 (0.19-0.35)				
	Huisache	438	01/02/2005 - 12/28/2010	0.24 - 0.24	298 (68)	16.72	0 (0)	0 (0)	0.58 (0.47-0.72)				
1,2-Dibromoethane	Dona Park	348	01/06/2005 - 12/28/2010	0.2 - 0.2	6 (1.7)	0.01	0 (0)	6 (1.7)	----				Yes
	Hillcrest	483	01/04/2005 - 12/28/2010	0.2 - 0.2	20 (4.1)	0.18	0 (0)	20 (4.1)	----				
	Huisache	438	01/02/2005 - 12/28/2010	0.2 - 0.2	20 (4.6)	0.1	0 (0)	20 (4.6)	----				
1,1-Dichloroethane	Dona Park	348	01/06/2005 - 12/28/2010	0.19 - 0.19	4 (1.1)	0.02	0 (0)	0 (0)	----				No
	Hillcrest	483	01/04/2005 - 12/28/2010	0.19 - 0.19	16 (3.3)	0.09	0 (0)	0 (0)	----				
	Huisache	438	01/02/2005 - 12/28/2010	0.19 - 0.19	10 (2.3)	0.03	0 (0)	0 (0)	----				
1,2-Dichloroethane	Dona Park	348	01/06/2005 - 12/28/2010	0.27 - 0.35	92 (26)	0.06	0 (0)	92 (26)	0.0091 (0.0077-0.011)			✓	Yes
	Hillcrest	483	01/04/2005 - 12/28/2010	0.27 - 0.35	143 (30)	0.15	0 (0)	143 (30)	0.011 (0.0091-0.012)	✓		✓	
	Huisache	438	01/02/2005 - 12/28/2010	0.27 - 0.35	113 (26)	0.09	0 (0)	113 (26)	0.0093 (0.0079-0.011)			✓	
1,2-Dichloropropane	Dona Park	348	01/06/2005 - 12/28/2010	0.17 - 0.17	20 (5.7)	0.27	0 (0)	4 (1.1)	----				Yes
	Hillcrest	483	01/04/2005 - 12/28/2010	0.17 - 0.17	35 (7.2)	0.76	0 (0)	17 (3.5)	----				

Table 13B. TCEQ Canisters (2005–2010) Refined Data Screening Results (page 3 of 6)

Chemical*	***Location***	***TCEQ Canister Data (2005–2010)***												***Is this Chemical of Potential Concern for 2005–2010?***
						Maximum			***Mean***					
		Total Number of Samples	***Time Period***	***Method Detection Limits† (ppb)***	***Number (and Percent) of Samples above MRL****	***Level (ppb)***	***Number (and Percent) of Samples above Short-term CV***	***Number (and Percent) of Samples above Long-term CV***	***Level (LCL–UCL) (ppb)***	***Mean above Long-term CV‡***	***LCL above Long-term CV‡***	***UCL above Long-term CV‡***		
1,2-Dichloropropane (continued)	Huisache	438	01/02/2005 - 12/28/2010	0.17 - 0.17	10 (2.3)	0.23	0 (0)	5 (1.1)	----					Yes
Ethylbenzene	Dona Park	348	01/06/2005 - 12/28/2010	0.27 - 0.32	265 (76)	0.39	0 (0)	4 (1.1)	0.046 (0.041-0.052)					No
	Hillcrest	483	01/04/2005 - 12/28/2010	0.27 - 0.32	376 (78)	0.83	0 (0)	19 (3.9)	0.06 (0.053-0.067)					
	Huisache	438	01/02/2005 - 12/28/2010	0.27 - 0.32	371 (85)	0.84	0 (0)	61 (14)	0.11 (0.099-0.12)					
2-Methyl-2-Butene	Dona Park	348	01/06/2005 - 12/28/2010	0.23 - 0.23	121 (35)	0.62	0 (0)	NA	0.018 (0.014-0.023)	NA	NA	NA		Yes
	Hillcrest	483	01/04/2005 - 12/28/2010	0.23 - 0.23	238 (49)	1.65	0 (0)	NA	0.083 (0.066-0.1)	NA	NA	NA		
	Huisache	438	01/02/2005 - 12/28/2010	0.23 - 0.23	328 (75)	14.14	0 (0)	NA	0.28 (0.22-0.36)	NA	NA	NA		
Methyl Butyl Ketone (MBK) (2-Hexanone)	Dona Park	200	01/06/2005 - 05/30/2008	1 - 1	0 (0)	ND	NA	NA	----					No
	Hillcrest	256	01/04/2005 - 05/30/2008	1 - 1	1 (0.39)	1.31	0 (0)	1 (0.39)	----					
	Huisache	290	01/02/2005 - 05/30/2008	1 - 1	4 (1.4)	0.21	0 (0)	0 (0)	----					
Methyl t-Butyl ether	Dona Park	200	01/06/2005 - 05/30/2008	1.42 - 1.42	27 (14)	0.63	0 (0)	0 (0)	----					No
	Hillcrest	256	01/04/2005 - 05/30/2008	1.42 - 1.42	48 (19)	1.65	0 (0)	0 (0)	----					
	Huisache	290	01/02/2005 - 05/30/2008	1.42 - 1.42	142 (49)	2.2	0 (0)	0 (0)	0.11 (0.082-0.14)					
Methylene Chloride (Dichloromethane)	Dona Park	348	01/06/2005 - 12/28/2010	0.14 - 0.14	211 (61)	0.19	0 (0)	0 (0)	0.044 (0.041-0.046)					No
	Hillcrest	483	01/04/2005 - 12/28/2010	0.14 - 0.14	282 (58)	93.08	0 (0)	1 (0.21)	0.22 (0.036-0.62)					

Table 13B. TCEQ Canisters (2005–2010) Refined Data Screening Results (page 4 of 6)

Chemical*	Location	TCEQ Canister Data (2005–2010)											Is this Chemical of Potential Concern for 2005–2010?
		Total Number of Samples	Time Period	Method Detection Limits† (ppb)	Number (and Percent) of Samples above MRL*	Maximum			Mean				
						Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV‡	LCL above Long-term CV‡	UCL above Long-term CV‡	
Methylene Chloride (continued)	Huisache	438	01/02/2005 - 12/28/2010	0.14 - 0.14	224 (51)	0.15	0 (0)	0 (0)	0.034 (0.032-0.037)				No
1-Pentene	Dona Park	348	01/06/2005 - 12/28/2010	0.27 - 0.6	74 (21)	0.68	0 (0)	NA	0.014 (0.0097-0.019)	NA	NA	NA	Yes
	Hillcrest	483	01/04/2005 - 12/28/2010	0.27 - 0.6	129 (27)	0.94	0 (0)	NA	0.049 (0.037-0.062)	NA	NA	NA	
	Huisache	438	01/02/2005 - 12/28/2010	0.27 - 0.6	245 (56)	5.97	0 (0)	NA	0.16 (0.13-0.2)	NA	NA	NA	
c-2-Pentene	Dona Park	348	01/06/2005 - 12/28/2010	0.25 - 0.25	84 (24)	0.34	0 (0)	NA	0.0098 (0.0076-0.013)	NA	NA	NA	Yes
	Hillcrest	483	01/04/2005 - 12/28/2010	0.25 - 0.25	175 (36)	0.72	0 (0)	NA	0.039 (0.031-0.049)	NA	NA	NA	
	Huisache	438	01/02/2005 - 12/28/2010	0.25 - 0.25	240 (55)	5.12	0 (0)	NA	0.13 (0.1-0.16)	NA	NA	NA	
t-2-Pentene	Dona Park	348	01/06/2005 - 12/28/2010	0.27 - 0.76	127 (36)	0.59	0 (0)	NA	0.021 (0.017-0.026)	NA	NA	NA	Yes
	Hillcrest	483	01/04/2005 - 12/28/2010	0.27 - 0.76	248 (51)	1.26	0 (0)	NA	0.081 (0.065-0.098)	NA	NA	NA	
	Huisache	438	01/02/2005 - 12/28/2010	0.27 - 0.76	318 (73)	9.18	0 (0)	NA	0.26 (0.21-0.32)	NA	NA	NA	
1,1,2,2-Tetrachloroethane	Dona Park	348	01/06/2005 - 12/28/2010	0.2 - 0.2	19 (5.5)	0.02	0 (0)	19 (5.5)	----				Yes
	Hillcrest	483	01/04/2005 - 12/28/2010	0.2 - 0.2	26 (5.4)	0.02	0 (0)	26 (5.4)	----				
	Huisache	438	01/02/2005 - 12/28/2010	0.2 - 0.2	21 (4.8)	0.05	0 (0)	21 (4.8)	----				
Tetrachloroethylene	Dona Park	348	01/06/2005 - 12/28/2010	0.24 - 0.24	134 (39)	0.06	0 (0)	0 (0)	0.0087 (0.0079-0.0095)				No
	Hillcrest	483	01/04/2005 - 12/28/2010	0.24 - 0.24	134 (28)	1.88	0 (0)	1 (0.21)	0.011 (0.0065-0.018)				

Table 13B. TCEQ Canisters (2005–2010) Refined Data Screening Results (page 5 of 6)

Chemical*	Location	TCEQ Canister Data (2005–2010)				Maximum			Mean				Is this Chemical of Potential Concern for 2005–2010?
		Total Number of Samples	Time Period	Method Detection Limits† (ppb)	Number (and Percent) of Samples above MRL*	Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV‡	LCL above Long-term CV‡	UCL above Long-term CV‡	
Tetrachloroethylene (continued)	Huisache	438	01/02/2005 - 12/28/2010	0.24 - 0.24	110 (25)	0.05	0 (0)	0 (0)	0.0065 (0.0058-0.0072)				No
1,1,2-Trichloroethane	Dona Park	348	01/06/2005 - 12/28/2010	0.21 - 0.21	5 (1.4)	0.07	0 (0)	1 (0.29)	----				Yes
	Hillcrest	483	01/04/2005 - 12/28/2010	0.21 - 0.21	11 (2.3)	0.1	0 (0)	2 (0.41)	----				
	Huisache	438	01/02/2005 - 12/28/2010	0.21 - 0.21	6 (1.4)	0.03	0 (0)	2 (0.46)	----				
Trichloroethylene	Dona Park	348	01/06/2005 - 12/28/2010	0.29 - 0.29	60 (17)	0.05	0 (0)	3 (0.86)	----				Yes
	Hillcrest	483	01/04/2005 - 12/28/2010	0.29 - 0.29	84 (17)	0.55	0 (0)	13 (2.7)	----				
	Huisache	438	01/02/2005 - 12/28/2010	0.29 - 0.29	79 (18)	0.16	0 (0)	13 (3)	----				
1,2,4-Trimethylbenzene	Dona Park	348	01/06/2005 - 12/28/2010	0.27 - 0.31	183 (53)	0.35	0 (0)	0 (0)	0.026 (0.022-0.03)				No
	Hillcrest	483	01/04/2005 - 12/28/2010	0.27 - 0.31	298 (62)	0.45	0 (0)	0 (0)	0.039 (0.034-0.044)				
	Huisache	438	01/02/2005 - 12/28/2010	0.27 - 0.31	316 (72)	0.67	0 (0)	0 (0)	0.054 (0.048-0.06)				
Vinyl Chloride	Dona Park	348	01/06/2005 - 12/28/2010	0.17 - 0.17	24 (6.9)	0.14	0 (0)	2 (0.57)	----				Yes
	Hillcrest	483	01/04/2005 - 12/28/2010	0.17 - 0.17	51 (11)	0.64	0 (0)	5 (1)	----				
	Huisache	438	01/02/2005 - 12/28/2010	0.17 - 0.17	29 (6.6)	0.29	0 (0)	5 (1.1)	----				

Data source: Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) web interface. Data downloaded from TAMIS through three separate queries performed with the target list 'Canister Parameters' group, 24-hour concentrations for dates within the range >=1/1/1990 to <1/1/2011 for monitors in the Corpus Christi area. Data queried on 29 May 2013.

Table 13B. TCEQ Canisters (2005–2010) Refined Data Screening Results (page 6 of 6)

* Information for the chemicals 1-butene, c-2-butene, t-2-butene, ethane, and propane are not included in this table because ATSDR did not complete a public health evaluation of these chemicals in this document. See Appendix I for clarification.

† There are two types of data limits: the method detection limit (MDL) and the method reporting limit (MRL). The MRL is 0.01 ppb and is the value below which the instrument is not capable of measuring and reporting a value, and is considered nondetect. Any value less than the MDL but above the MRL represents a value in which there is less than 99% confidence that the value is greater than background (or zero), representing a qualified value.

‡ Blank cells indicate mean, LCL, and UCL values are either below the long-term comparison value, or no mean, LCL, and UCL values could be calculated for comparison.

✓ A check mark indicates value is above the long-term comparison value.

--- A mean, lower confidence limit, and upper confidence limit could not be calculated because the detection rate was ≤20%.

CV health-based comparison value
LCL lower confidence limit
MRL method reporting limit
NA not applicable
ND not detected
ppb parts per billion
UCL upper confidence limit

Table 14B. Industry Canisters (pre-2005) Refined Data Screening Results (page 1 of 6)

Chemical	Location	Industry Canister Data (pre-2005)											Is this Chemical of Potential Concern prior to 2005?
		Total Number of Samples	Time Period	Detection Limits (ppb)	Number (and Percent) of Samples above DL	Maximum			Mean				
						Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV*	LCL above Long-term CV*	UCL above Long-term CV*	
Benzaldehyde	Crossley Elementary School	313	03/04/1996 - 05/21/2004	0.09 - 0.56	295 (94)	3.57	0 (0)	8 (2.6)	0.71 (0.65-0.78)				No
	Oak Park Elementary School	315	03/04/1996 - 05/21/2004	0.09 - 0.63	286 (91)	2.95	0 (0)	6 (1.9)	0.59 (0.54-0.65)				
	Tuloso Midway Elementary School	359	08/07/1996 - 02/21/2004	0.08 - 0.72	214 (60)	2.73	0 (0)	1 (0.28)	0.16 (0.15-0.19)				
	Tuloso Midway Middle School	356	08/07/1996 - 02/21/2004	0.08 - 0.69	257 (72)	0.99	0 (0)	0 (0)	0.18 (0.17-0.2)				
	Up River Road	312	03/04/1996 - 05/21/2004	0.09 - 0.66	269 (86)	3.18	0 (0)	3 (0.96)	0.49 (0.45-0.55)				
Benzene	Crossley Elementary School	332	03/04/1996 - 12/23/2004	0.04 - 0.41	324 (98)	6.55	0 (0)	324 (98)	0.63 (0.55-0.72)	✓	✓	✓	Yes
	Oak Park Elementary School	334	03/04/1996 - 12/23/2004	0.05 - 0.41	328 (98)	7.62	0 (0)	328 (98)	0.88 (0.78-0.99)	✓	✓	✓	
	Tuloso Midway Elementary School	388	08/07/1996 - 12/23/2004	0.05 - 0.41	377 (97)	3.59	0 (0)	377 (97)	0.48 (0.44-0.53)	✓	✓	✓	
	Tuloso Midway Middle School	385	08/07/1996 - 12/23/2004	0.03 - 0.41	374 (97)	1.59	0 (0)	374 (97)	0.36 (0.34-0.39)	✓	✓	✓	
	Up River Road	331	03/04/1996 - 12/23/2004	0.05 - 0.41	322 (97)	3.1	0 (0)	322 (97)	0.39 (0.37-0.42)	✓	✓	✓	
1,3-Butadiene	Crossley Elementary School	332	03/04/1996 - 12/23/2004	0.03 - 0.33	192 (58)	0.69	0 (0)	191 (58)	0.076 (0.068-0.085)	✓	✓	✓	Yes
	Oak Park Elementary School	334	03/04/1996 - 12/23/2004	0.03 - 0.32	209 (63)	0.53	0 (0)	209 (63)	0.072 (0.068-0.08)	✓	✓	✓	
	Tuloso Midway Elementary School	388	08/07/1996 - 12/23/2004	0.03 - 0.35	149 (38)	0.82	0 (0)	149 (38)	0.061 (0.055-0.07)	✓	✓	✓	

Table 14B. Industry Canisters (pre-2005) Refined Data Screening Results (page 2 of 6)

Chemical	Location	Industry Canister Data (pre-2005)											Is this Chemical of Potential Concern prior to 2005?
		Total Number of Samples	Time Period	Detection Limits (ppb)	Number (and Percent) of Samples above DL	Maximum			Mean				
						Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV*	LCL above Long-term CV*	UCL above Long-term CV*	
1,3-Butadiene (continued)	Tuloso Midway Middle School	385	08/07/1996 - 12/23/2004	0.03 - 0.33	139 (36)	2.97	0 (0)	139 (36)	0.061 (0.052-0.079)	✓	✓	✓	Yes
	Up River Road	331	03/04/1996 - 12/23/2004	0.03 - 0.3	117 (35)	2.38	0 (0)	115 (35)	0.054 (0.044-0.078)	✓	✓	✓	
1-Butanol	Crossley Elementary School	313	03/04/1996 - 05/21/2004	0.08 - 0.77	270 (86)	61.4	NA	NA	9.2 (8.2-10)	NA	NA	NA	Yes
	Oak Park Elementary School	310	03/04/1996 - 05/21/2004	0.07 - 0.8	242 (78)	46.2	NA	NA	9.6 (8.6-11)	NA	NA	NA	
	Tuloso Midway Elementary School	359	08/07/1996 - 02/21/2004	0.08 - 1.21	55 (15)	2.64	NA	NA	----	NA	NA	NA	
	Tuloso Midway Middle School	356	08/07/1996 - 02/21/2004	0.08 - 0.94	91 (26)	1.46	NA	NA	0.16 (0.16-0.21)	NA	NA	NA	
	Up River Road	313	03/04/1996 - 05/21/2004	0.08 - 0.67	258 (82)	36.6	NA	NA	8.1 (7.3-9)	NA	NA	NA	
Carbon Tetrachloride	Crossley Elementary School	314	03/04/1996 - 05/21/2004	0.05	313 (100)	1.39	0 (0)	313 (100)	0.11 (0.1-0.12)	✓	✓	✓	Yes
	Oak Park Elementary School	316	03/04/1996 - 05/21/2004	0.05	315 (100)	0.49	0 (0)	315 (100)	0.1 (0.099-0.11)	✓	✓	✓	
	Tuloso Midway Elementary School	359	08/07/1996 - 02/21/2004	0.05 - 0.08	357 (99)	0.35	0 (0)	357 (99)	0.1 (0.098-0.1)	✓	✓	✓	
	Tuloso Midway Middle School	356	08/07/1996 - 02/21/2004	NA	356 (100)	0.65	0 (0)	356 (100)	0.11 (0.1-0.11)	✓	✓	✓	
	Up River Road	313	03/04/1996 - 05/21/2004	0.05 - 0.08	311 (99)	0.57	0 (0)	311 (99)	0.1 (0.099-0.11)	✓	✓	✓	
1,1-Dichloroethane	Crossley Elementary School	314	03/04/1996 - 05/21/2004	0.01 - 0.08	7 (2.2)	0.08	0 (0)	0 (0)	----				No
	Oak Park Elementary School	316	03/04/1996 - 05/21/2004	0.01 - 0.07	1 (0.32)	0.01	0 (0)	0 (0)	----				

Table 14B. Industry Canisters (pre-2005) Refined Data Screening Results (page 3 of 6)

Chemical	Location	Industry Canister Data (pre-2005)				Maximum			Mean				Is this Chemical of Potential Concern prior to 2005?
		Total Number of Samples	Time Period	Detection Limits (ppb)	Number (and Percent) of Samples above DL	Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV*	LCL above Long-term CV*	UCL above Long-term CV*	
1,1-Dichloroethane (continued)	Tuloso Midway Elementary School	359	08/07/1996 - 02/21/2004	0.01 - 0.08	3 (0.84)	0.3	0 (0)	0 (0)	----				No
	Tuloso Midway Middle School	356	08/07/1996 - 02/21/2004	0.01 - 0.07	6 (1.7)	0.51	0 (0)	1 (0.28)	----				
	Up River Road	313	03/04/1996 - 05/21/2004	0.01 - 0.07	2 (0.64)	0.07	0 (0)	0 (0)	----				
1,2-Dichloroethane	Crossley Elementary School	314	03/04/1996 - 05/21/2004	0.02 - 0.1	21 (6.7)	0.54	0 (0)	21 (6.7)	----				Yes
	Oak Park Elementary School	316	03/04/1996 - 05/21/2004	0.01 - 0.1	15 (4.7)	0.27	0 (0)	15 (4.7)	----				
	Tuloso Midway Elementary School	359	08/07/1996 - 02/21/2004	0.02 - 0.1	5 (1.4)	0.08	0 (0)	5 (1.4)	----				
	Tuloso Midway Middle School	356	08/07/1996 - 02/21/2004	0.01 - 0.1	12 (3.4)	0.65	0 (0)	12 (3.4)	----				
	Up River Road	313	03/04/1996 - 05/21/2004	0.01 - 0.1	14 (4.5)	0.17	0 (0)	14 (4.5)	----				
Ethylbenzene	Crossley Elementary School	332	03/04/1996 - 12/23/2004	0.01 - 0.11	281 (85)	2.05	0 (0)	61 (18)	0.16 (0.14-0.19)				No
	Oak Park Elementary School	334	03/04/1996 - 12/23/2004	0.01 - 0.12	296 (89)	0.78	0 (0)	56 (17)	0.13 (0.12-0.14)				
	Tuloso Midway Elementary School	388	08/07/1996 - 12/23/2004	0.01 - 0.11	268 (69)	1.01	0 (0)	18 (4.6)	0.073 (0.064-0.085)				
	Tuloso Midway Middle School	385	08/07/1996 - 12/23/2004	0.01 - 0.11	256 (66)	0.56	0 (0)	13 (3.4)	0.062 (0.057-0.069)				
	Up River Road	331	03/04/1996 - 12/23/2004	0.01 - 0.11	257 (78)	2.2	0 (0)	6 (1.8)	0.073 (0.064-0.086)				
Methyl t-Butyl ether	Crossley Elementary School	332	03/04/1996 - 12/23/2004	0.01 - 0.2	187 (56)	21.5	0 (0)	8 (2.4)	0.33 (0.21-0.52)				No

Table 14B. Industry Canisters (pre-2005) Refined Data Screening Results (page 4 of 6)

Chemical	Location	Industry Canister Data (pre-2005)											Is this Chemical of Potential Concern prior to 2005?
						Maximum			Mean				
		Total Number of Samples	Time Period	Detection Limits (ppb)	Number (and Percent) of Samples above DL	Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV*	LCL above Long-term CV*	UCL above Long-term CV*	
Methyl t-Butyl ether (continued)	Oak Park Elementary School	334	03/04/1996 - 12/23/2004	0.01 - 0.2	197 (59)	3.77	0 (0)	3 (0.9)	0.18 (0.15-0.23)				No
	Tuloso Midway Elementary School	388	08/07/1996 - 12/23/2004	0.01 - 0.2	184 (47)	2.15	0 (0)	0 (0)	0.099 (0.082-0.12)				
	Tuloso Midway Middle School	385	08/07/1996 - 12/23/2004	0.01 - 0.2	179 (46)	1.06	0 (0)	0 (0)	0.077 (0.067-0.089)				
	Up River Road	331	03/04/1996 - 12/23/2004	0.01 - 0.2	164 (50)	28.8	0 (0)	2 (0.6)	0.2 (0.11-0.38)				
Naphthalene	Crossley Elementary School	332	03/04/1996 - 12/23/2004	0.03 - 0.5	65 (20)	0.43	0 (0)	65 (20)	----				Yes
	Oak Park Elementary School	334	03/04/1996 - 12/23/2004	0.03 - 0.41	77 (23)	0.21	0 (0)	76 (23)	0.058 (0.055-0.068)	✓	✓	✓	
	Tuloso Midway Elementary School	388	08/07/1996 - 12/23/2004	0.05 - 0.57	17 (4.4)	0.08	0 (0)	17 (4.4)	----				
	Tuloso Midway Middle School	385	08/07/1996 - 12/23/2004	0.05 - 0.45	24 (6.2)	0.72	0 (0)	23 (6)	----				
	Up River Road	331	03/04/1996 - 12/23/2004	0.03 - 0.38	26 (7.9)	0.58	0 (0)	26 (7.9)	----				
Tetrachloroethylene	Crossley Elementary School	332	03/04/1996 - 12/23/2004	0.02 - 0.11	97 (29)	0.49	0 (0)	0 (0)	0.033 (0.029-0.04)				No
	Oak Park Elementary School	334	03/04/1996 - 12/23/2004	0.02 - 0.09	87 (26)	0.5	0 (0)	0 (0)	0.031 (0.028-0.038)				
	Tuloso Midway Elementary School	388	08/07/1996 - 12/23/2004	0.02 - 0.11	80 (21)	0.35	0 (0)	0 (0)	0.027 (0.024-0.036)				
	Tuloso Midway Middle School	385	08/07/1996 - 12/23/2004	0.02 - 0.11	91 (24)	8.57	0 (0)	2 (0.52)	0.062 (0.026-0.12) †				
	Up River Road	331	03/04/1996 - 12/23/2004	0.01 - 0.09	68 (21)	0.22	0 (0)	0 (0)	0.025 (0.023-0.03)				

Table 14B. Industry Canisters (pre-2005) Refined Data Screening Results (page 5 of 6)

Chemical	Location	Industry Canister Data (pre-2005)				Maximum			Mean				Is this Chemical of Potential Concern prior to 2005?
		Total Number of Samples	Time Period	Detection Limits (ppb)	Number (and Percent) of Samples above DL	Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV*	LCL above Long-term CV*	UCL above Long-term CV*	
Toluene	Crossley Elementary School	332	03/04/1996 - 12/23/2004	not available	332 (100)	21.3	0 (0)	0 (0)	1.3 (1.1-1.5)				No
	Oak Park Elementary School	329	03/04/1996 - 12/23/2004	not available	329 (100)	861	0 (0)	1 (0.3)	4.5 (1.2-12) †				
	Tuloso Midway Elementary School	388	08/07/1996 - 12/23/2004	0.06	387 (100)	7	0 (0)	0 (0)	0.57 (0.51-0.64)				
	Tuloso Midway Middle School	385	08/07/1996 - 12/23/2004	0.05	384 (100)	268	0 (0)	1 (0.26)	1.3 (0.46-3.3) †				
	Up River Road	331	03/04/1996 - 12/23/2004	0.05	330 (100)	25.3	0 (0)	0 (0)	0.65 (0.56-0.8)				
Trichloroethylene	Crossley Elementary School	332	03/04/1996 - 12/23/2004	0.03 - 0.12	103 (31)	0.47	0 (0)	49 (15)	0.031 (0.03-0.038)				No
	Oak Park Elementary School	334	03/04/1996 - 12/23/2004	0.03 - 0.09	62 (19)	0.16	0 (0)	16 (4.8)	----				
	Tuloso Midway Elementary School	388	08/07/1996 - 12/23/2004	0.03 - 0.1	70 (18)	0.18	0 (0)	22 (5.7)	----				
	Tuloso Midway Middle School	385	08/07/1996 - 12/23/2004	0.03 - 0.11	88 (23)	0.59	0 (0)	34 (8.8)	0.034 (0.033-0.044)				
	Up River Road	331	03/04/1996 - 12/23/2004	0.03 - 0.09	67 (20)	0.38	0 (0)	22 (6.6)	----				
1,2,4-Trimethylbenzene	Crossley Elementary School	315	09/12/1996 - 12/23/2004	0.05 - 0.32	290 (92)	1.96	0 (0)	1 (0.32)	0.2 (0.18-0.23)				No
	Oak Park Elementary School	317	09/12/1996 - 12/23/2004	0.05 - 0.07	302 (95)	0.91	0 (0)	0 (0)	0.19 (0.18-0.21)				
	Tuloso Midway Elementary School	385	09/12/1996 - 12/23/2004	0.02 - 0.33	283 (74)	0.57	0 (0)	0 (0)	0.07 (0.066-0.078)				
	Tuloso Midway Middle School	382	09/12/1996 - 12/23/2004	0.02 - 0.31	293 (77)	1.23	0 (0)	0 (0)	0.083 (0.074-0.096)				

Table 14B. Industry Canisters (pre-2005) Refined Data Screening Results (page 6 of 6)

Chemical	Location	Industry Canister Data (pre-2005)											Is this Chemical of Potential Concern prior to 2005?
		Total Number of Samples	Time Period	Detection Limits (ppb)	Number (and Percent) of Samples above DL	Maximum			Mean				
						Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV*	LCL above Long-term CV*	UCL above Long-term CV*	
1,2,4-Trimethylbenzene (continued)	Up River Road	314	09/12/1996 - 12/23/2004	0.03 - 0.33	266 (85)	1.03	0 (0)	0 (0)	0.096 (0.087-0.11)				No

Data source: ToxStrategies, Inc. 2011. September 8th email from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005–2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

* Blank cells indicate value is either below the long-term comparison value, or no value could be calculated for comparison.
† The bootstrap confidence interval appears biased high because of a potential outlier.
✓ A check mark indicates value is above the long-term comparison value.
--- A mean, lower confidence limit, and upper confidence limit could not be calculated because the detection rate was ≤20%.

CV health-based comparison value
DL detection limit
LCL lower confidence limit
NA not applicable
ppb parts per billion
UCL upper confidence limit

Table 15B. Industry Canisters (2005–2010) Refined Data Screening Results (page 1 of 4)

Chemical*	***Location***	***Industry Canister Data (2005–2010)***											***Is this Chemical of Potential Concern for 2005–2010?***
		Total Number of Samples	***Time Period***	***Detection Limits (ppb)***	***Number (and Percent) of Samples above DL***	***Maximum***			***Mean***				
						Level (ppb)	***Number (and Percent) of Samples above Short-term CV***	***Number (and Percent) of Samples above Long-term CV***	***Level (LCL–UCL) (ppb)***	***Mean above Long-term CV†***	***LCL above Long-term CV†***	***UCL above Long-term CV†***	
Benzene	Crossley Elementary School	222	01/04/2005 - 12/22/2010	0.05 - 0.41	197 (89)	5.08	0 (0)	197 (89)	0.28 (0.24-0.33)	✓	✓	✓	Yes
	Oak Park Elementary School	221	01/04/2005 - 12/22/2010	0.05 - 0.41	196 (89)	9.58	1 (0.45)	196 (89)	0.61 (0.47-0.77)	✓	✓	✓	
	Tuloso Midway Elementary School	222	01/04/2005 - 12/22/2010	0.05 - 0.41	199 (90)	1.26	0 (0)	199 (90)	0.28 (0.25-0.31)	✓	✓	✓	
	Tuloso Midway Middle School	223	01/04/2005 - 12/22/2010	0.05 - 0.41	195 (87)	2.19	0 (0)	195 (87)	0.21 (0.19-0.23)	✓	✓	✓	
	Up River Road	222	01/04/2005 - 12/22/2010	0.05 - 0.41	196 (88)	1.5	0 (0)	195 (88)	0.23 (0.21-0.26)	✓	✓	✓	
1,3-Butadiene	Crossley Elementary School	222	01/04/2005 - 12/22/2010	0.05 - 0.15	31 (14)	0.19	0 (0)	30 (14)	----				Yes
	Oak Park Elementary School	221	01/04/2005 - 12/22/2010	0.05 - 0.14	27 (12)	0.51	0 (0)	26 (12)	----				
	Tuloso Midway Elementary School	222	01/04/2005 - 12/22/2010	0.05 - 0.15	20 (9)	5.74	0 (0)	20 (9)	----				
	Tuloso Midway Middle School	223	01/04/2005 - 12/22/2010	0.05 - 0.13	20 (9)	3.42	0 (0)	19 (8.5)	----				
	Up River Road	222	01/04/2005 - 12/22/2010	0.04 - 0.154	20 (9)	0.26	0 (0)	19 (8.6)	----				
Ethylbenzene	Crossley Elementary School	222	01/04/2005 - 12/22/2010	0.03 - 0.14	108 (49)	0.21	0 (0)	0 (0)	0.038 (0.035-0.044)				No
	Oak Park Elementary School	221	01/04/2005 - 12/22/2010	0.03 - 0.16	108 (49)	0.21	0 (0)	0 (0)	0.043 (0.04-0.05)				
	Tuloso Midway Elementary School	222	01/04/2005 - 12/22/2010	0.03 - 0.16	85 (38)	0.4	0 (0)	1 (0.45)	0.036 (0.033-0.044)				

Table 15B. Industry Canisters (2005–2010) Refined Data Screening Results (page 2 of 4)

Chemical*	Location	Industry Canister Data (2005–2010)											Is this Chemical of Potential Concern for 2005–2010?
		Total Number of Samples	Time Period	Detection Limits (ppb)	Number (and Percent) of Samples above DL	Maximum			Mean				
						Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV†	LCL above Long-term CV†	UCL above Long-term CV†	
Ethylbenzene (continued)	Tuloso Midway Middle School	223	01/04/2005 - 12/22/2010	0.03 - 0.146	69 (31)	0.18	0 (0)	0 (0)	0.025 (0.023-0.03)				No
	Up River Road	222	01/04/2005 - 12/22/2010	0.03 - 0.172	82 (37)	0.24	0 (0)	1 (0.45)	0.03 (0.028-0.036)				
Methyl t-Butyl ether	Crossley Elementary School	222	01/04/2005 - 12/22/2010	0.05 - 0.332	7 (3.2)	0.26	0 (0)	0 (0)	----				No
	Oak Park Elementary School	221	01/04/2005 - 12/22/2010	0.04 - 0.342	11 (5)	0.26	0 (0)	0 (0)	----				
	Tuloso Midway Elementary School	222	01/04/2005 - 12/22/2010	0.04 - 0.354	12 (5.4)	0.26	0 (0)	0 (0)	----				
	Tuloso Midway Middle School	223	01/04/2005 - 12/22/2010	0.04 - 0.326	8 (3.6)	0.08	0 (0)	0 (0)	----				
	Up River Road	222	01/04/2005 - 12/22/2010	0.04 - 0.388	10 (4.5)	0.75	0 (0)	0 (0)	----				
Naphthalene	Crossley Elementary School	222	01/04/2005 - 12/22/2010	0.1 - 0.568	9 (4.1)	0.44	0 (0)	9 (4.1)	----				Yes
	Oak Park Elementary School	221	01/04/2005 - 12/22/2010	0.09 - 0.592	5 (2.3)	0.1	0 (0)	5 (2.3)	----				
	Tuloso Midway Elementary School	222	01/04/2005 - 12/22/2010	0.09 - 0.608	1 (0.45)	0.09	0 (0)	1 (0.45)	----				
	Tuloso Midway Middle School	223	01/04/2005 - 12/22/2010	0.09 - 0.562	5 (2.2)	0.2	0 (0)	4 (1.8)	----				
	Up River Road	222	01/04/2005 - 12/22/2010	0.09 - 0.666	5 (2.3)	0.14	0 (0)	4 (1.8)	----				
Tetrachloroethylene	Crossley Elementary School	222	01/04/2005 - 12/22/2010	0.05 - 0.13	18 (8.1)	0.56	0 (0)	0 (0)	----				No
	Oak Park Elementary School	221	01/04/2005 - 12/22/2010	0.05 - 0.12	16 (7.2)	0.42	0 (0)	0 (0)	----				

Table 15B. Industry Canisters (2005–2010) Refined Data Screening Results (page 3 of 4)

*Chemical**	*Location*	*Industry Canister Data (2005–2010)*											*Is this Chemical of Potential Concern for 2005–2010?*
		Total Number of Samples	*Time Period*	*Detection Limits (ppb)*	*Number (and Percent) of Samples above DL*	*Maximum*			*Mean*				
						Level (ppb)	*Number (and Percent) of Samples above Short-term CV*	*Number (and Percent) of Samples above Long-term CV*	*Level (LCL–UCL) (ppb)*	*Mean above Long-term CV†*	*LCL above Long-term CV†*	*UCL above Long-term CV†*	
Tetrachloroethylene (continued)	Tuloso Midway Elementary School	222	01/04/2005 - 12/22/2010	0.05 - 0.13	19 (8.6)	0.22	0 (0)	0 (0)	----				No
	Tuloso Midway Middle School	223	01/04/2005 - 12/22/2010	0.05 - 0.11	12 (5.4)	0.13	0 (0)	0 (0)	----				
	Up River Road	222	01/04/2005 - 12/22/2010	0.04 - 0.132	16 (7.2)	0.1	0 (0)	0 (0)	----				
Toluene	Crossley Elementary School	222	01/04/2005 - 12/22/2010	not available	222 (100)	5.5	0 (0)	0 (0)	0.47 (0.41-0.54)				No
	Oak Park Elementary School	221	01/04/2005 - 12/22/2010	not available	221 (100)	8.23	0 (0)	0 (0)	0.74 (0.62-0.86)				
	Tuloso Midway Elementary School	222	01/04/2005 - 12/22/2010	0.05 - 0.08	217 (98)	2.69	0 (0)	0 (0)	0.36 (0.32-0.4)				
	Tuloso Midway Middle School	223	01/04/2005 - 12/22/2010	0.05 - 0.074	218 (98)	4.06	0 (0)	0 (0)	0.26 (0.23-0.3)				
	Up River Road	222	01/04/2005 - 12/22/2010	0.05	221 (100)	5.37	0 (0)	0 (0)	0.37 (0.32-0.43)				
Trichloroethylene	Crossley Elementary School	222	01/04/2005 - 12/22/2010	0.05 - 0.14	13 (5.9)	0.2	0 (0)	10 (4.5)	----				Yes
	Oak Park Elementary School	221	01/04/2005 - 12/22/2010	0.05 - 0.14	8 (3.6)	0.12	0 (0)	2 (0.9)	----				
	Tuloso Midway Elementary School	222	01/04/2005 - 12/22/2010	0.05 - 0.14	9 (4.1)	0.42	0 (0)	4 (1.8)	----				
	Tuloso Midway Middle School	223	01/04/2005 - 12/22/2010	0.05 - 0.13	5 (2.2)	0.06	0 (0)	2 (0.9)	----				
	Up River Road	222	01/04/2005 - 12/22/2010	0.04 - 0.14	6 (2.7)	0.04	0 (0)	0 (0)	----				
1,2,4-Trimethylbenzene	Crossley Elementary School	222	01/04/2005 - 12/22/2010	0.05 - 0.19	124 (56)	0.26	0 (0)	0 (0)	0.043 (0.038-0.049)				No

Table 15B. Industry Canisters (2005–2010) Refined Data Screening Results (page 4 of 4)

Chemical*	Location	Industry Canister Data (2005–2010)											Is this Chemical of Potential Concern for 2005–2010?
		Total Number of Samples	Time Period	Detection Limits (ppb)	Number (and Percent) of Samples above DL	Maximum			Mean				
						Level (ppb)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (ppb)	Mean above Long-term CV†	LCL above Long-term CV†	UCL above Long-term CV†	
1,2,4-Trimethylbenzene (continued)	Oak Park Elementary School	221	01/04/2005 - 12/22/2010	0.05 - 0.22	134 (61)	0.24	0 (0)	0 (0)	0.046 (0.043-0.052)				No
	Tuloso Midway Elementary School	222	01/04/2005 - 12/22/2010	0.05 - 0.21	69 (31)	0.29	0 (0)	0 (0)	0.03 (0.026-0.035)				
	Tuloso Midway Middle School	223	01/04/2005 - 12/22/2010	0.05 - 0.19	65 (29)	0.31	0 (0)	0 (0)	0.025 (0.021-0.03)				
	Up River Road	222	01/04/2005 - 12/22/2010	0.05 - 0.2	88 (40)	0.14	0 (0)	0 (0)	0.032 (0.029-0.037)				

Data source: ToxStrategies, Inc. 2011. September 8th email from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005–2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

* Benzaldehyde, 1-butanol, carbon tetrachloride, 1,1-dichloroethane, and 1,2-dichloroethane were dropped from the list of analytes inmid-2004 and therefore are not a part of this 2005–2010 dataset summary table.
† Blank cells indicate value is either below the long-term comparison value, or no value could be calculated for comparison.
✓ A check mark indicates value is above the long-term comparison value.
--- A mean, lower confidence limit, and upper confidence limit could not be calculated because the detection rate was ≤20%.

CV health-based comparison value
DL detection limit
LCL lower confidence limit
ppb parts per billion
UCL upper confidence limit

Table 16B. Metals – Dona Park Stationary Air Monitor (pre-2005) Refined Data Screening Results (page 1 of 2)

Chemical	Metals – Dona Park Data (pre-2005)				Maximum			Mean				Is this Chemical of Potential Concern prior to 2005?
	Total Number of Samples	Time Period	Method Detection Limits (µg/m³)	Number (and Percent) of Samples above MDL	Level (µg/m³)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (µg/m³)	Mean above Long-term CV*	LCL above Long-term CV*	UCL above Long-term CV*	
Arsenic	239	01/31/2001 - 12/29/2004	0.0005 - 0.00099	65 (27)	0.00242	0 (0)	65 (27)	0.00108 (0.00105-0.00112)	✓	✓	✓	Yes
Cadmium	239	01/31/2001 - 12/29/2004	0.0042 - 0.0055	26 (11)	0.01315	0 (0)	26 (11)	----				Yes
Chlorine†	239	01/31/2001 - 12/29/2004	0.0015 - 0.0033	146 (61)	1.53	NA	NA	0.104 (0.0785-0.13)				Yes
Chromium‡	239	01/31/2001 - 12/29/2004	0.00063 - 0.0013	151 (63)	0.0157	0 (0)	151 (63)	0.00174 (0.0015-0.00201)	✓	✓	✓	Yes
Cobalt	239	01/31/2001 - 12/29/2004	0.00056 - 0.0007	16 (6.7)	0.00094	0 (0)	16 (6.7)	----				Yes
Lead§	239	01/31/2001 - 12/29/2004	0.0011 - 0.0056	61 (26)	0.0133	0 (0)	NA	0.00243 (0.00234-0.00254)				No
Nickel¶	239	01/31/2001 - 12/29/2004	0.0005 - 0.0013	163 (68)	0.0168	0 (0)	2 (0.84)	0.00142 (0.00122-0.00164)				No

Data Source: Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through a query performed with the target list 'PM2.5-parameters' group, 24-hour concentrations, for dates within the range >=1/1/1990 to <1/1/2011 at the Dona Park stationary air monitor. Data downloaded on 26 January 2013.

* Blank cells indicate value is either below the long-term comparison value, or no value could be calculated for comparison.
✓ A check mark indicates value is above the long-term comparison value.
--- A mean, lower confidence limit, and upper confidence limit could not be calculated because the detection rate was ≤20%.
† Although comparison values exist for chlorine in its gaseous (vapor) phase, no comparison values exist for chlorine as a particulate.
‡ Screened against comparison values available for hexavalent chromium.
§ Screened against national ambient air quality standard (NAAQS) 3-month average for lead.
¶ Screened against comparison values available for nickel refinery dust.

CV health-based comparison value

Table 16B. Metals – Dona Park Stationary Air Monitor (pre-2005) Refined Data Screening Results (page 2 of 2)

LCL lower confidence limit
MDL method detection limit
µg/m^3 micrograms per cubic meter
NA not available
UCL upper confidence limit

Table 17B. Metals – Dona Park Stationary Air Monitor (2005–2010) Refined Data Screening Results (page 1 of 2)

Chemical	Metals – Dona Park Data (2005–2010)											Is this Chemical of Potential Concern for 2005–2010?
	Total Number of Samples	Time Period	Method Detection Limits (µg/m³)	Number (and Percent) of Samples above MDL	Maximum			Mean				
					Level (µg/m³)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (µg/m³)	Mean above Long-term CV*	LCL above Long-term CV*	UCL above Long-term CV*	
Arsenic	333	01/04/2005 - 12/28/2010	0.0001 - 0.005	33 (9.9)	0.00278	0 (0)	33 (9.9)	----				Yes
Cadmium	333	01/04/2005 - 12/28/2010	0.0032 - 0.0104	6 (1.8)	0.06106	1 (0.3)	6 (1.8)	----				Yes
Chlorine†	333	01/04/2005 - 12/28/2010	0.001 - 0.003	293 (88)	2.73493	NA	NA	0.276 (0.228-0.328)				Yes
Chromium‡	333	01/04/2005 - 12/28/2010	0.0006 - 0.0019	91 (27)	0.02368	0 (0)	91 (27)	0.00156 (0.00128-0.00189)	✓	✓	✓	Yes
Cobalt	333	01/04/2005 - 12/28/2010	0.0001 - 0.0016	2 (0.6)	0.00112	0 (0)	2 (0.6)	----				Yes
Lead§	333	01/04/2005 - 12/28/2010	0.0015 - 0.0071	48 (14)	0.17449	1 (0.3)	NA	----				Yes
Nickel¶	333	01/04/2005 - 12/28/2010	0.0004 - 0.0015	164 (49)	0.00496	0 (0)	0 (0)	0.00108 (0.000993-0.00117)				No

Data Source: Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) web interface. Data downloaded from TAMIS through a query performed with the target list 'PM2.5-parameters' group, 24-hour concentrations, for dates within the range >=1/1/1990 to <1/1/2011 at the Dona Park stationary air monitor. Data downloaded on 26 January 2013.

* Blank cells indicate value is either below the long-term comparison value, or no value could be calculated for comparison.
✓ A check mark indicates value is above the long-term comparison value.
--- A mean, lower confidence limit, and upper confidence limit could not be calculated because the detection rate was ≤20%.
† Although comparison values exist for chlorine in its gaseous (vapor) phase, no comparison values exist for chlorine as a particulate. [verify wording]
‡ Screened against comparison values available for hexavalent chromium.
§ Screened against national ambient air quality standard (NAAQS) 3-month average for lead.
¶ Screened against comparison values available for nickel refinery dust.

CV health-based comparison value

Table 17B. Metals – Dona Park Stationary Air Monitor (2005–2010) Refined Data Screening Results (page 2 of 2)

LCL lower confidence limit
MDL method detection limit
µg/m^3 micrograms per cubic meter
NA not available
UCL upper confidence limit

Table 18B. Metals – 1980s Stationary Air Monitor Refined Data Screening Results (page 1 of 4)

Chemical	Location	Metals – 1980s Stationary Air Monitor Data											Is this Chemical of Potential Concern prior to 2005?
						Maximum			Mean				
		Total Number of Samples	Time Period	Method Detection Limits (µg/m³)	Number (and Percent) of Samples above MDL	Level (µg/m³)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (µg/m³)	Mean above Long-term CV*	LCL above Long-term CV*	UCL above Long-term CV*	
Arsenic	Fire Station #5	36	05/22/1981 - 12/30/1981	0.05 - 0.05	0 (0)	ND	NA	NA	----				Yes
	Navigation Boulevard	33	05/22/1981 - 12/30/1981	0.05 - 0.05	0 (0)	ND	NA	NA	----				
	Old Galveston Road	50	01/04/1980 - 04/04/1981	0.05 - 0.05	0 (0)	ND	NA	NA	----				
	West Guth Park	65	01/04/1980 - 03/29/1981	0.05 - 0.05	3 (4.6)	0.093	0 (0)	3 (4.6)	----				
Barium	Fire Station #5	36	05/22/1981 - 12/30/1981	0.08 - 0.08	20 (56)	1.754	0 (0)	3 (8.3)	0.19 (0.1-0.3)				Yes
	Navigation Boulevard	33	05/22/1981 - 12/30/1981	0.08 - 0.08	22 (67)	6.335	1 (3)	9 (27)	0.54 (0.26-0.97)	✓		✓	
	Old Galveston Road	50	01/04/1980 - 04/04/1981	0.08 - 0.08	19 (38)	1.527	0 (0)	1 (2)	0.11 (0.069-0.18)				
	West Guth Park	65	01/04/1980 - 03/29/1981	0.08 - 0.08	23 (35)	0.563	0 (0)	1 (1.5)	0.094 (0.066-0.12)				
Cadmium	Fire Station #5	36	05/22/1981 - 12/30/1981	0.06 - 0.06	2 (5.6)	0.175	2 (5.6)	2 (5.6)	----				Yes
	Navigation Boulevard	33	05/22/1981 - 12/30/1981	0.06 - 0.06	0 (0)	ND	NA	NA	----				
	Old Galveston Road	50	01/04/1980 - 04/04/1981	0.06 - 0.06	0 (0)	ND	NA	NA	----				
	West Guth Park	65	01/04/1980 - 03/29/1981	0.06 - 0.06	0 (0)	ND	NA	NA	----				

Table 18B. Metals – 1980s Stationary Air Monitor Refined Data Screening Results (page 2 of 4)

Chemical	Location	Metals – 1980s Stationary Air Monitor Data											Is this Chemical of Potential Concern prior to 2005?
		Total Number of Samples	Time Period	Method Detection Limits (µg/m³)	Number (and Percent) of Samples above MDL	Maximum			Mean				
						Level (µg/m³)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (µg/m³)	Mean above Long-term CV*	LCL above Long-term CV*	UCL above Long-term CV*	
Chromium†	Fire Station #5	36	05/22/1981 - 12/30/1981	0.05 - 0.05	10 (28)	0.349	7 (19)	10 (28)	0.069 (0.032-0.12)	✓	✓	✓	Yes
	Navigation Boulevard	33	05/22/1981 - 12/30/1981	0.05 - 0.05	17 (52)	0.731	12 (36)	17 (52)	0.12 (0.076-0.18)	✓	✓	✓	
	Old Galveston Road	50	01/04/1980 - 04/04/1981	0.05 - 0.05	13 (26)	0.493	9 (18)	13 (26)	0.071 (0.034-0.12)	✓	✓	✓	
	West Guth Park	65	01/04/1980 - 03/29/1981	0.05 - 0.05	3 (4.6)	0.091	0 (0)	3 (4.6)	---				
Cobalt	Fire Station #5	36	05/22/1981 - 12/30/1981	0.03- 0.03	0 (0)	ND	NA	NA	---				Yes
	Navigation Boulevard	33	05/22/1981 - 12/30/1981	0.03- 0.03	0 (0)	ND	NA	NA	---				
	Old Galveston Road	50	01/04/1980 - 04/04/1981	0.03- 0.03	0 (0)	ND	NA	NA	---				
	West Guth Park	65	01/04/1980 - 03/29/1981	0.03- 0.03	0 (0)	ND	NA	NA	---				
Lead‡	Fire Station #5	235	05/22/1981 - 06/26/1987	0.002 - 0.002	171 (73)	0.61	61 (26)	NA	0.1 (0.087-0.12)				Yes
	Navigation	131	03/08/1985 - 06/26/1987	0.002 - 0.002	73 (56)	0.19	5 (3.8)	NA	0.04 (0.032-0.049)				
	Navigation Boulevard	219	05/22/1981 - 06/26/1987	0.002 - 0.002	114 (52)	0.23	6 (2.7)	NA	0.035 (0.029-0.04)				
	Old Galveston Road	50	01/04/1980 - 04/04/1981	0.002 - 0.003	49 (98)	3.03	34 (68)	NA	0.26 (0.18-0.4)				
	West Guth Park	65	01/04/1980 - 03/29/1981	0.002 - 0.003	63 (97)	2.98	5 (7.7)	NA	0.21 (0.073-0.38)				

Table 18B. Metals – 1980s Stationary Air Monitor Refined Data Screening Results (page 3 of 4)

Chemical	Location	Metals – 1980s Stationary Air Monitor Data											Is this Chemical of Potential Concern prior to 2005?
						Maximum			Mean				
		Total Number of Samples	Time Period	Method Detection Limits (µg/m³)	Number (and Percent) of Samples above MDL	Level (µg/m³)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (µg/m³)	Mean above Long-term CV*	LCL above Long-term CV*	UCL above Long-term CV*	
Nickel§	Fire Station #5	36	05/22/1981 - 12/30/1981	0.02 - 0.02	1 (2.8)	0.038	0 (0)	1 (2.8)	----				No¶
	Navigation Boulevard	33	05/22/1981 - 12/30/1981	0.02 - 0.02	1 (3)	0.021	0 (0)	1 (3)	----				
	Old Galveston Road	50	01/04/1980 - 04/04/1981	0.02 - 0.02	0 (0)	ND	NA	NA	----				
	West Guth Park	65	01/04/1980 - 03/29/1981	0.02 - 0.02	2 (3.1)	0.05	0 (0)	2 (3.1)	----				
Vanadium**	Fire Station #5	36	05/22/1981 - 12/30/1981	0.002 - 0.002	23 (64)	0.123	0 (0)	3 (8.3)	0.011 (0.004-0.02)				No
	Navigation Boulevard	33	05/22/1981 - 12/30/1981	0.002 - 0.002	20 (61)	0.073	0 (0)	1 (3)	0.007 (0.0035-0.012)				
	Old Galveston Road	50	01/04/1980 - 04/04/1981	0.002 - 0.003	30 (60)	0.042	0 (0)	0 (0)	0.0063 (0.0045-0.0084)				
	West Guth Park	65	01/04/1980 - 03/29/1981	0.002 - 0.003	27 (42)	0.015	0 (0)	0 (0)	0.0032 (0.0025-0.004)				

Data Source: Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) web interface. Data downloaded from TAMIS through a query performed with the target list 'TSP-parameters' group, 24-hour concentrations, for dates within the range >=1/1/1980 to <1/1/2011 at the Fire Station #5, Navigation Boulevard, Old Galveston Road, and West Guth Park stationary air monitors. The query included the Navigation monitor for TSP/lead speciation. Data downloaded on 13 January 2014.

* Blank cells indicate value is either below the long-term comparison value, or no value could be calculated for comparison.
✓ A check mark indicates value is above the long-term comparison value.
--- A mean, lower confidence limit, and upper confidence limit could not be calculated because the detection rate was ≤20%.
† Screened against comparison values available for hexavalent chromium.
‡ Screened against national ambient air quality standard (NAAQS) 3-month average for lead.
§ Screened against comparison values available for nickel refinery dust.

Table 18B. Metals – 1980s Stationary Air Monitor Refined Data Screening Results (page 4 of 4)

¶ Although a mean could not be calculated for the 1980s metals dataset, mean nickel concentrations for both the pre-2005 and 2005–2010 Dona Park datasets were below the nickel long-term CV.

** Screened against the lowest comparison value available for vanadium pentoxide.

CV	health-based comparison value
LCL	lower confidence limit
MDL	method detection limit
µg/m^3	micrograms per cubic meter
NA	not available
ND	not detected
UCL	upper confidence limit

Table 19B. Particulate Matter – Stationary Air Monitor (pre-2005) Refined Data Screening Results (Page 1 of 2)

Chemical	Location	Particulate Matter – Stationary Air Monitor Data (pre-2005)												Is this Chemical of Potential Concern prior to 2005?
		Total Number of Samples	Time Period	Method Detection Limits (µg/m³)	Number (and Percent) of Samples above MDL	Maximum			Mean					
						Level (µg/m³)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (µg/m³)	Mean above Long-term CV*	LCL above Long-term CV*	UCL above Long-term CV*		
$PM_{2.5}$	Dona Park	238	01/31/2001 - 12/29/2004	2 - 2	235 (99)	28	0 (0)	47 (20)	9.1 (8.5-9.7)					Yes
	Huisache	606	01/07/2000 - 12/29/2004	2 - 2	600 (99)	37.8	1 (0.17)	158 (26)	10 (9.8-11)					
	Navigation	300	01/07/2000 - 09/23/2002	2 - 2	297 (99)	38.9	1 (0.33)	84 (28)	10 (9.9-11)					
PM_{10}	Dona Park	134	10/05/2002 - 12/29/2004	4 - 4	134 (100)	66	0 (0)	NA	22 (20-24)	NA	NA	NA		No†
	Fire Station #5	230	01/01/1993 - 12/29/1996	4 - 4	230 (100)	78	0 (0)	NA	24 (23-26)	NA	NA	NA		
	Navigation	643	01/01/1993 - 09/29/2002	4 - 4	643 (100)	102	0 (0)	NA	32 (31-33)	NA	NA	NA		

Data Sources:

Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through a query performed for Pm10 Total 0-10um Stp and Pm10 - Lc, 24-hour concentrations, for dates within the range >=1/1/1984 to <1/1/2011 at the Dona Park, Fire Station #5, and Navigation stationary air monitors. Data downloaded on November 19, 2013.

Texas Commission on Environmental Quality. 2014. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through a query performed for Parameter Pm2.5 - Local Conditions, 24-hour concentrations, for dates within the range >=1/1/1980 to <1/1/2011 at the Dona Park, Huisache, and Navigation stationary air monitors. Data downloaded on 23 June 2014.

* Blank cells indicate value is below the long-term comparison value.

† In 2006, U.S. EPA revoked the annual PM_{10} standard because available evidence generally did not suggest a link between long-term exposure to coarse particles and health problems.

Table 19B. Particulate Matter – Stationary Air Monitor (pre-2005) Refined Data Screening Results (Page 2 of 2)

CV	health-based comparison value
LCL	lower confidence limit
MDL	method detection limit
$\mu g/m^3$	micrograms per cubic meter
NA	not applicable
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
PM_{10}	particulate matter less than 10 microns in diameter
UCL	upper confidence limit

Table 20B. Particulate Matter – Stationary Air Monitor (2005–2010) Refined Data Screening Results

Chemical	Location	Particulate Matter – Stationary Air Monitor Data (2005–2010)											Is this Chemical of Potential Concern 2005–2010?
						Maximum			Mean				
		Total Number of Samples	Time Period	Method Detection Limits (µg/m³)	Number (and Percent) of Samples above MDL	Level (µg/m³)	Number (and Percent) of Samples above Short-term CV	Number (and Percent) of Samples above Long-term CV	Level (LCL–UCL) (µg/m³)	Mean above Long-term CV*	LCL above Long-term CV*	UCL above Long-term CV*	
$PM_{2.5}$	Dona Park	333	01/04/2005 - 12/28/2010	2 - 2	333 (100)	31.29	0 (0)	80 (24)	9.9 (9.4-10)				Yes†
	Huisache	1,248	01/01/2005 - 12/31/2010	2 - 2	1,248 (100)	33.5	0 (0)	393 (31)	11 (10-11)				
PM_{10}	Dona Park	345	01/04/2005 - 12/28/2010	4 - 4	345 (100)	95	0 (0)	NA	24 (23-25)	NA	NA	NA	No†

Data Sources:

Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through a query performed for Pm10 Total 0-10um Stp and Pm10 - Lc, 24-hour concentrations, for dates within the range >=1/1/1984 to <1/1/2011 at the Dona Park, Fire Station #5, and Navigation stationary air monitors. Data downloaded on November 19, 2013.

Texas Commission on Environmental Quality. 2014. Texas Air Monitoring Information System (TAMIS) Web interface. Data downloaded from TAMIS through a query performed for Parameter Pm2.5 - Local Conditions, 24-hour concentrations, for dates within the range >=1/1/1980 to <1/1/2011 at the Dona Park, Huisache, and Navigation stationary air monitors. Data downloaded on 23 June 2014.

* Blank cells indicate value is below the long-term comparison value.

† In 2006, U.S. EPA revoked the annual PM_{10} standard because available evidence generally did not suggest a link between long-term exposure to coarse particles and health problems.

CV health-based comparison value
LCL lower confidence limit
MDL method detection limit
µg/m³ micrograms per cubic meter
NA not available
$PM_{2.5}$ particulate matter less than 2.5 microns in diameter
PM_{10} particulate matter less than 10 microns in diameter
UCL upper confidence limit

Table 21B. Sulfur Compounds – Hourly Stationary Air Monitor Refined Data Screening Results (page 1 of 3)

Chemical	*Location*	*Time Period*	*Sulfur Compounds Hourly Data*									*Is this Chemical of Potential Concern?*
			Total Number of Samples	*Number (and Percent) of Samples above DL*	*Maximum*			*Mean*				
					Level (ppb)	*Number (and Percent) of Samples above Short-Term CV*	*Number (and Percent) of Samples above Long-Term CV*	*Level (LCL–UCL) (ppb)*	*Mean above Long-Term CV**	*LCL above Long-Term CV**	*UCL above Long-Term CV**	
Hydrogen sulfide	Dona Park	2005 - 2010	39,406	20,584 (52)	31.23	0 (0)	2,091 (5.3)	0.511 (0.492-0.53)				Yes
	Huisache†	Oct. 1997 - Dec. 1997	1,653	403 (24)	16.04	0 (0)	278 (17)	1.44 (1.4-1.48)	✓	✓	✓	
	Huisache†	1998 - 2004	53,044	20,241 (38)	364.87	16 (0.03)	6,101 (12)	1.06 (0.952-1.16)				
	Huisache†	2005 - 2010	46,653	31,229 (67)	57.25	0 (0)	5,825 (12)	0.81 (0.759-0.86)				
	JI Hailey	2005 - 2010	41,970	26,286 (63)	341.22	9 (0.021)	6,273 (15)	0.987 (0.883-1.09)				
	Off Up River Road	2005 - 2010	40,939	34,863 (85)	34.41	0 (0)	1,829 (4.5)	0.463 (0.445-0.48)				
	Port Grain Elevator	2005 - 2010	41,536	31,775 (76)	38.73	0 (0)	2,212 (5.3)	0.478 (0.455-0.501)				
	Solar Estates	2005 - 2010	42,121	28,725 (68)	9.17	0 (0)	1,657 (3.9)	0.426 (0.412-0.439)				
	West End Inner Harbor	2005 - 2010	42,206	24,789 (59)	41.97	0 (0)	4,873 (12)	0.87 (0.834-0.906)				
Sulfur Dioxide	Dona Park	2005 - 2010	43,581	16,427 (38)	72.9	259 (0.59)	NA	0.806 (0.754-0.859)				Yes
	Huisache†	Oct. 1997 - Dec. 1997	2,071	448 (22)	63.62	119 (5.7)	NA	2.37 (2.22-2.52)				
	Huisache†	1998 - 2004	55,555	20,723 (37)	277.56	2983 (5.4)	NA	2.11 (1.93-2.29)				
	Huisache†	2005 - 2010	49,976	32,135 (64)	283.05	741 (1.5)	NA	1.11 (1-1.23)				

Table 21B. Sulfur Compounds – Hourly Stationary Air Monitor Refined Data Screening Results (page 2 of 3)

Chemical	Location	Time Period	Sulfur Compounds Hourly Data									Is this Chemical of Potential Concern?
			Total Number of Samples	Number (and Percent) of Samples above DL	Maximum			Mean				
					Level (ppb)	Number (and Percent) of Samples above Short-Term CV	Number (and Percent) of Samples above Long-Term CV	Level (LCL–UCL) (ppb)	Mean above Long-Term CV*	LCL above Long-Term CV*	UCL above Long-Term CV*	
Sulfur Dioxide (continued)	JI Hailey	2005 - 2010	44,880	23,225 (52)	288.57	1378 (3.1)	NA	1.79 (1.51-2.07)				Yes
	Off Up River Road	2005 - 2010	44,946	17,743 (39)	33.82	83 (0.18)	NA	0.718 (0.683-0.753)				
	Port Grain Elevator	2005 - 2010	44,529	8,198 (18)	145.26	368 (0.83)	NA	0.969 (0.889-1.05)				
	Solar Estates	2005 - 2010	45,093	15,191 (34)	92.86	163 (0.36)	NA	0.705 (0.66-0.751)				
	Tuloso Midway Middle School†	1984 - 1997	101,537	21,710 (21)	630	2193 (2.2)	NA	2.69 (2.48-2.89)				
	Tuloso Midway Middle School†	1998 - 2004	57,932	21,831 (38)	75.97	286 (0.49)	NA	1.04 (0.982-1.1)				
	Tuloso Midway Middle School†	2005 - 2010	49,865	28,972 (58)	19.22	25 (0.05)	NA	0.637 (0.604-0.669)				
	West End Inner Harbor	2005 - 2010	44,756	9,767 (22)	92.44	256 (0.57)	NA	0.681 (0.614-0.747)				

Data Source: Texas Commission on Environmental Quality. 2013. Texas Air Monitoring Information System (TAMIS) web interface. Data downloaded from TAMIS through queries on hourly hydrogen sulfide and sulfur dioxide measurements for dates within the range >=1/1/1980 to <1/1/2011 (separate queries for each parameter by decade) for monitors in the Corpus Christi area. Data downloaded on 28 August 2013.

* Blank cells for hydrogen sulfide indicate value is below the long-term comparison value. Sulfur dioxide does not have a long-term comparison value so its cells are blank.

✓ A check mark indicates value is above the long-term comparison value.

† The Huisache and Tuloso Midway Middle School air monitoring stations operated prior to 2005 and 2005–2010. The data presented in these rows are broken down by various time frames to match the time period breakdowns in other sections of this document and to show trends over time.

Table 21B. Sulfur Compounds – Hourly Stationary Air Monitor Refined Data Screening Results (page 3 of 3)

CV health-based comparison value
DL detection limit
LCL lower confidence limit
NA not applicable
ppb parts per billion
UCL upper confidence limit

Table 22B. Sulfur Dioxide – Mobile Monitoring Events Refined Data Screening Results (page 1 of 2)

Type of Sample	*Sulfur Dioxide Mobile Monitoring Event Data*						
	Total Number of Samples	*Maximum Level (ppb)*	*Number (and Percent) of Samples above 10* ppb*	*Number (and Percent) of Samples above 75† ppb*	*Number (and Percent) of Samples above 200‡ ppb*	*Number (and Percent) of Samples above 400‡ ppb*	*Number (and Percent) of Samples above 1,000‡ ppb*
5-minute Average (July 1993 & Dec 1995)	805	1,665	391 (49)	12 (1.5)	10 (1.2)	7 (0.87)	2 (0.25)
Peak Concentration (Feb 1993 - Mar 2008)	1,109	6,745	524 (47)	71 (6.4)	18 (1.6)	11 (0.99)	4 (0.36)
30-minute Average (Feb 1994 - Mar 2008)	308	1,010	133 (43)	12 (3.9)	2 (0.65)	1 (0.32)	1 (0.32)
Auto - GC Maximum (Dec 1995 – Feb 1996)	38	1,800	18 (47	11 (29)	3 (7.9)	3 (7.9)	3 (7.9)

Data sources:

Texas Natural Resource Conservation Commission. 1994. Corpus Christi mobile laboratory trip, February 19-25, 1994; RTGC and Composite Sampling. Austin, TX.

Texas Natural Resource Conservation Commission. 1995. Valero, Citgo, and Koch Refineries sampling trip for SO_2 and H_2S, December 8-12, 1995. Austin, TX.

Texas Natural Resource Conservation Commission. 1996. Corpus Christi area monitoring network summary of measurements for the period March 1994 – March 1996. Report date 3 June 1996. Austin, TX.

Texas Natural Resource Conservation Commission. 1996. Toxicological evaluation of the results of the mobile monitoring, volatile organic and sulfur compounds, February 4-9, 1996. Report date 12 June 1996. Austin, TX.

Texas Natural Resource Conservation Commission. 1997. Toxicological evaluation of results of mobile monitoring for sulfur compounds, VOCs, carbon monoxide, respirable particulate matter, and metals, Corpus Christi, Nueces County, February 1-7, 1997. Report date 20 May 1997. Austin, TX.

Texas Natural Resource Conservation Commission. 1998. Toxicological evaluation of results of mobile monitoring VOCs and sulfur compounds, Corpus Christi, Nueces County, January 31- February 6, 1998. Austin, TX.

Texas Natural Resource Conservation Commission. 1998. Toxicological evaluation of results of mobile monitoring VOCs, Corpus Christi, Nueces County, December 11 - 15 , 1998. Austin, TX.

Table 22B. Sulfur Dioxide – Mobile Monitoring Events Refined Data Screening Results (page 2 of 2)

Texas Natural Resource Conservation Commission. 2000. Toxicological evaluation of results of mobile monitoring volatile organic compounds and sulfur compounds, Corpus Christi, Nueces County, February 5 – 11, 2000. Report date 16 June 2000. Austin, TX.

Texas Natural Resource Conservation Commission. 2001. Toxicological evaluation of mobile monitoring results for VOCs, H2S, and SO2, Corpus Christi and Three Rivers TX, February 24 - March 1, 2001. Austin, TX.

Texas Commission on Environmental Quality. 2002. Results from Corpus Christi mobile laboratory VOC sampling trip, February 23 – March 1, 2002. Austin, TX.

Texas Commission on Environmental Quality. 2003. Results from Corpus Christi mobile laboratory sampling trip, February 1 – 6, 2003. Austin, TX.

Texas Commission on Environmental Quality. 2003. Results from Corpus Christi mobile laboratory sampling trip, November 15 – 20, 2003. Austin, TX.

Texas Commission on Environmental Quality. 2004. Results from Corpus Christi mobile laboratory sampling trip, November 14-19, 2004. Austin, TX.

Texas Commission on Environmental Quality. 2007. Corpus Christi monitoring project, March 1-8, 2007. Report date 14 September 2007. Austin, TX.

Texas Commission on Environmental Quality. 2009. Corpus Christi monitoring project, March 29-April 4, 2008 and April 21, 2008. Report date 22 June 2009. Austin, TX.

* The short-term comparison value for sulfur dioxide is 10 ppb.

† The primary 1-hour national ambient air quality standard for sulfur dioxide is 75 ppb.

‡ The 200 ppb, 400 ppb, and 1,000 ppb sulfur dioxide levels represent health endpoints from clinical studies. Specifically, 200 ppb is the documented level of asymptomatic effects in sensitive populations, 400 ppb is the documented level of symptomatic effects in sensitive populations, and 1,000 ppb is the documented level of symptomatic effects in the general population.

Auto GC automated gas chromatograph
ppb parts per billion

Table 23B. Sulfur Dioxide – 5-minute Average Stationary Air Monitor Refined Data Screening Results

Location	*Sulfur Dioxide 5-Minute Average Data (2005–2009)*					
	Total Number of Samples	*Maximum Level (ppb)*	*Number (and Percent) of Samples above 10* ppb*	*Number (and Percent) of Samples above 75† ppb*	*Number (and Percent) of Samples above 200‡ ppb*	*Number (and Percent) of Samples above 400‡ ppb*
Huisache	525,470	535.02	21,437 (4.1)	13,085 (2.5)	8,873 (1.7)	2,564 (0.49)
Tuloso Midway Middle School	499,947	41.1	720 (0.14)	0 (0)	0 (0)	0 (0)

Data Source: Texas Commission on Environmental Quality. 2012. Data posted to FTP site by Heather Stewart, TCEQ, and downloaded by Rachel Worley, ATSDR. Contains 2005-2009 sulfur dioxide 5-minute data for the Huisache and Tuloso air monitoring sites. Austin, TX.

* The short-term comparison value for sulfur dioxide is 10 ppb.

† The primary 1-hour national ambient air quality standard for sulfur dioxide is 75 ppb.

‡ The 200 ppb and 400 ppb sulfur dioxide levels represent health endpoints from clinical studies. Specifically, 200 ppb is the documented level of asymptomatic effects in sensitive populations and 400 ppb is the documented level of symptomatic effects in sensitive populations.

ppb parts per billion

Table 24B. TRI Reported Facility Rank in the U.S. based on Total Air Emissions by Chemical and Year*

Chemical	Year	Total Number of U.S. Facilities†	Facility Rank in the U.S. Based on Total Air Emissions by Chemical and Year‡								
			CITGO Deep Sea Terminal	CITGO East	CITGO West	Elementis Chromium	Equistar	Flint Hills East	Flint Hills West	Valero East	Valero West
1,3-Butadiene	2010	179		135	161		27	146	122	159	113
	2005	188		71	75		44	135	125	127	141
	2000	189		NR	NR		75				160
Benzene	2010	736	419	87	422		47	161	21	24	85
	2005	793	733	37	231		112	100	8	32	111
	2000	836	186	57	420		216	110	31	29	153
Chlorine	2010	497		404	376		NR				159
	2005	596		90	50		NR	404		62	33
	2000	749		572			NR		47	NR	117
Chromium Compounds	2010	913				21					
	2005	1003				13					
	2000	1075				16				763	

Source: US Environmental Protection Agency. 2012. Toxics Release Inventory (TRI) Explorer. Releases: facility report: air emissions (in pounds) for facilities in all industries in the US. Facility data downloaded for 1,3-butadiene, benzene, chlorine, and chromium compounds for the years 2000, 2005 and 2010. TRI data updates as of 12 March 2012. Data downloaded from www.epa.gov/tri on 18 April 2012 and 6 September 2012.

* Of the 11 facilities in the Refinery Row areas reporting to TRI, BTB Refining and Martin Operating LP did not report any chemicals of concern noted in this health assessment to during 2000, 2005, and 2010.

† ATSDR did not include in the total number of U.S. facilities column those facilities that reported "0" or "NA" to TRI.

‡ Blank table cells indicate the facility was not listed in TRI to have point source and fugitive air emission releases of the chemical during that year.

NR Not ranked. CITGO East and CITGO West reported "NA" point source and fugitive air emissions of 1,3-butadiene released in 2000. For chlorine point source and fugitive air emissions, Equistar reported "0" in 2010, Equistar reported "NA" in 2005 and 2000, and Valero East reported "0" in 2000. "NA" denotes that the facility submitted Form A and the data for release, waste transfers or quantities of TRI chemicals in waste are not applicable.

TRI Toxics Release Inventory

Table 25B. TRI Reported Nueces County Rank in the U.S. based on Total Air Emissions by Chemical and Year

Chemical	*Year*	*Total Number of Counties**	*Nueces County Rank*
1,3-Butadiene	2010	91	13
	2005	102	21
	2000	102	45
Benzene	2010	362	4
	2005	382	7
	2000	371	9
Chlorine	2010	311	120
	2005	366	17
	2000	457	40
Chromium Compounds	2010	565	28
	2005	597	16
	2000	637	17

Source: US Environmental Protection Agency. 2012. Toxics Release Inventory (TRI) Explorer. Releases: geography county report: air emissions (in pounds) for facilities in all industries in the U.S. County data searches for chemicals 1,3-butadiene, benzene, chlorine, and chromium compounds for the years 2000, 2005 and 2010. TRI data updates as of 10 October 2012. Data downloaded from www.epa.gov/tri on 6 November 2012.

* ATSDR did not include in the total number of counties column those counties that reported a ".", "0", or "NA" to TRI.

TRI Toxics Release Inventory

Table 26B. TRI Reported Total Benzene Emissions (pounds) in Nueces County by Facility and Year

Facility	*Year*	*Total Benzene Emissions (pounds)*
CITGO Deep Sea Terminal	2010	430
	2005	22
	2000	6,586
CITGO East	2010	13,153
	2005	43,510
	2000	34,330
CITGO West	2010	410
	2005	2,765
	2000	798
Equistar	2010	24,561
	2005	12,249
	2000	4,661
Flint Hills East	2010	5,274
	2005	14,636
	2000	17,063
Flint Hills West	2010	40,140
	2005	76,153
	2000	49,447
Ticona Polymers*	2010	3,311
	2005	2,514
	2000	6,339
Valero East	2010	35,732
	2005	45,695
	2000	51,049
Valero West	2010	13,561
	2005	12,292
	2000	9,524

Source: US Environmental Protection Agency. 2012. Toxics Release Inventory (TRI) Explorer. Releases: facility report: air emissions (in pounds) for facilities in all industries in the US. Facility data downloaded for benzene for the years 2000, 2005 and 2010. TRI data updates as of 12 March 2012. Data downloaded from www.epa.gov/tri on 18 April 2012 and 6 September 2012.

* Located in Bishop, Nueces County, TX.

TRI Toxics Release Inventory

Table 27B. Various Concentrations of Select Chemicals and associated Cancer Risks

Chemical	*Concentration (ppb) associated with a*			*Highest Refinery Row Mean (ppb)*
	1×10^{-4} Cancer Risk	*1×10^{-5} Cancer Risk*	*1×10^{-6} Cancer Risk*	
Arsenic	0.0075	0.00075	0.000075	0.00035
Benzene	4	0.4	0.04	2.21
1,3-Butadiene	1.5	0.15	0.015	0.076
Cadmium	0.012	0.0012	0.00012	0.00128*
Carbon Tetrachloride	2.6	0.26	0.026	0.11
Chloroform	0.89	0.089	0.0089	0.017
Chloroprene	0.091	0.0091	0.00091	0.007†
Chromium	0.0039	0.00039	0.000039	0.0008
Cobalt	0.0046	0.00046	0.000046	0.00028*
1,2-Dibromoethane	0.022	0.0022	0.00022	0.01*
1,2-Dichloroethane	0.95	0.095	0.0095	0.011
1,2-Dichloropropane	2.2	0.22	0.022	0.03*
Isoprene	120	12	1.2	0.086
Lead	0.15	0.015	0.0015	0.00029
Naphthalene	0.6	0.06	0.006	0.058
1,1,2,2-Tetrachloroethane	0.25	0.025	0.0025	0.01*
1,1,2-Trichloroethane	1.1	0.11	0.011	0.007†
Trichloroethylene	4.5	0.45	0.045	0.055
Vinyl Chloride	4.4	0.44	0.044	0.059*

* The 95th percentile is provided, not the mean, because the chemical was detected in less than 20% of the samples.

† Because the chemical was detected in less than 5% of the samples at each location, the 95th percentile represents a nondetect value. As a result, ATSDR provides the reporting limit (0.01 ppb) divided by the square root of two.

ATSDR Agency for Toxic Substances and Disease Registry
ppb parts per billion

Table 28B. Corpus Christi Refinery Row Cancer Risks of Select Chemicals (page 1 of 2)

Chemical	*Highest Mean ($\mu g/m^3$)*	*U.S. EPA IUR ($\mu g/m^3$)$^{-1}$*	*Quantitative Cancer Risk Estimate**	*Qualitative Cancer Risk†*	*Percent Contribution to Overall Cancer Risk‡*
Arsenic	0.00108	4.3×10^{-3}	4.6×10^{-6}	Very Low	2.6
Benzene	7.06	7.8×10^{-6}	5.5×10^{-5}	Low	31
1,3-Butadiene	0.168	3.0×10^{-5}	5.0×10^{-6}	Very Low	2.8
Cadmium	0.0059§	1.8×10^{-3}	1.1×10^{-5}	Low	6.1
Carbon Tetrachloride	0.692	6.0×10^{-6}	4.2×10^{-6}	Very Low	2.3
Chloroform	0.083	2.3×10^{-5}	1.9×10^{-6}	Very Low	1.1
Chloroprene	0.0253¶	3.0×10^{-4}	7.6×10^{-6}	Very Low	4.2
Chromium	0.0017	1.2×10^{-2}**	2.0×10^{-5}	Low	11
Cobalt	0.00068§	9.0×10^{-3}	6.1×10^{-6}	Very Low	3.4
1,2-Dibromoethane	0.077§	6.0×10^{-4}	4.6×10^{-5}	Low	26
1,2-Dichloroethane	0.045	2.6×10^{-5}	1.2×10^{-6}	Very Low	0.7
1,2-Dichloropropane	0.139§	1.0×10^{-5}††	1.4×10^{-6}	Very Low	0.8
Isoprene	0.24	8.1×10^{-7}‡‡	7.0×10^{-8}	Insignificant	0.0
Lead	0.00243	8.0×10^{-5}§§	1.9×10^{-7}	Insignificant	0.1
Naphthalene	0.304	3.4×10^{-5}††	1.0×10^{-5}	Low	5.6
1,1,2,2-Tetrachloroethane	0.069§	5.8×10^{-5}††	4.0×10^{-6}	Very Low	2.2
1,1,2-Trichloroethane	0.038¶	1.6×10^{-5}	6.1×10^{-7}	Insignificant	0.3
Trichloroethylene	0.296	4.1×10^{-6}	1.2×10^{-6}	Very Low	0.7
Vinyl Chloride	0.151§	8.8×10^{-6}	1.3×10^{-6}	Very Low	0.7

* Quantitative cancer risk estimates were calculated by multiplying the highest mean chemical concentration by its U.S. EPA IUR. Cancer risk estimates are expressed as a probability; that is, the proportion of a population that may be affected by a carcinogen during a lifetime of exposure (24 hours/day, 365 days/year, for 70 years). For example, an estimated cancer risk of 1×10^{-5} represents a possible 1 excess cancer case in a population of 100,000.

† The qualitative cancer risk descriptions provided in this table were developed for this public health evaluation to assist in describing the level of estimated cancer risk posed by Refinery Row air toxics.

‡ The percent contribution to overall cancer risk for each chemical was calculated by dividing the chemical's quantitative cancer risk estimate by the cumulative cancer risk estimate for Refinery Row (1.8×10^{-4}).

§ The 95th percentile is provided, not the mean, because the chemical was detected in less than 20% of the samples.

¶ Because the chemical was detected in less than 5% of the samples at each location, the 95th percentile represents a nondetect value. As a result, ATSDR provides the reporting limit divided by the square root of two.

** The U.S. EPA IUR is for hexavalent chromium.

†† The value provided is the California EPA IUR, not the U.S. EPA IUR.

‡‡ The value provided is the Texas Commission on Environmental Quality cancer unit risk factor in (parts per billion)$^{-1}$.

Table 28B. Corpus Christi Refinery Row Cancer Risks of Select Chemicals (page 2 of 2)

§§ California EPA has IURs for 4 lead compounds, and lead acetate was the highest and most conservative (although all were within an order of magnitude). The value provided is for lead acetate.

CV	health-based comparison value
IUR	inhalation unit risk
$\mu g/m^3$	micrograms per cubic meter
U.S. EPA	U.S. Environmental Protection Agency

Table 29B. Hazard Quotient of Select Chemicals

*Chemical**	*Hazard Quotient*†
Arsenic	0.072
Benzene	0.74
1,3-Butadiene	0.084
Carbon Tetrachloride	0.053
Chloroform	0.0085
Chromium	0.34‡
1,2-Dichloroethane	0.011
Hydrogen Sulfide	1.0
Isoprene	0.043
Naphthalene	0.10
Toluene	0.056
Trichloroethylene	0.15

* Chemicals listed in this table met these three criteria:

1. Were selected for further consideration based on ATSDR's data screening (see Table 2 in Section 4.3.3),
2. Had a readily available minimal risk level (MRL) or reference concentration (RfC), and
3. Were detected in more than 20% of the samples, allowing ATSDR to calculate a mean concentration based on the procedures described in Appendix G.

† The hazard quotient (HQ) is calculated by dividing the highest mean concentration of a chemical by its MRL or RfC, whichever is lowest.

‡ The MRL for hexavalent chromium was used in the HQ calculation.

HQ hazard quotient
MRL minimal risk level
RfC reference concentration

Table 30B. Hazard Index for Select Chemicals

Endpoint (Organ System)	*Hazard Quotient**					*Hazard Index*†
	Benzene	*Chromium*	*Hydrogen Sulfide*	*Naphthalene*	*Trichloroethylene*	
Respiratory	0.74	0.34‡	1.0‡	0.10‡		2.2
Hematological	0.74‡					0.74
Hepatic					0.15	0.15
Renal		0.34			0.15	0.49
Endocrine (adrenal)			1.0			1.0
Immunological	0.74				0.15	0.89
Neurological	0.74		1.0		0.15	1.9
Developmental and Reproductive	0.74				0.15‡	0.89

* Hazard quotients (HQs) are provided in Table 29B, Appendix B. Only chemicals with HQs greater than 0.1 are included in this table. Blank cells indicate the chemical is not expected to be toxic for the endpoint of concern so no HQ was provided.

† The hazard index (HI) is the sum of the HQs for a specific endpoint.

‡ The critical (and most sensitive) endpoint used in the derivation of the MRL or RfD. ATSDR acknowledges that the chemical's contribution to other health effects (especially those that have been documented to occur at higher concentrations than the critical endpoint) may be overestimated by the hazard quotient.

HI hazard index
HQ hazard quotient
MRL minimal risk level
RfD reference dose

Table 31B. ATSDR and DSHS History of Events, Corpus Christi, TX (page 1 of 3)

Date	*Event*
1995	ATSDR received its first of seven petitions related to Corpus Christi
August 1995	TDH released a symptom and prevalence survey report of the Oak Park Neighborhood
December 1996	TDH released a health consultation that addressed the former smelter petition
January 2001	TDH released a health consultation that addressed the landfill petition
August 2001	TDH released a report that analyzed the total birth defect occurrence in a list of ZIP codes covering almost all of Nueces County
September 2001	TDH analyzed data for birth prevalence of 49 routinely analyzed birth defects
April 2002	TDH released a report that analyzed the geographic distribution of the six birth defects showing excess rates
February 2003	ATSDR began its activities related to the Corpus Christi Refinery Row petition
December 2003	TDH completed a case-control study of birth defects and proximity of mother's residence to sites of concern in Corpus Christi
July 2006	DSHS reexamined specific birth defects to determine which (if any) were elevated among babies born from 1996–2002 to mothers in the original area of concern, the list of ZIP codes covering almost all of Nueces County
January 2008	DSHS conducted a follow-up case-control study to measure the association between the 15 selected birth defects and proximity of mother's residence to the sites of concern in Corpus Christi
December 2008	DSHS' TCR examined the occurrence of cancer in zip code 78407, Corpus Christi
July 2009	Congressman Solomon Ortiz requested ATSDR find answers for the community
November 2009	ATSDR's Director met with local community leaders, residents, elected officials, government partners, and industry representatives

Table 31B. ATSDR and DSHS History of Events (page 2 of 3)

Date	*Event*
December 2009	ATSDR visited the site to engage in discussions with interested stakeholders, to participate in a community meeting, and to tour the locations of the ambient air monitors
January 2010	ATSDR met with community member to solicit input for the Exposure Investigation
March 2010	ATSDR conducted field activities as part of the Exposure Investigation
April 2010	ATSDR participated in an Corpus Christi Air Quality Project Advisory Board meeting
May 2010	ATSDR mailed participants of the Exposure Investigation letters that contained their individual test results and what they mean
June 2010	ATSDR staff were available to meet one-on-one with Exposure Investigation participants to address questions about their individual results
December 2010	DSHS compared occurrence of birth defects in the three-county Corpus Christi area (Nueces, Kleberg, San Patricio Counties) with the rest of the Texas Birth Defects Registry area and with the other counties covered by a program to screen for cardiovascular birth defects
January 2011	ATSDR released the Exposure Investigation report and discussed the report at a public meeting
March 2011	ATSDR participated in the Regional Health Awareness Board public information forum
June 2011	ATSDR worked with local partners and held workshops in Corpus Christi to address environmental, safety, and health issues of concern to the community
July 2011	ATSDR participated in the 46th Annual Health Fair
July 2011	DSHS collected blood and urine samples from Dona Park, Manchester Place, and Academy Heights residents
September 2011	DSHS mailed letters with individual test results and an explanation of what they mean to residents who participated in the July 2011 biological screening
October 2011	DSHS held a second biological screening for Dona Park, Manchester Place, and Academy Heights residents, and later in the month, mailed letters with individual test results and an explanation of what they mean to participants

Table 31B. ATSDR and DSHS History of Events (page 3 of 3)

Date	*Event*
November 2011	DSHS released its final report on blood and urine screening of the Dona Park, Manchester Place, and Academy Heights neighborhoods
November 2011	TCEQ, DSHS, and EPA held a meeting to present the Dona Park biological and environmental results to the public
November 2011	ATSDR participated in the EPA Environmental Summit in Corpus Christi
April 2012	ATSDR participated in the Environmental Justice Interagency Working Group meeting
July 2012	ATSDR participated in the 47th Annual Health Fair
May 2013	ATSDR released a Community Activity Report that updated residents on Corpus Christi Refinery Row activities

ATSDR Agency for Toxic Substances and Disease Registry
EPA U.S. Environmental Protection Agency
TCR Texas Cancer Registry
TDH Texas Department of Health (note: name changed to the Texas Department of State Health Services in 2004)
DSHS Texas Department of State Health Services

Table 32B. Comparison of Benzene Data from AQS and Industry Auto GCs by Wind Direction, Corpus Christi, TX*

Wind Direction	Kendall's Tau	p-value
NNE	0.28	<0.001
ENE	0.21	<0.001
E	0.17	<0.001
ESE	0.20	<0.001
SSE	0.15	<0.001
S	0.23	<0.001
SSW	0.38	<0.001
WSW	0.42	<0.001
W	0.37	<0.001
WNW	0.40	<0.001
NNW	0.36	<0.001
N	0.32	<0.001

Data Sources:

Texas Commission on Environmental Quality. 2010. Data posted to FTP site by Melanie Hotchkiss, TCEQ, and downloaded by John Wilhelmi, Eastern Research Group, Inc. Contains continuous 2005-2009 sulfur compound and volatile organic compound data for both TCEQ and Corpus Christi Air Quality Project air monitoring sites. Austin, TX.

ToxStrategies, Inc. 2011. September 8th email from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005–2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

The University of Texas. 2011. April 25th email from Dr. David Sullivan, The University of Texas at Austin, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing an Excel attachment with the continuous 2010 volatile organic compounds data for the Solar Estates and Oak Park air monitoring sites. Austin, TX.

* Wind direction was categorized by the four cardinal directions (North, East, South, and West) and 8 intra-cardinal directions (North by Northeast (NNE), East by Northeast (ENE), East by Southeast (ESE), South by Southwest (SSW), West by Southwest (WSW), West by Northwest (WNW), and North by Northwest(NNW)). The wind direction sectors correspond to 30 degrees of a circle. See also Figure 10A, Appendix A.

AQP Corpus Christi Air Quality Project
Auto GC automatic gas chromatograph

Table 33B. Long Term Trends in Benzene Concentrations (Industry Canister Data), Corpus Christi, TX*

Site	*Kendall's Tau*	*P*	*Slope (change in concentration per year)*	*Intercept (at year 1996)*
Crossley Elementary School	-0.28	<0.001	-0.022	0.51
Oak Park Elementary School	-0.19	<0.001	-0.023	0.66
Tuloso Midway Elementary School	-0.2	<0.001	-0.016	0.47
Tuloso Midway Middle School	-0.25	<0.001	-0.014	0.38
Up River Road	-0.28	<0.001	-0.016	0.41

Data Source: ToxStrategies, Inc. 2011. September 8th email from Dr. Laurie Haws, ToxStrategies, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing attachments with the pre-2005 and 2005−2010 Huisache Auto GC and industry canister data for the Corpus Christi site. Austin, TX.

* Monotonic trends in concentrations of benzene at industry sites using Kendall's Tau and Akritas-Theil-Sen nonparametric line, with the Turnbull estimate of intercept. Intercept is the expected median value of benzene in 1996.

Table 34B. Mother's Age, Educational Attainment, and Race/Ethnicity by Areas of Increasing Distance Surrounding Corpus Christi Refinery Row: DSHS Birth Defects Registry, 1999-2007

Characteristics	*Proximity to Refinery Row*			
	Up to 2 miles N=1,768	*2 to 5 miles N=2,971*	*5 to 10 miles N=4,023*	*More than 10 miles N=2,951*
Mother's age	Number (percentage)			
< 20 years	308 (17.4%)	607 (20.4%)	560 (13.9%)	492 (16.7%)
20-24 years	624 (35.3%)	891 (30.0%)	1,236 (30.7%)	1,024 (34.7%)
25-29 years	389 (22.0%)	745 (25.1%)	1,060 (26.4%)	643 (21.8%)
30-34 years	276 (15.6%)	371 (12.5%)	609 (15.1%)	494 (16.7%)
35-39 years	114 (6.5%)	236 (7.9%)	410 (10.2%)	230 (7.8%)
40+ years	57 (3.2%)	121 (4.1%)	148 (3.7%)	68 (2.3%)
Mother's age was not statistically significantly different among proximity areas.*				
Mother's education	Number (percentage)			
Less than high school (HS) graduate	843 (48.0%)	1,129 (38.4%)	884 (22.1%)	814 (27.7%)
HS graduate	640 (36.4%)	1,019 (34.7%)	1,333 (33.3%)	1,012 (34.4%)
More than HS	275 (16.6%)	792 (26.9%)	1,783 (44.6%)	1,116 (37.9%)
missing	10	31	23	9
A statistically significant difference was observed for maternal education across the proximity areas, p<0.0001.* A greater percentage of mothers living up to 2 miles away had less than a high school education.				
Mother's race/ethnicity	Number (percentage)			
Hispanic	1,433 (81.0%)	2,371 (79.8%)	2,510 (62.4%)	1,676 (56.8%)
White non-Hispanic	247 (14.0%)	460 (15.5%)	1,285 (31.9%)	1,165 (39.5%)
Black non-Hispanic	80 (4.5%)	124 (4.2%)	153 (3.8%)	80 (2.7%)
Other non-Hispanic	8 (0.5%)	16 (0.5%)	75 (1.9%)	30 (1.0%)
A statistically significant difference was observed for race/ethnicity across the proximity areas, p<0.0001.*A greater percentage of mothers living up to 2 miles away were of Hispanic origin.				

Data Source: Texas Department of Birth Defect Registry data for 1999–2007 for 63 birth defects.

* Chi-square test of independence was used. The Chi-square statistical test was used to compare globally percentages within maternal categories across the four areas of proximity. The Chi-square test uses marginal numbers in the cross-tabulation of maternal characteristic and proximity areas to calculate expected value. The statistical test compares expected values with observed. For determination of statistical significance, ATSDR considered p < 0.05 to be statistically significant. The p value is the probability that the deviation of the observed from that expected is due to chance alone. In this case, using p < 0.05, one would expect the deviation to be due to chance alone 5% of the time or less.

DSHS Texas Department of State Health Services
N total number of mothers within the specified proximity area

Table 35B. Number and Prevalence of Selected Birth Defects in the Corpus Christi area by Areas of Increasing Distance from Refinery Row, 1999–2007 (page 1 of 3)

Code	*Description*	*Number of Birth Defect Cases (Prevalence per 10,000 births)*			
		Up to 2 miles	*2 to 5 miles*	*5 to 10 miles*	*More than 10 miles*
Total Birth Defects					
	Cases with one or more birth defects	560 (701.7)	931 (670.8)	1,240 (644.2)	913 (627.9)
Birth Defects With Codes < 740.0					
243.9	Hypothyroidism, congenital	1 (1.2)	5 (3.6)	7 (3.6)	3 (2.1)
279.1	DiGeorge syndrome	1 (1.2)	3 (2.2)	3 (1.6)	4 (2.7)
524.0	Abnormalities of jaw size – micro/macrognathia	20 (25.1)	40 (28.8)	46 (23.9)	39 (26.8)
Brain, Eye, Ear Defects					
742.1	Microcephalus	15 (18.8)	14 (10.1)	23 (11.9)	16 (11.0)
742.4	Other specified anomalies of brain	18 (22.5)	17 (12.2)	23 (11.9)	22 (15.1)
742.5	Other specified anomalies of spinal cord	4 (5.01)	2 (1.4)	8 (4.2)	7 (4.8)
742.9	Unspecified anomalies of central nervous system	1 (1.2)	1 (0.7)	1 (0.5)	1 (0.7)
743.1	Microphthalmos	2 (2.5)	8 (5.8)	7 (3.6)	4 (2.7)
743.2	Buphthalmos	1 (1.2)	3 (2.2)	1 (0.5)	1 (0.7)
743.6	Cong. Anomalies of eyelids, lacrimal system, orbit	12 (15.0)	5 (3.6)	11 (5.7)	11 (7.6)
744.2	Other specified anomalies of ear	19 (23.8)	41 (29.5)	53 (27.5)	39 (26.8)
744.3	Unspecified anomalies of ear	1 (1.2)	1 (0.7)	5 (2.6)	1 (0.7)
744.8	Other specified anomalies of face and neck	4 (5.0)	15 (10.8)	17 (8.8)	13 (8.9)
744.9	Unspecified anomalies of face and neck	14 (17.5)	30 (21.6)	23 (11.9)	26 (17.9)
Cardiovascular Defects					
745.0	Common truncus	1 (1.2)	5 (3.6)	3 (1.6)	1 (0.7)
745.4	Ventricular septal defect	91 (114.0)	126 (90.8)	188 (97.7)	111 (76.3)
745.5	Ostium secundum type atrial septal defect	328 (411.0)	552 (397.7)	732 (380.3)	528 (363.1)
746.0	Anomalies of pulmonary valve	9 (11.3)	12 (8.6)	30 (15.9)	23 (15.8)
746.3	Congenital stenosis of aortic valve	4 (5.0)	2 (1.4)	10 (5.2)	6 (4.1)
746.4	Congenital insufficiency of aortic valve	7 (8.8)	5 (3.6)	15 (7.8)	10 (6.9)
746.8	Other specified anomalies of the heart	52 (65.1)	97 (69.9)	119 (61.8)	104 (71.5)
747.0	Patent ductus arteriosus	102 (127.8)	179 (129.0)	265 (137.7)	199 (136.8)
747.1	Coarctation of aorta	9 (11.3)	14 (10.1)	21 (10.9)	17 (11.7)
747.2	Other anomalies of aorta	49 (61.4)	54 (38.9)	101 (52.5)	65 (44.7)
747.3	Anomalies of pulmonary artery	154 (193.0)	253 (182.3)	324 (168.3)	246 (169.2)
747.6	Other anomalies of peripheral vascular system	2 (2.5)	14 (10.1)	3 (1.6)	10 (6.9)
747.8	Other specified anomalies of circulatory system	2 (2.5)	3 (2.2)	2 (1.0)	4 (2.7)

Table 35B. Number and Prevalence of Selected Birth Defects in the Corpus Christi area by Areas of Increasing Distance from Refinery Row, 1999–2007 (page 2 of 3)

Code	Description	*Number of Birth Defect Cases (Prevalence per 10,000 births)*			
		Up to 2 miles	*2 to 5 miles*	*5 to 10 miles*	*More than 10 miles*
Respiratory System Defects					
748.5	Agenesis or aplasia of lung	4 (5.0)	7 (5.0)	12 (6.2)	9 (6.2)
748.6	Other anomalies of the lung	2 (2.5)	1 (0.7)	1 (0.5)	1 (0.7)
748.8	Other specified anomalies of respiratory system	0	0	4 (2.1)	0
Digestive System Defects					
750.2	Other specified anomalies of mouth and pharynx	9 (11.3)	19 (13.7)	13 (6.7)	10 (6.9)
750.5	Congenital hypertrophic pyloric stenosis	34 (42.6)	57 (41.1)	71 (36.9)	58 (39.9)
750.6	Congenital hiatus hernia	1 (1.2)	1 (0.7)	2 (1.0)	3 (2.1)
751.2	Atresia/stenosis of large intestine, rectum, anal canal	9 (11.3)	7 (5.0)	16 (8.3)	11 (7.6)
751.4	Anomalies of intestinal fixation	2 (2.5)	9 (6.5)	17 (8.8)	19 (13.1)
751.5	Other anomalies of intestine	9 (11.3)	14 (10.1)	19 (9.9)	13 (8.9)
Genitourinary Defects					
752.4	Anom. of cervix, vagina, external female genitalia	5 (6.3)	12 (8.6)	18 (9.3)	9 (6.2)
753.0	Renal agenesis and dysgenesis	8 (10.0)	10 (7.1)	20 (10.4)	11 (7.6)
753.2	Obstructive defects of renal pelvis and ureter	45 (56.4)	90 (64.8)	112 (58.2)	72 (49.5)
753.3	Other specified anomalies of kidney	6 (7.5)	11 (7.9)	16 (8.3)	11 (7.6)
753.8	Other specified anomalies of bladder and urethra	4 (5.0)	4 (2.9)	8 (4.2)	4 (2.7)
Musculoskeletal Defects					
754.0	Certain anomalies of skull, face, and jaw	15 (18.8)	28 (20.2)	48 (24.9)	33 (22.7)
754.5	Varus (inward) deformities of feet	9 (11.3)	21 (15.1)	20 (10.4)	13 (8.9)
754.6	Valgus (outward) deformities of feet	10 (12.5)	14 (10.1)	27 (14.0)	12 (8.2)
754.8	Other specified cong musculoskeletal deformities	10 (12.5)	26 (18.7)	33 (17.1)	26 (17.9)
755.1	Syndactyly	6 (7.5)	15 (10.8)	11 (5.7)	17 (11.7)
755.3	Reduction defects of lower limb	3 (3.8)	5 (3.6)	6 (3.1)	2 (1.4)
755.5	Other anomalies of upper limb, inc shoulder girdle	7 (8.8)	15 (10.8)	22 (11.4)	22 (15.1)
755.6	Other anomalies of lower limb, inc pelvic girdle	9 (11.3)	26 (18.7)	35 (18.2)	24 (16.5)
755.8	Other specified anomalies of unspecified limb	7 (8.8)	9 (6.5)	9 (4.7)	14 (9.6)
756.0	Anomalies of skull and face bones	26 (32.3)	42 (30.3)	55 (28.6)	38 (26.1)
756.1	Anomalies of spine	6 (7.5)	14 (10.1)	14 (7.3)	11 (7.6)
756.3	Other anomalies of ribs and sternum	6 (7.5)	15 (10.8)	20 (10.4)	6 (4.1)
756.6	Anomalies of diaphragm	6 (7.5)	8 (5.6)	13 (6.7)	8 (5.5)

Table 35B. Number and Prevalence of Selected Birth Defects in the Corpus Christi area by Areas of Increasing Distance from Refinery Row, 1999–2007 (page 3 of 3)

Code	Description	Number of Birth Defect Cases (Prevalence per 10,000 births)			
		Up to 2 miles	2 to 5 miles	5 to 10 miles	More than 10 miles
756.70	Omphalocele	0	3 (2.2)	6 (3.1)	5 (3.4)
756.71	Gastroschisis	4 (5.0)	10 (7.2)	15 (7.8)	10 (6.9)
Miscellaneous Defects					
757.3	Other specified anomalies of skin	8 (10.0)	16 (11.5)	27 (4.0)	16 (11.0)
757.5	Specified anomalies of nails	4 (5.0)	7 (5.0)	14 (7.3)	7 (4.81)
757.8	Other specified anomalies of the integument	0	1 (0.72)	6 (3.1)	3 (2.06)
758.4	Balanced autosomal translocation in normal indl.	0	2 (1.4)	1 (0.5)	0
758.9	Conditions due to anom of unspec chromosomes	1 (1.2)	1 (0.7)	1 (0.5)	1 (0.69)
759.2	Anomalies of other endocrine glands	1 (1.2)	2 (1.4)	5 (2.6)	7 (4.81)
Other Defects					
	Neural Tube Defects (27 of 55 cases did not map to areas)	5 (6.3)	7 (5.0)	10 (5.2)	6 (4.13)
	Conotruncal Heart Defects	5 (6.3)	15 (10.8)	18 (9.3)	16 (11.0)

Data Source: Texas Department of Birth Defect Registry data for 1999–2007 for 63 birth defects.

Table 36B. Prevalence Ratios of Selected Birth Defects in the Corpus Christi Area within 2 Miles of Refinery Row versus More than 10 Miles from Refinery Row, 1999–2007 (page 1 of 3)

Code	Description	*Prevalence Ratios (up to 2 miles versus more than 10 miles)*	
		*Crude Ratio (95% CI)**	*Adjusted Ratio (95% CI)*[†]
Total Birth Defects			
	Cases with one or more birth defects	1.1 (1.0 – 1.2)	1.1 (1.0 – 1.2)
Birth Defects With Codes < 740.0			
243.9	Hypothyroidism, congenital	0.6 (0.3 – 4.7)	0.5 (0.0 – 5.3)
279.1	DiGeorge syndrome	0.4 (0.0 – 3.1)	0.5 (0.0 – 5.5)
524.0	Abnormalities of jaw size – micro/macrognathia	0.9 (0.5 – 1.6)	0.8 (0.4 – 1.5)
Brain, Eye, Ear Defects			
742.1	Microcephalus	1.7 (0.8 – 3.5)	1.3 (0.5 – 3.3)
742.4	Other specified anomalies of brain	1.5 (0.8 – 2.8)	1.4 (0.6 – 3.2)
742.5	Other specified anomalies of spinal cord	1.0 (0.3 – 3.4)	1.2 (0.3 – 4.9)
742.9	Unspecified anomalies of central nervous system	1.8 (0.1 – 46.0)	1.2 (0.3 – 39.1)
743.1	Microphthalmos	0.9 (0.1 – 4.7)	0.7 (0.1 – 3.3)
743.2	Buphthalmos	1.8 (0.1 – 46.0)	1.8 (0.2 – 19.7)
743.6	Cong. Anomalies of eyelids, lacrimal system, orbit	2.0 (0.9 – 4.6)	1.8 (0.8 – 4.3)
744.2	Other specified anomalies of ear	0.9 (0.5 – 1.5)	0.8 (0.4 – 1.4)
744.3	Unspecified anomalies of ear	1.8 (0.1 – 46.0)	--
744.8	Other specified anomalies of face and neck	0.6 (0.2 – 1.6)	0.5 (0.1 – 1.5)
744.9	Unspecified anomalies of face and neck	1.0 (0.5 – 1.8)	0.9 (0.5 – 1.6)
Cardiovascular Defects			
745.0	Common truncus	1.8 (.01 – 46.0)	1.9 (0.0 – 119)
745.4	Ventricular septal defect	**1.5 (1.1 – 2.0)**	**1.4 (1.1 – 1.8)**
745.5	Ostium secundum type atrial septal defect	1.1 (1.0 – 1.3)	1.1 (1.0 - 1.3)
746.0	Anomalies of pulmonary valve	0.7 (0.3 – 1.5)	0.8 (0.3 – 1.8)
746.3	Congenital stenosis of aortic valve	1.2 (0.3 – 4.2)	1.4 (0.3 - 5.7)
746.4	Congenital insufficiency of aortic valve	1.3 (0.5 – 3.3)	1.3 (0.3 – 4.9)
746.8	Other specified anomalies of the heart	0.9 (.06 – 1.3)	0.9 (0.7 – 1.3)
747.0	Patent ductus arteriosus	0.9 (0.7 – 1.2)	0.9 (0.7 – 1.2)
747.1	Coarctation of aorta	1.0 (0.4 – 2.1)	0.9 (0.4 – 2.0)
747.2	Other anomalies of aorta	1.4 (0.9 – 2.0)	1.4 (0.9 – 2.1)
747.3	Anomalies of pulmonary artery	1.1 (0.9 – 1.4)	1.1 (0.9 – 1.4)
747.6	Other anomalies of peripheral vascular system	0.4 (0.1 – 1.4)	0.4 (0.1 – 1.6)
747.8	Other specified anomalies of circulatory system	0.9 (0.1 – 4.7)	1.1 (0.1 – 8.2)
Respiratory System Defects			
748.5	Agenesis or aplasia of lung	0.8 (0.2 – 2.5)	0.8 (0.2 – 3.0)
748.6	Other anomalies of the lung	3.6 (0.3 – 78.3)	6.7 (0.6 – 137)
748.8	Other specified anomalies of respiratory system	--	--

Table 36B. Prevalence Ratios of Selected Birth Defects in the Corpus Christi Area within 2 Miles of Refinery Row versus More than 10 Miles from Refinery Row, 1999–2007 (page 2 of 3)

Code	*Description*	*Prevalence Ratios (up to 2 miles versus more than 10 miles)*	
		*Crude Ratio (95% CI)**	*Adjusted Ratio (95% CI)*[†]
Digestive System Defects			
750.2	Other specified anomalies of mouth and pharynx	1.6 (0.6 – 4.1)	1.5 (0.6 – 3.9)
750.5	Congenital hypertrophic pyloric stenosis	1.1 (0.7 – 1.6)	1.0 (0.6 – 1.7)
750.6	Congenital hiatus hernia	0.6 (0.0 – 4.7)	0.6 (0.0 – 9.7)
751.2	Atresia/stenosis of large intestine, rectum, anal canal	1.5 (0.6 – 3.6)	1.8 (0.5 – 5.6)
751.4	Anomalies of intestinal fixation	0.2 (0.0 – 0.7)	0.2 (0.0 – 0.7)
751.5	Other anomalies of intestine	1.3 (0.5 – 2.9)	1.5 (0.6 – 3.7)
Genitourinary Defects			
752.4	Anom. of cervix, vagina, external female genitalia	1.0 (0.3 – 2.9)	1.0 (0.2 – 3.8)
753.0	Renal agenesis and dysgenesis	1.3 (0.5 – 3.3)	1.2 (0.4 – 3.5)
753.2	Obstructive defects of renal pelvis and ureter	1.1 (0.8 – 1.6)	1.0 (0.7 – 1.5)
753.3	Other specified anomalies of kidney	1.0 (0.3 – 2.6)	0.9 (0.3 – 2.2)
753.8	Other specified anomalies of bladder and urethra	1.8 (0.4 – 7.7)	2.1 (0.5 – 8.4)
Musculoskeletal Defects			
754.0	Certain anomalies of skull, face, and jaw	0.8 (0.4 – 1.5)	0.8 (0.4 – 1.4)
754.5	Varus (inward) deformities of feet	1.3 (0.5 – 2.9)	1.3 (0.3 – 3.6)
754.6	Valgus (outward) deformities of feet	1.5 (0.6 – 3.5)	1.7 (0.7 – 4.2)
754.8	Other specified cong musculoskeletal deformities	0.7 (0.3 – 1.4)	0.6 (0.3 – 1.3)
755.1	Syndactyly	0.6 (0.2 – 1.5)	0.6 (0.2 – 1.7)
755.3	Reduction defects of lower limb	2.7 (0.4 – 20.7)	2.1 (0.1 – 32.2)
755.5	Other anomalies of upper limb, inc shoulder girdle	0.6 (0.2 – 1.3)	0.5 (0.2 – 1.1)
755.6	Other anomalies of lower limb, inc pelvic girdle	0.7 (0.3 – 1.4)	0.6 (0.3 – 1.2)
755.8	Other specified anomalies of unspecified limb	0.9 (0.3 – 2.2)	0.8 (0.2 – 2.4)
756.0	Anomalies of skull and face bones	1.2 (0.7 – 2.0)	1.1 (0.7 – 1.9)
756.1	Anomalies of spine	1.0 (0.3 – 2.6)	0.9 (0.3 – 2.4)
756.3	Other anomalies of ribs and sternum	1.8 (0.6 – 5.8)	1.9 (0.6 – 5.7)
756.6	Anomalies of diaphragm	1.4 (0.4 – 3.9)	1.3 (0.3 – 5.8)
756.70	Omphalocele	--	--
756.71	Gastroschisis	0.7 (0.2 – 2.2)	0.8 (0.2 – 2.2)
Miscellaneous Defects			
757.3	Other specified anomalies of skin	0.9 (0.4 – 2.1)	1.0 (0.4 – 2.4)
757.5	Specified anomalies of nails	1.0 (0.3 – 3.4)	1.0 (0.2 – 4.3)
757.8	Other specified anomalies of the integument	--	--
758.4	Balanced autosomal translocation in normal indl.	--	--

Table 36B. Prevalence Ratios of Selected Birth Defects in the Corpus Christi Area within 2 Miles of Refinery Row versus More than 10 Miles from Refinery Row, 1999–2007 (page 3 of 3)

Code	*Description*	*Prevalence Ratios (up to 2 miles versus more than 10 miles)*	
		*Crude Ratio (95% CI)**	*Adjusted Ratio (95% CI)†*
758.9	Conditions due to anom of unspec chromosomes	1.8 (0.1 – 46.0)	2.2 (0.1 – 69)
759.2	Anomalies of other endocrine glands	0.3 (0.0 – 1.5)	0.2 (0.0 – 1.7)
Other Defects			
	Neural Tube Defects (27 of 55 cases did not map to areas)	1.5 (0.4 – 5.0)	2.0 (0.5 - 7.6)
	Conotruncal Heart Defects	0.6 (0.2 – 1.4)	0.8 (0.3 – 1.8)

Data Source: Texas Department of Birth Defect Registry data for 1999–2007 for 63 birth defects.

* A prevalence rate ratio and 95% confidence interval (CI) for birth defect occurrence up to 2 miles compared with the occurrence in the area more than 10 miles from Refinery Row using crude and adjusted prevalence rate ratios. A 95% CI that does not include 1.0 indicates a statistically significant increase of the birth defect in close proximity to Refinery Row.

† Adjusted for maternal age, race/ethnicity, and educational attainment.

-- Indicates not enough cases to calculate the prevalence ratio.

Table 37B. Number and Prevalence of Selected Birth Defects in the Corpus Christi area by Areas of Increasing Distance from Refinery Row, 1999–2007, Hispanic/Latino Mothers only (page 1 of 3)

Code	Description	Number of Birth Defect Cases (Prevalence per 10,000 births)			
		Up to 2 miles	2 to 5 miles	5 to 10 miles	More than 10 miles
Total Birth Defects					
	Cases with one or more birth defects	449 (693.4)	728 (656.9)	768 (644.4)	524 (593.5)
Birth Defects With Codes < 740.0					
243.9	Hypothyroidism, congenital	1 (1.5)	5 (4.5)	5 (4.2)	2 (2.3)
279.1	DiGeorge syndrome	1 (1.5)	3 (2.7)	3 (2.5)	1 (1.1)
524.0	Abnormalities of jaw size – micro/macrognathia	19 (29.3)	36 (32.5)	34 (28.5)	21 (23.8)
Brain, Eye, Ear Defects					
742.1	Microcephalus	14 (21.6)	12 (10.8)	18 (15.1)	13 (14.7)
742.4	Other specified anomalies of brain	11 (17.0)	14 (12.6)	18 (15.1)	8 (9.1)
742.5	Other specified anomalies of spinal cord	3 (4.6)	2 (1.8)	4 (3.4)	5 (5.7)
742.9	Unspecified anomalies of central nervous system	1 (1.5)	1 (0.9)	1 (0.8)	1 (1.3)
743.1	Microphthalmos	2 (3.1)	8 (7.2)	4 (3.4)	2 (2.3)
743.2	Buphthalmos	1 (1.5)	3 (2.7)	1 (0.8)	1 (1.1)
743.6	Cong. Anomalies of eyelids, lacrimal system, orbit	11 (17.0)	4 (3.6)	5 (4.2)	6 (6.8)
744.2	Other specified anomalies of ear	16 (24.7)	37 (33.4)	36 (30.2)	26 (29.4)
744.3	Unspecified anomalies of ear	1 (1.5)	1 (0.9)	4 (3.4)	1 (1.1)
744.8	Other specified anomalies of face and neck	4 (6.2)	13 (11.7)	9 (7.5)	9 (10.2)
744.9	Unspecified anomalies of face and neck	12 (18.5)	26 (23.5)	17 (14.3)	14 (15.9)
Cardiovascular Defects					
745.0	Common truncus	1 (1.5)	4 (3.6)	3 (2.5)	0
745.4	Ventricular septal defect	76 (117.4)	109 (98.4)	118 (99.0)	68 (77.0)
745.5	Ostium secundum type atrial septal defect	261 (403.1)	435 (392.5)	444 (372.5)	289 (327.3)
746.0	Anomalies of pulmonary valve	7 (10.8)	11 (9.9)	18 (15.1)	12 (13.6)
746.3	Congenital stenosis of aortic valve	4 (6.2)	1 (0.9)	7 (5.9)	3 (3.4)
746.4	Congenital insufficiency of aortic valve	5 (7.7)	5 (4.5)	12 (10.1)	6 (6.8)
746.8	Other specified anomalies of the heart	42 (64.9)	77 (69.5)	76 (63.8)	59 (66.8)
747.0	Patent ductus arteriosus	73 (112.7)	145 (130.8)	153 (128.4)	112 (126.8)
747.1	Coarctation of aorta	7 (10.8)	10 (9.0)	18 (15.1)	10 (11.3)
747.2	Other anomalies of aorta	40 (61.8)	40 (36.1)	69 (57.9)	30 (34.0)
747.3	Anomalies of pulmonary artery	122 (188.4)	198 (178.7)	198 (166.1)	138 (156.3)
747.6	Other anomalies of peripheral vascular system	1 (1.5)	10 (9.0)	2 (1.7)	4 (4.5)
747.8	Other specified anomalies of circulatory system	2 (3.1)	0	1 (0.8)	2 (2.3)

Table 37B. Number and Prevalence of Selected Birth Defects in the Corpus Christi area by Areas of Increasing Distance from Refinery Row, 1999–2007, Hispanic/Latino Mothers only (page 2 of 3)

Code	*Description*	*Number of Birth Defect Cases (Prevalence per 10,000 births)*			
		Up to 2 miles	*2 to 5 miles*	*5 to 10 miles*	*More than 10 miles*
Respiratory System Defects					
748.5	Agenesis or aplasia of lung	3 (4.6)	6 (5.4)	7 (5.9)	7 (7.9)
748.6	Other anomalies of the lung	1 (1.5)	0	0	0
748.8	Other specified anomalies of respiratory system	0	0	3 (2.5)	0
Digestive System Defects					
750.2	Other specified anomalies of mouth and pharynx	8 (12.3)	15 (13.5)	9 (7.5)	6 (6.8)
750.5	Congenital hypertrophic pyloric stenosis	27 (41.7)	40 (36.1)	50 (41.9)	33 (37.4)
750.6	Congenital hiatus hernia	1 (1.5)	0	1 (0.8)	2 (2.3)
751.2	Atresia/stenosis of large intestine, rectum, anal canal	7 (10.8)	4 (3.6)	10 (8.4)	7 (7.9)
751.4	Anomalies of intestinal fixation	2 (3.1)	7 (6.3)	9 (7.5)	9 (10.2)
751.5	Other anomalies of intestine	8 (12.3)	10 (9.0)	10 (8.4)	4 (4.5)
Genitourinary Defects					
752.4	Anom. of cervix, vagina, external female genitalia	4 (6.2)	8 (7.2)	12 (10.1)	6 (6.8)
753.0	Renal agenesis and dysgenesis	7 (10.8)	9 (8.1)	13 (10.9)	9 (10.2)
753.2	Obstructive defects of renal pelvis and ureter	40 (61.8)	73 (65.9)	76 (63.8)	41 (46.4)
753.3	Other specified anomalies of kidney	6 (9.3)	10 (9.0)	13 (10.9)	6 (6.8)
753.8	Other specified anomalies of bladder and urethra	2 (3.1)	4 (3.6)	7 (5.9)	2 (2.3)
Musculoskeletal Defects					
754.0	Certain anomalies of skull, face, and jaw	14 (21.6)	23 (20.7)	27 (22.6)	17 (19.2)
754.5	Varus (inward) deformities of feet	8 (12.3)	17 (15.3)	12 (10.1)	8 (9.1)
754.6	Valgus (outward) deformities of feet	10 (15.4)	11 (9.9)	12 (10.1)	6 (6.8)
754.8	Other specified cong musculoskeletal deformities	7 (10.8)	23 (20.7)	20 (16.8)	15 (17.0)
755.1	Syndactyly	5 (7.7)	11 (9.9)	6 (5.0)	13 (14.7)
755.3	Reduction defects of lower limb	3 (4.6)	4 (3.6)	3 (2.5)	1 (1.1)
755.5	Other anomalies of upper limb, inc shoulder girdle	6 (9.2)	14 (12.6)	16 (13.4)	13 (14.7)
755.6	Other anomalies of lower limb, inc pelvic girdle	9 (13.9)	21 (18.9)	24 (20.1)	17 (19.2)
755.8	Other specified anomalies of unspecified limb	7 (10.8)	6 (5.4)	2 (1.7)	7 (7.9)
756.0	Anomalies of skull and face bones	23 (35.5)	38 (34.3)	33 (27.7)	25 (28.3)
756.1	Anomalies of spine	6 (9.3)	11 (9.9)	10 (8.4)	8 (9.1)
756.3	Other anomalies of ribs and sternum	5 (7.7)	10 (9.0)	15 (12.6)	3 (3.4)
756.6	Anomalies of diaphragm	5 (7.7)	6 (5.4)	9 (7.5)	4 (4.5)
756.70	Omphalocele	0	2 (1.8)	3 (2.5)	3 (3.4)

Table 37B. Number and Prevalence of Selected Birth Defects in the Corpus Christi area by Areas of Increasing Distance from Refinery Row, 1999–2007, Hispanic/Latino Mothers only (page 3 of 3)

Code	***Description***	***Number of Birth Defect Cases (Prevalence per 10,000 births)***			
		Up to 2 miles	***2 to 5 miles***	***5 to 10 miles***	***More than 10 miles***
756.71	Gastroschisis	3 (4.6)	8 (7.2)	6 (5.0)	4 (4.5)
Miscellaneous Defects					
757.3	Other specified anomalies of skin	5 (7.7)	14 (12.6)	14 (11.7)	8 (9.1)
757.5	Specified anomalies of nails	3 (4.6)	7 (6.3)	8 (6.7)	4 (4.5)
757.8	Other specified anomalies of the integument	0	1 (0.9)	4 (3.4)	2 (2.3)
758.4	Balanced autosomal translocation in normal indl.	0	2 (1.8)	1 (0.8)	0
758.9	Conditions due to anom of unspec chromosomes	1 (1.5)	1 (0.9)	0	1 (1.1)
759.2	Anomalies of other endocrine glands	1 (1.5)	2 (1.8)	4 (3.4)	6 (6.8)
Other Defects					
	Neural Tube Defects (27 of 55 cases did not map to areas)	5 (7.7)	6 (5.4)	4 (3.4)	5 (5.7)
	Conotruncal Heart Defects	5 (7.7)	13 (11.7)	14 (11.7)	7 (7.9)

Data Source: Texas Department of Birth Defect Registry data for 1999–2007 for 63 birth defects.

Table 38B. Prevalence Ratios of Selected Birth Defects in the Corpus Christi Within 2 Miles from Refinery Row versus More than 10 Miles away from Refinery Row, 1999-2007, Hispanic/Latino Mothers only (page 1 of 3)

Code	*Description*	*Prevalence Ratios (up to 2 miles versus more than 10 miles)*	
		*Crude Ratio (95% CI) **	*Adjusted Ratio (95% CI)*†
Total Birth Defects			
	Cases with one or more birth defects	1.2 (1.0 – 1.3)	1.2 (1.0 – 1.3)
Birth Defects With Codes < 740.0			
243.9	Hypothyroidism, congenital	0.7 (0.0 – 7.1)	0.7 (0.0 – 12.0)
279.1	DiGeorge syndrome	1.4 (0.0 – 34.4)	1.8 (0.0 – 315)
524.0	Abnormalities of jaw size – micro/macrognathia	1.2 (0.7 – 2.3)	1.1 (0.5 – 2.5)
Brain, Eye, Ear Defects			
742.1	Microcephalus	1.5 (0.7 – 3.2)	1.3 (0.6 – 2.7)
742.4	Other specified anomalies of brain	1.9 (0.8 – 4.8)	1.7 (0.6 – 4.4)
742.5	Other specified anomalies of spinal cord	0.8 (0.2 – 3.3)	1.0 (0.1 – 5.4)
742.9	Unspecified anomalies of central nervous system	1.4 (0.0 – 34.4)	1.2 (0.0 – 39.1)
743.1	Microphthalmos	1.4 (0.2 – 11.4)	1.1 (0.1 – 8.2)
743.2	Buphthalmos	1.4 (0.0 - 34.4)	1.8 (0.2 – 19.7)
743.6	Cong. Anomalies of eyelids, lacrimal system, orbit	2.5 (0.9 - 7.3)	2.1 (0.9 – 5.1)
744.2	Other specified anomalies of ear	0.8 (0.4 – 1.5)	0.8 (0.4 – 1.6)
744.3	Unspecified anomalies of ear	1.4 (0.0 – 34.4)	--
744.8	Other specified anomalies of face and neck	0.6 (0.2 – 1.9)	0.6 (0.1 – 2.0)
744.9	Unspecified anomalies of face and neck	1.2 (0.5 – 2.5)	1.1 (0.5 – 2.3)
Cardiovascular Defects			
745.0	Common truncus	--	--
745.4	Ventricular septal defect	**1.5 (1.1 – 2.1)**	**1.5 (1.1 – 2.0)**
745.5	Ostium secundum type atrial septal defect	1.2 (1.0 – 1.5)	1.2 (1.0 – 1.4)
746.0	Anomalies of pulmonary valve	0.8 (0.3 – 2.0)	0.9 (0.3 – 2.6)
746.3	Congenital stenosis of aortic valve	1.8 (0.4 – 9.2)	2.1 (0.3 – 2.6)
746.4	Congenital insufficiency of aortic valve	1.1 (0.3 – 3.8)	2.1 (0.3 – 19.3)
746.8	Other specified anomalies of the heart	1.0 (0.6 – 1.4)	1.3 (0.2 – 7.1)
747.0	Patent ductus arteriosus	0.9 (0.7 – 1.2)	0.9 (0.6 – 1.3)
747.1	Coarctation of aorta	0.9 (0.3 – 2.5)	1.0 (0.3 – 2.5)
747.2	Other anomalies of aorta	**1.8 (1.1 – 2.9)**	1.8 (1.0 – 3.3)
747.3	Anomalies of pulmonary artery	1.2 (0.9 – 1.5)	1.2 (0.9 – 1.5)
747.6	Other anomalies of peripheral vascular system	0.3 (0.0 – 2.3)	0.3 (0.0 – 1.2)
747.8	Other specified anomalies of circulatory system	--	--
Respiratory System Defects			
748.5	Agenesis or aplasia of lung	0.6 (0.1 – 2.1)	0.7 (0.1 – 3.2)
748.6	Other anomalies of the lung	--	--
748.8	Other specified anomalies of respiratory system	--	--

Table 38B. Prevalence Ratios of Selected Birth Defects in the Corpus Christi Within 2 Miles from Refinery Row versus More than 10 Miles away from Refinery Row, 1999-2007, Hispanic/Latino Mothers only (page 2 of 3)

Code	*Description*	*Prevalence Ratios (up to 2 miles versus more than 10 miles)*	
		*Crude Ratio (95% CI) **	*Adjusted Ratio (95% CI)†*
Digestive System Defects			
750.2	Other specified anomalies of mouth and pharynx	1.8 (0.6 – 5.5)	1.7 (0.6 – 5.2)
750.5	Congenital hypertrophic pyloric stenosis	1.1 (0.7 – 1.8)	1.1 (0.6 – 1.8)
750.6	Congenital hiatus hernia	--	--
751.2	Atresia/stenosis of large intestine, rectum, anal canal	1.4 (0.5 – 4.0)	1.6 (0.4 – 7.4)
751.4	Anomalies of intestinal fixation	0.3 (0.0 – 1.2)	0.3 (0.0 – 1.2)
751.5	Other anomalies of intestine	2.7 (0.9 – 10.2)	2.8 (0.8 – 11.0)
Genitourinary Defects			
752.4	Anom. of cervix, vagina, external female genitalia	0.9 (0.2 – 3.2)	0.9 (0.1 – 4.2)
753.0	Renal agenesis and dysgenesis	1.1 (0.4 – 2.8)	1.1 (0.4 – 3.3)
753.2	Obstructive defects of renal pelvis and ureter	1.3 (0.9 – 2.1)	1.3 (0.9 – 1.8)
753.3	Other specified anomalies of kidney	1.4 (0.4 – 4.4)	1.4 (0.5 – 3.5)
753.8	Other specified anomalies of bladder and urethra	1.4 (0.2 – 11.4)	1.6 (0.2 – 10.6)
Musculoskeletal Defects			
754.0	Certain anomalies of skull, face, and jaw	1.1 (0.5 – 2.3)	1.0 (0.5 – 2.0)
754.5	Varus (inward) deformities of feet	1.4 (0.5 – 3.7)	1.4 (0.3 – 6.0)
754.6	Valgus (outward) deformities of feet	2.3 (0.8 – 6.7)	2.3 (0.8 – 7.6)
754.8	Other specified cong musculoskeletal deformities	0.6 (0.2 – 1.5)	0.6 (0.3 – 1.2)
755.1	Syndactyly	0.5 (0.2 – 1.4)	0.5 (0.1 – 1.4)
755.3	Reduction defects of lower limb	4.1 (0.5 – 82.6)	3.4 (0.1 – 467)
755.5	Other anomalies of upper limb, inc shoulder girdle	0.6 (0.2 – 1.6)	0.6 (0.2 – 1.5)
755.6	Other anomalies of lower limb, inc pelvic girdle	0.7 (0.3 – 1.6)	0.7 (0.3 – 1.5)
755.8	Other specified anomalies of unspecified limb	1.4 (0.5 – 4.0)	1.1 (0.4 – 3.5)
756.0	Anomalies of skull and face bones	1.2 (0.7 – 2.2)	1.1 (0.6 – 2.2)
756.1	Anomalies of spine	1.0 (0.3 – 2.9)	1.1 (0.4 – 2.8)
756.3	Other anomalies of ribs and sternum	2.3 (0.6 – 11.1)	2.3 (0.6 – 10.3)
756.6	Anomalies of diaphragm	1.7 (0.4 – 6.9)	1.5 (0.3 – 8.0)
756.70	Omphalocele	--	--
756.71	Gastroschisis	1.0 (0.2 – 4.6)	0.9 (0.2 – 4.8)
Miscellaneous Defects			
757.3	Other specified anomalies of skin	0.8 (0.3 – 2.5)	0.9 (0.3 – 2.7)
757.5	Specified anomalies of nails	1.0 (0.2 – 4.6)	1.0 (0.1 – 6.0)
757.8	Other specified anomalies of the integument	--	--
758.4	Balanced autosomal translocation in normal indl.	--	--
758.9	Conditions due to anom of unspec chromosomes	--	--

Table 38B. Prevalence Ratios of Selected Birth Defects in the Corpus Christi Within 2 Miles from Refinery Row versus More than 10 Miles away from Refinery Row, 1999-2007, Hispanic/Latino Mothers only (page 3 of 3)

Code	*Description*	*Prevalence Ratios (up to 2 miles versus more than 10 miles)*	
		*Crude Ratio (95% CI) **	*Adjusted Ratio (95% CI)†*
759.2	Anomalies of other endocrine glands	0.2 (0.0 – 1.3)	0.2 (0.0 – 2.6)
Other Defects			
	Neural Tube Defects (27 of 55 cases did not map to areas)	1.4 (0.4 – 4.9)	1.3 (0.3 – 5.2)
	Conotruncal Heart Defects	1.0 (0.3 – 3.0)	1.2 (0.6 – 2.4)

Data Source: Texas Department of Birth Defect Registry data for 1999–2007 for 63 birth defects.

* Prevalence rate ratio and 95% confidence interval for birth defect occurrence up to 2 miles compared with the occurrence in the area more than 10 miles from Refinery Row. A 95% CI with a lower bound more than 1.0 indicates a statistically significant increase in the occurrence of that birth defect in closer proximity to Refinery Row.

† Adjusted for maternal age and educational attainment.

-- Indicates not enough cases to calculate the prevalence ratio.

Table 39B. Odor Threshold Data (page 1 of 3)

Chemical	***Odor Threshold Limit Values (ppb) from Three Sources****		
	AIHA (1989)	***U.S. EPA (1992)***	***TCEQ (2013)***
1,1,1-Trichloroethane	390,000	385,000	380,000
1,1,2,2-Tetrachloroethane	7,300	7,300	7,300
1,2,4-Trimethylbenzene	2,400		140
1,2-Dichloroethane	26,000		6,000
1,2-Dichloropropane	260		250
1,3,5-Trimethylbenzene (Mesitylene)	2,200		
1,3-Butadiene	450	450	230
1-Butanol	1,200		
1-Butene			360
1-Hexene And 2-Methyl-1-Pentene			140
1-Pentene			100
2,2,4-Trimethylpentane			670
2,3-Dimethylbutane			420
2,3-Dimethylpentane			4,500
2,4-Dimethylpentane			940
2-Butanone (Methyl Ethyl Ketone)	16,000	17,000	440
2-Methyl-1-Pentene			140
2-Methylheptane			110
2-Methylhexane (Isoheptane)			420
2-Methylpentane (Isohexane)			7,000
3-Methyl-1-Butene			250
3-Methylheptane			1,500
3-Methylhexane			840
3-Methylpentane			8,900
3-Pentanone (Diethyl ketone)	2,800		850
4-Methyl-1-Pentene			140
Benzene	61,000	61,000	2,700
Butyl Acetate	310		45
Butyraldehyde			4.7
Carbon Tetrachloride	250,000	250,000	4,600
Chlorobenzene	1,300	1,300	1,300
Chloroform	192,000	192,000	3,800
Cyclohexane	780,000		2,500
Ethyl Acetate	18,000		390
Ethylbenzene			170
Ethylene	270,000		270,000
Isopentane			1,300

Table 39B. Odor Threshold Data (page 2 of 3)

Chemical	*Odor Threshold Limit Values (ppb) from Three Sources**		
	AIHA (1989)	*U.S. EPA (1992)*	*TCEQ (2013)*
Isoprene			48
Isopropylbenzene (Cumene)	32	32	48
Methyl Butyl Ketone (MBK) (2-Hexanone)			24
Methyl Isobutyl Ketone	880	880	170
Methyl t-Butyl ether			130
Methylcyclohexane			150
Methylcyclopentane			1,700
Methylene Chloride		144,000	160,000
Propane			1,500,000
Propylene	23,000		13,000
Styrene	140	150	25
Tetrachloroethylene	47,000	47,000	770
Toluene	1,600	2,800	920
Trichloroethylene	82,000	82,000	3,900
Trichlorofluoromethane (Freon 11)			5,000
a-Pinene			18
b-Pinene			33
c-2-Butene			2,100
c-2-Hexene			140
Isobutyraldehyde			47
m-Diethylbenzene			70
m-Ethyltoluene			18
n-Butane			1,200,000
n-Decane			620
n-Heptane	230,000		670
n-Hexane			1,500
n-Octane	150,000		1,700
n-Pentane			1,400
n-Propyl Acetate	180		240
n-Propylbenzene			48
n-Undecane			870
o-Ethyltoluene			74
o-Xylene	5,400	5,400	380
p-Diethylbenzene			70
p-Ethyltoluene			8.1
p-Xylene + m-Xylene			80
t-2-Butene			2,100

Table 39B. Odor Threshold Data (page 3 of 3)

Chemical	***Odor Threshold Limit Values (ppb) from Three Sources****		
	AIHA (1989)	***U.S. EPA (1992)***	***TCEQ (2013)***
t-2-Hexene			140
Naphthalene	38	38	38
Xylenes (o,p,m)	20,000		
Hydrogen sulfide†	4.5		
Sulfur dioxide‡	2,700		
Acetaldehyde	67	67	8.5
Acetone	62,000		42,000
Acrolein	1,800		3.6
Crotonaldehyde	110		23
Formaldehyde			500
Heptaldehyde			50
Hexaldehyde			20
Isovaleraldehyde			28
Methacrolein			5.7
Methyl ethyl ketone	16,000	17,000	440
Propionaldehyde		40	9
Valeraldehyde			30

Data Sources:

American Industrial Hygiene Association. 1989. Odor thresholds for chemicals with established occupational health standards. Akron, OH.

Texas Commission on Environmental Quality. 2013. Air toxics, air monitoring comparison values (AMCV). Excel table last modified September 2013.

US Environmental Protection Agency. 1992. Reference guide to odor thresholds for hazardous air pollutants listed in the Clean Air Act Amendments of 1990. Washington, DC: EPA/600/R-92/047.

* Blank table cells indicate no odor threshold value is available.

† ATSDR finds there is considerable individual variability in the odor threshold for hydrogen sulfide in people, ranging from 0.5 to 300 ppb [ATSDR 2006].

‡ ATSDR finds most people can smell sulfur dioxide at levels of 300 to 1,000 ppb [ATSDR 2011b].

AIHA American Industrial Hygiene Association
ATSDR Agency for Toxic Substances and Disease Registry
U.S. EPA U.S. Environmental Protection Agency
ppb parts per billion
TCEQ Texas Commission on Environmental Quality

Table 40B. Mobile Monitoring Odor Screening Results (page 1 of 3)

Chemical	*Monitoring Type*	*Total Number of Samples*	*Maximum Level Detected (ppb)*	*Date of Maximum Level Detected*	*Number (and Percent) of Samples above Odor Threshold*
Benzene	Canister*	798	370,000	7/31/2000	8 (1.0)
Butyraldehyde	Canister	143	8.3	3/5/2007	1 (0.70)
Isopentane	Canister	485	26,000	7/31/2000	5 (1.0)
Isopentane + c-2-butene	Auto GC High 1-hr Average	56	1,800	3/3/2007	1 (1.)†
	Auto GC Maximum	56	4,600	3/3/2007	1 (1.8)‡
Isoprene	Auto GC Continuous Average	82	80.63	11/15/2004	1 (1.2)
	Auto GC High 1-hr Average	82	130	11/15/2004	3 (3.7)
	Auto GC Maximum	82	330	11/15/2004	7 (8.5)
	Canister	485	99	2/26/2002	1 (0.21)
Isopropylbenzene	Auto GC Continuous Average	58	110	11/14/2004	1 (1.7)
	Auto GC High 1-hr Average	58	240	11/14/2004	2 (3.5)
	Auto GC Maximum	58	330	11/14/2004	4 (6.9)
Methyl t-butyl ether	Canister	292	460	2/4/2003	4 (1.4)
Methylcyclohexane	Canister	292	200	3/4/2007	1 (0.34)
Styrene	Auto GC High 1-hr Average	237	87.9	2/28/2002	8 (3.4)
	Auto GC Maximum	237	150	2/28/2002	9 (3.8)
Toluene	Auto GC Maximum	744	1,000	3/2/2007	1 (0.13)
	Canister	775	1,300	5/31/2000	2 (0.26)
n-Pentane	Auto GC Maximum	84	2,500	3/3/2007	1 (1.2)

Table 40B. Mobile Monitoring Odor Screening Results (page 2 of 3)

Chemical	Monitoring Type	Total Number of Samples	Maximum Level Detected (ppb)	Date of Maximum Level Detected	Number (and Percent) of Samples above Odor Threshold
m-Xylene + p-Xylene	Auto GC - High 1-hr Average	217	130	11/15/2004	1 (0.46)
	Auto GC - Maximum	217	280	11/15/2004	2 (0.92)
	Canister	292	100	2/5/2003	1 (0.34)

Data Sources:

Texas Natural Resource Conservation Commission. 1996a. Corpus Christi area monitoring network summary of measurements for the period March 1994 – March 1996. Report date 3 June 1996. Austin, TX.

Texas Natural Resource Conservation Commission. 1996b. Toxicological evaluation of the results of the mobile monitoring, volatile organic and sulfur compounds, February 4-9, 1996. Report date 12 June 1996. Austin, TX.

Texas Natural Resource Conservation Commission. 1997. Toxicological evaluation of results of mobile monitoring for sulfur compounds, VOCs, carbon monoxide, respirable particulate matter, and metals, Corpus Christi, Nueces County, February 1-7, 1997, Report date 20 May 1997. Austin, TX.

Texas Natural Resource Conservation Commission. 1998a. Toxicological evaluation of results of mobile monitoring VOCs and sulfur compounds, Corpus Christi, Nueces County, January 31- February 6, 1998. Austin, TX.

Texas Natural Resource Conservation Commission. 1998b. Toxicological evaluation of results of mobile monitoring VOCs, Corpus Christi, Nueces County, November 20 - 22, 1998. Austin, TX.

Texas Natural Resource Conservation Commission. 1999. Toxicological evaluation of results of mobile monitoring VOCs, Corpus Christi, Nueces County, January 9 - 13, 1999. Austin, TX

Texas Natural Resource Conservation Commission. 2000a. Toxicological evaluation of results of mobile monitoring volatile organic compounds and sulfur compounds, Corpus Christi, Nueces County, February 5–11, 2000. Report date 16 June 2000. Austin, TX.

Texas Natural Resource Conservation Commission. 2000b. Toxicological evaluation of results of ambient air sampling for benzene and other VOCs, hydrocarbon seep at Elementis Chromium, and Amerada Hess Recovery Wells in Oak Park Neighborhood (Cenizo Street), Corpus Christi, Nueces County. Report date 1 March 2000. Austin, TX.

Texas Natural Resource Conservation Commission. 2000c. Toxicological evaluation of results of ambient air sampling for benzene and other VOCs, Corpus Christi, Nueces County, April 27 - 30, 2000. Austin, TX.

Texas Natural Resource Conservation Commission. 2000d. Toxicological evaluation of air sampling results, benzene and other volatile organic compounds (VOCs), hydrocarbon seep and remediation activities at Elementis Chromium, recovery wells at Coastal Refining and Marketing – East and West Plants, Corpus Christi, Nueces County, July 31, 2000. Report date 9 November 2000. Austin, TX.

Texas Natural Resource Conservation Commission. 2001. Toxicological evaluation of mobile monitoring results for VOCs, H_2S, and SO_2, Corpus Christi and Three Rivers TX, February 24 - March 1, 2001. Austin, TX.

Texas Commission on Environmental Quality. 2002. Results from Corpus Christi mobile laboratory VOC sampling trip, February 23 – March 1, 2002. Austin, TX.

Texas Commission on Environmental Quality. 2003. Results from Corpus Christi mobile laboratory sampling trip, February 1 – 6, 2003. Austin, TX.

Texas Commission on Environmental Quality. 2003. Results from Corpus Christi mobile laboratory sampling trip, November 15 – 20, 2003. Austin, TX.

Texas Commission on Environmental Quality. 2004. Results from Corpus Christi mobile laboratory sampling trip, November 14-19, 2004. Austin, TX.

Table 40B. Mobile Monitoring Odor Screening Results (page 3 of 3)

Texas Commission on Environmental Quality. 2006. Region 14 VOC survey project, August 18-24, 2006. Report date 25 October 2006. Austin, TX.

Texas Commission on Environmental Quality. 2007. Corpus Christi monitoring project, March 1-8, 2007. Report date 14 September 2007. Austin, TX.

Texas Commission on Environmental Quality. 2009. Corpus Christi monitoring project, March 29-April 4, 2008 and April 21, 2008. Report date 22 June 2009. Austin, TX.

* The durations for the canister samples varied across reports. Most of the canister samples were 3 hour canisters, but some were 1 hour and some were 30 minute.

† Concentration is below the c-2-butene odor threshold value of 2,100 ppb but above the isopentane odor threshold value of 1,300 ppb.

‡ Concentration is above the c-2-butene odor threshold value of 2,100 ppb and above the isopentane odor threshold value of 1,300 ppb.

hr hour
ppb parts per billion
VOC volatile organic compound

Table 41B. Stationary Air Monitoring Data—Hydrogen Sulfide Odor Screening Results

Air Monitoring Station Name	Stationary Air Monitoring Data – Hydrogen Sulfide				
	Total Number of 1-hour Samples	Maximum H_2S Level Detected (ppb)	Date of Maximum Level Detected	Number (and Percent) of Samples above 4.5 ppb*	Number (and Percent) of Samples above 0.5 ppb†
Dona Park	39,385	31.23	5/8/2008	59 (0.15)	6,492 (16)
Huisache‡	54,972	364.87	10/21/2000	1,039 (1.9)	13,494 (25)
Huisache§	46,630	57.25	11/17/2005	823 (1.8)	13,667 (29)
JI Hailey	41,949	341.22	7/27/2007	395 (0.94)	12,793 (31)
Off Up River Road	40,918	34.42	10/15/2008	80 (0.20)	7,970 (19)
Port Grain Elevator	41,515	38.73	8/24/2010	242 (0.58)	7,731 (19)
Solar Estates	42,100	9.17	10/29/2008	33 (0.08)	6,928 (16)
West End Inner Harbor	42,182	41.97	6/2/2009	456 (1.1)	11,318 (27)

Data Sources:

Texas Commission on Environmental Quality. 2010. Data posted to FTP site by Melanie Hotchkiss, TCEQ, and downloaded by John Wilhelmi, Eastern Research Group, Inc. Contains continuous 2005-2009 sulfur compound and volatile organic compound data for both TCEQ and Corpus Christi Air Quality Project air monitoring sites. Austin, TX.

The University of Texas. 2011. March 9th email from Dr. David Sullivan, The University of Texas at Austin, to Rachel Worley, Agency for Toxic Substances and Disease Registry, containing an Excel attachment with the event-triggered data and the 2010 H_2S and SO_2 data for the Corpus Christi site. Austin, TX.

* Source of odor threshold value is: American Industrial Hygiene Association. 1989. Odor thresholds for chemicals with established occupational health standards. Akron, OH

† Source of odor threshold value is: Ruth JH. 1986. Odor thresholds and irritation levels of several chemical substances: A review. Am Ind Hyg Assoc J 47:142-151.

‡ Huisache data collected and analyzed prior to 2005.

§ Huisache data collected and analyzed 2005–2010.

H_2S hydrogen sulfide
ppb parts per billion

Table 42B. Mobile Monitoring Data—Sulfur Dioxide Odor Screening Results (page 1 of 2)

Type of Sample	*Mobile Monitoring Data—Sulfur Dioxide*			
	Total Number of Samples	*Maximum SO_2 Level Detected (ppb)*	*Date of Maximum Level Detected*	*Number (and Percent) of Samples above Odor Threshold*
5-minute Average (July 1993 & Dec 1995)	805	1,665	7/13/1993	10 (1.2)
Peak Concentration (Feb 1993 - Mar 2008)	1,109	6,745	7/13/1993	12 (1.1)
30-minute Average (Feb 1994 - Mar 2008)	308	1,010	2/23/1994	1 (0.32)
Auto - GC Maximum (Dec 1995 – Feb 1996)	38	1,800	12/3/1995	3 (7.9)
Auto - GC High 1-hr Average (Dec 1995 – Feb 1996)	38	440	12/3/1995	3 (7.9)
Auto – GC Continuous Average (Dec 1995 – Feb 1996)	38	73	12/3/1995	0 (0)

Data sources:

Texas Natural Resource Conservation Commission. 1994. Corpus Christi mobile laboratory trip, February 19-25, 1994; RTGC and Composite Sampling. Austin, TX.

Texas Natural Resource Conservation Commission. 1995. Valero, Citgo, and Koch Refineries sampling trip for SO_2 and H_2S, December 8-12, 1995. Austin, TX.

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Texas Commission on Environmental Quality. 2003. Results from Corpus Christi mobile laboratory sampling trip, February 1 – 6, 2003. Austin, TX.

Texas Commission on Environmental Quality. 2003. Results from Corpus Christi mobile laboratory sampling trip, November 15 – 20, 2003. Austin, TX.

Table 42B. Mobile Monitoring Data—Sulfur Dioxide Odor Screening Results (page 2 of 2)

Texas Commission on Environmental Quality. 2004. Results from Corpus Christi mobile laboratory sampling trip, November 14-19, 2004. Austin, TX.

Texas Commission on Environmental Quality. 2007. Corpus Christi monitoring project, March 1-8, 2007. Report date 14 September 2007. Austin, TX.

Texas Commission on Environmental Quality. 2009. Corpus Christi monitoring project, March 29-April 4, 2008 and April 21, 2008. Report date 22 June 2009. Austin, TX.

$S0_2$ sulfur dioxide
ppb parts per billion

Table 43B. Mobile Monitoring Data—Hydrogen Sulfide Odor Screening Results (page 1 of 2)

Type of Sample	Mobile Monitoring Data—Hydrogen Sulfide				
	Total Number of Samples	Maximum H_2S Level Detected (ppb)	Date of Maximum Level Detected	Number (and Percent) of Samples above 4.5 ppb*	Number (and Percent) of Samples above 0.5 ppb†
5-minute Average (July 1993 & Dec 1995)	785	243	7/12/1993	500 (64)	664 (85)
Peak Concentration (July 1993 - Mar 2008)	1,099	1,870	2/28/2001	801 (73)	998 (91)
30-minute Average (Feb 1994 - Mar 2008)	321	1,086	2/2/1997	214 (67)	308 (96)
Impinger Sample (Feb 1996 - Mar 2008)	38	2,000	2/2/1997	38 (100)	38 (100)
Auto - GC Maximum (Feb 2002)	117	233	2/23/2002	54 (46)	55 (47)
Auto – GC Continuous Average (Feb 1994 - Feb 2001)	237	504	2/27/2001	134 (57)	151 (64)

Data sources:

Texas Natural Resource Conservation Commission. 1994. Corpus Christi mobile laboratory trip, February 19-25, 1994; RTGC and Composite Sampling. Austin, TX.

Texas Natural Resource Conservation Commission. 1995. Valero, Citgo, and Koch Refineries sampling trip for SO_2 and H_2S, December 8-12, 1995. Austin, TX.

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Texas Commission on Environmental Quality. 2002. Results from Corpus Christi mobile laboratory VOC sampling trip, February 23 – March 1, 2002. Austin, TX.

Texas Commission on Environmental Quality. 2003. Results from Corpus Christi mobile laboratory sampling trip, February 1 – 6, 2003. Austin, TX.

Texas Commission on Environmental Quality. 2003. Results from Corpus Christi mobile laboratory sampling trip, November 15 – 20, 2003. Austin, TX.

Table 43B. Mobile Monitoring Data—Hydrogen Sulfide Odor Screening Results (page 2 of 2)

Texas Commission on Environmental Quality. 2004. Results from Corpus Christi mobile laboratory sampling trip, November 14-19, 2004. Austin, TX.

Texas Commission on Environmental Quality. 2007. Corpus Christi monitoring project, March 1-8, 2007. Report date 14 September 2007. Austin, TX.

Texas Commission on Environmental Quality. 2009. Corpus Christi monitoring project, March 29-April 4, 2008 and April 21, 2008. Report date 22 June 2009. Austin, TX.

* Source of odor threshold value is: American Industrial Hygiene Association. 1989. Odor thresholds for chemicals with established occupational health standards. Akron, OH.

† Source of odor threshold value is: Ruth JH. 1986. Odor thresholds and irritation levels of several chemical substances: A review. Am Ind Hyg Assoc J 47:142-151.

H_2S hydrogen sulfide
ppb parts per billion

Appendix C. Supplemental Background Information

In this appendix, the Agency for Toxic Substances and Disease Registry (ATSDR) provides additional background information, such as the history of Corpus Christi, information on land use in the area, and the results of its Social Vulnerability Index (SVI) analysis for the Refinery Row area. ATSDR also describes its major public health activities in the Corpus Christi area.

1C. History of Corpus Christi

Established in 1839, Corpus Christi, Texas, began as a small trading post and camp for soldiers during the Mexican War. In 1848, the city began dredging a deep-water seaport, a long-term project that continued through secession, the Civil War, and Reconstruction [Williams 2009]. In 1926, the completed Port of Corpus Christi became an important part of Corpus Christi's economic development [O'Rear 2009].

Between 1920 and 1970, the city's population grew from 10,000 to approximately 285,000 [Lessoff 2008]. This growth was largely the result of the deep-sea port, petrochemical and related industries, and large military establishments in the area. The city also benefitted from growth in Texas's larger economic centers [Walraven 1997]. Between 1965 and 2005, the city experienced moderate growth mostly due to occasional expansion of existing industry [Lessoff 2008].

In the 1970s, people began moving away from Corpus Christi. The net outmigration was estimated at over 28,000 persons. Outmigration of high school graduates was estimated at 50%, though the later addition of a regional public university and a locally financed community college slowed this trend [Lessoff 2008]. Unemployment hovered around 4.3%, much higher than other fast-growing Texas cities [O'Rear 2009]. A 1973 Community Renewal study suggested that unemployment in Corpus Christi would have been higher had faster-growing cities not been able to absorb some of Corpus Christi's jobless population [City of Corpus Christi 1973].

Off-shore drilling, the refinement of imported oil, and natural gas production, supported Corpus Christi's economy until the 1980s [Walraven 1997]. Then the Texas oil bust of the 1980s resulted in the movement of technical and administrative operations to corporate headquarters away from Corpus Christi [Walraven 1997]. But in the 1990s, dredging of the Port of Corpus Christi to 45 feet made it "the deepest port in the Gulf" [O'Rear 2009]. The city became a receiving point for imported oil from the Middle East, Nigeria, and Venezuela, as well as a staging ground for Gulf of Mexico oil operations. As a result, through the 1990s and in to the 2000s the industry managed moderate growth [Lessoff 2008].

In addition to the petrochemical industry, one of Corpus Christi's largest industrial employers was a military installation southeast of the ship channel [Williams 2009]. In the early 1990s, the Corpus Christi Army Depot employed over 4,400 civilians while the Corpus Christi Naval Air Station employed 1,700 military employees and 500 civilians. The Naval Air Station complex also included a Coast Guard Station, a U.S. Customs Office, and a Navy Hospital [Richards et al. 1977]. In August 2005, however, the Defense Department's Base Closing and Realignment Commission voted to close the military complex, resulting in the loss of thousands of military and civilian jobs [CRS 2005].

In the early 21st century, Corpus Christi began to shift its economic focus to cultural and tourist attractions [Lessoff 2008]. Corpus Christi has been a popular beach destination for Texans, and tourism efforts were expanded to attract visitors from more distant areas [Williams 2009]. A convention center, an 8,000 seat arena for concerts, basketball games and minor league hockey, and a baseball field for Texas-league baseball were built. Soon the tourist businesses employed approximately 9,000 persons in the metropolitan area. Today, tourism and the oil and petrochemicals industry drive the majority of the economy.

2C. Land Use

To cities such as Corpus Christi, land use is especially important. Land use controls industry, commerce, and housing within city boundaries. The City of Corpus Christi provided ATSDR with a map of the current land use designations for the area closest to the refineries (see Figure 44A, Appendix A.) This map shows that Refinery Row facilities are designated as "heavy industrial." It also shows that agricultural, residential, and vacant areas are in close proximity to the refineries.

3C. Social Vulnerability

Whether tornado, disease outbreak, or harmful chemical spill, every community must prepare for hazardous events and respond to those events when they occur. A number of factors, including poverty, lack of access to transportation, and crowded housing, can affect a community's response ability. These factors are "social vulnerability."

ATSDR's Geospatial Research, Analysis & Services Program (GRASP) created a tool to help public health officials identify and map the communities most likely in need of support before, during, and after a hazardous event. This tool is the Social Vulnerability Index (SVI.) The SVI uses U.S. Census data to determine the social vulnerability of every Census tract. The SVI ranks each tract on 14 social factors and groups them into four related themes. These themes are

1. Household composition,
2. Housing and transportation,
3. Socioeconomic status, and
4. Minority status and language.

The factors for each theme are

- **Household composition** — Derived from a combined percentile ranking of the variables age, dependency, disability, and single parenting.
- **Housing and transportation** — Derived from a combined percentile ranking of the variables housing structure, crowding, and access to a vehicle.
- **Socioeconomic status** — Derived from a combined percentile ranking of the variables income, poverty, employment and education.
- **Minority status and language** — Derived from a combined percentile ranking of the variables race, ethnicity and English language proficiency.

Each tract receives a ranking for each Census variable and for each of the four themes, as well as an overall ranking. Of note, the data are classed into quartiles, which means approximately 25% of all the values are contained in each class. The classes are designated as least vulnerable, somewhat vulnerable, moderately vulnerable, and most vulnerable.

ATSDR provides the results of SVI analysis to identify areas where populations are susceptible to hazardous event impacts like a chemical spill or release. According to the SVI, the following describes the results for the Refinery Row area:

- **Overall (Total) Vulnerability**. Figure 45A, Appendix A, shows that with regard to overall (total) vulnerability, most areas adjacent to Refinery Row north of I-37 and within the 1-mile boundary are classified as most vulnerable. The exception is one Census tract on the eastern end of Refinery Row classified as moderately vulnerable. South of I-37 and within the 2-mile boundary shows two breakdowns: areas to the southwest are moderately vulnerable and areas southeast are most vulnerable.
- **Household composition**. Figure 46A, Appendix A, shows that with regard to age, dependency, disability, and single parenting, most areas north of I-37 and within the 1-mile boundary are classified as most vulnerable. Areas south of I-37 and within the 2-mile boundary show Census tracts with a wide range of vulnerability with regard to household composition, (i.e., from least vulnerable to most vulnerable).
- **Housing and transportation**. Figure 47A, Appendix A, shows that with regard to housing structure, crowding, and access to a vehicle, most areas adjacent to Refinery Row north of I-37 and within the 1-mile boundary are classified as most vulnerable. The exception is one Census tract on the eastern end of Refinery Row classified as somewhat vulnerable. Areas south of I-37 and within the 2-mile boundary show Census tracts with a wide range of vulnerability (i.e. from least vulnerable to most vulnerable).
- **Socioeconomic status**. Figure 48A, Appendix A, shows that with regard to income, poverty, employment and education, most areas north of I-37 and within the 1-mile boundary are classified as moderately vulnerable on the western end of Refinery Row and most vulnerable on the eastern end. Areas south of I-37 and within the 2-mile boundary are classified as most vulnerable, except along the western end that ranges from somewhat to moderately vulnerable.
- **Minority status and language.** Figure 49A, Appendix A, shows that with regard to race, ethnicity and English language proficiency, most areas north of I-37 and within the 1-mile boundary are classified as moderately vulnerable. Areas south of I-37 and within the 2-mile boundary show Census tracts with a wide range of vulnerability (i.e., from somewhat vulnerable to most vulnerable).

Although the SVI toolkit's primary purpose is for public health officials in disaster scenarios such as a chemical spill or release, ATSDR can use these data for outreach activities. For example, ATSDR recognizes that not everyone in the Refinery Row area owns a car, has easy access to a computer, or understands English. Consequently, ATSDR both maintains a site-specific Web site for Corpus Christi at http://www.atsdr.cdc.gov/sites/corpuschristi/ and maintains a mailing list of over 5,000 addresses. This mailing list ensures our public health messages are sent directly to everyone living near Refinery Row, including vulnerable populations like the elderly, many of whom might not own a computer or car. And we deliver our public health messages in both English and Spanish.

4C. Texas Department of State Health Services Birth Defects Surveillance Program Activities

The Texas Department of State Health Services (DSHS)[40] Birth Defects Surveillance Program has conducted numerous investigations to better understand the increased rate of birth defects in the

[40] Referred to throughout this public health assessment as "Department of State Health Services" (DSHS).

Corpus Christi area. A report released in 2001 showed that the occurrence of total birth defects in 1996–1997 for Nueces County ZIP codes was almost twice as high as the state prevalence rate [TDH 2001b]. The program conducted a follow-up analysis of 49 specific routinely analyzed birth defects in the Nueces County ZIP codes. Six birth defects were significantly higher in the Nueces County area of concern: tetralogy of Fallot, ventricular septal defect, atrial septal defect, patent ductus arteriosus (all heart defects), obstructive genitourinary (G/U) defect, and probable/possible fetal alcohol syndrome [TDH 2001c]. The geographic distribution of the six birth defects showing excess rates did not indicate a particular clustering in the area [TDH 2002]. To further investigate the increased prevalence of the six birth defects in the Nueces County area, the program completed a case-control study which examined proximity of mother's residence to landfills, refineries and chemical manufacturing plants, airfields, and other sources of concern [TDH 2003]. This study found mothers of children with ventricular septal defect were 4.6 times more likely than controls to live within 1 mile of an airfield. Mothers of a child with obstructive G/U defect were 3.6 times more likely to live within 1 mile of an incinerator or injection well. Mothers of a child with possible/probable fetal alcohol syndrome were 11.3 times more likely to live within 1 mile of an incinerator or injection well.

In July 2006, DSHS examined a comprehensive range of specific birth defects to determine which—if any—were elevated among babies born from 1996–2002 to Corpus Christi mothers [DSHS 2006]. This study compared birth prevalence in the original study area (a list of ZIP codes comprising almost all of Nueces County) with birth prevalence in the rest of the Texas Birth Defects Registry. The study found 15 birth defects were significantly elevated and recommended them for inclusion in a follow-up case/control study. These 15 birth defects were

- 10 heart defects — tetralogy of Fallot, ventricular septal defect, atrial septal defect, anomalies of the pulmonary valve, anomalies of the tricuspid valve, insufficiency of the aortic valve, mitral valve insufficiency, patent ductus arteriosus, other anomalies of the aorta, anomalies of the pulmonary artery; and
- 5 defects of other systems — congenital hypertrophic pyloric stenosis, atresia/stenosis of the large intestine, obstructive genitourinary defects, anomalies of the diaphragm, gastroschisis.

In January 2008, DSHS's follow-up case-control study measured the association between the 15 selected birth defects and proximity of mother's residence to the sites of concern in Corpus Christi [DSHS 2008a]. Mother's residence near refineries and chemical manufacturing plants showed high odds ratios and proximity-response with anomalies of the diaphragm and gastroschisis, but those associations were not statistically significant.

At ATSDR's request, DSHS completed an analysis of data from the Texas Birth Defects Registry to identify those birth defects ATSDR would include in this public health evaluation [DSHS 2010]. DSHS compared the occurrence of birth defects in Nueces, San Patricio, and Kleberg Counties with a) the rest of the area covered by the registry, and b) other counties covered by a program to screen for cardiovascular birth defects. DSHS found that overall birth defects in those three counties were 74% higher than the rest of the registry, and 75% higher than the rest of the screening program area. DSHS recommended that ATSDR include in its evaluation total birth defects and 63 specific categories.

5C. ATSDR Activities

ATSDR and its cooperative agreement state partner, the Texas Department of State Health Services (DSHS), have been responding to health concerns expressed by Corpus Christi community members for many years. Between 1995 and 2008, ATSDR received seven petitions related to Corpus Christi. The petitions focused on concerns about

- Chemicals released to soil from a former smelter
- Chemicals released to the air, soil, and water from two landfills
- Chemicals released to the air from refineries and petrochemical companies
- Elevated birth defect rates

The following text and Table 31B, Appendix B, summarize some of the major events that ATSDR and DSHS engaged in while working in the Corpus Christi area; however, numerous actions have occurred over the years, and not all interactions are noted in this document, such as monthly conference calls with concerned residents and industry representatives.

1995

In August 1995, the Texas Department of Health[41] (TDH) released a symptom and prevalence survey report of the Oak Park Neighborhood [TDH 1995]. Residents had expressed concerns about personal safety as well as possible consequences of long-term exposure to hazardous substances. While the results of the health and household survey, completed by 67% of the Oak Park neighborhood, provided a good picture of the experiences as a whole, it could not find any direct, cause-and-effect relationship between increased prevalence of diseases and industrial pollution. Nevertheless, the survey reported that the frequency of asthma—although not medically confirmed—was of concern and required follow up.

1996

In December 1996, TDH completed a health consultation that addressed the former smelter petition [TDH 1996]. Residents were concerned that the former smelter site contaminated their yard soil. Blood lead testing indicated approximately 6% of the children were above 10 micrograms per deciliter (µg/dL)[42]; these children received appropriate follow-up. Overall, the health consultation concluded that with the exception of a few properties, potential exposure to lead in soil was minimal in the Dona Park neighborhood near the smelter.

In the health consultation, TDH found approximately seven percent of the samples exceeded a soil cadmium level of 49 milligrams per kilogram (mg/kg). However, excess exposure to cadmium was not indicated for the 95 individuals for whom urinary cadmium levels were determined. The health consultation concluded that cadmium concentrations measured in the neighborhood soil would not pose a significant public health risk to those persons who did not eat homegrown produce. Unless additional data indicate otherwise, TDH stated it would not be advisable to regularly eat vegetables grown in soil with cadmium levels greater than 49 mg/kg [TDH 1996].

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[41] In 2004, the Texas Department of Health (TDH) was renamed the Texas Department of State Health Services (DSHS).

[42] In 2012, the Centers for Disease Control and Prevention (CDC) adopted 5 micrograms per deciliter (µg/dL) as the reference level for initiation of public health actions.

2001

In January 2001, TDH completed a health consultation that addressed the landfill petition [TDH 2001a]. The health consultation concluded that people are not exposed to harmful chemical levels from the Chula Vista and Greenwood Landfills via indoor air, surface soil, drinking water, or groundwater, and that the potential is low for current health risks from past exposures.

2003

A community group filed a Corpus Christi Refinery Row (CCRR) petition with ATSDR. In February 2003, in response to the health concerns about refineries and petrochemical facilities expressed in the petition, ATSDR agreed to evaluate the public health effects of exposure to chemicals in the ambient air along Refinery Row. Over the years, ATSDR gathered available data related to air monitoring from Texas Commission on Environmental Quality (TCEQ) and other parties. ATSDR recognizes the community's dissatisfaction with the length of time the agency has taken to respond to the CCRR petition. But adequate airshed characterization required several years of air monitoring data.

2008

In February 2008, ATSDR received a petition requesting that the agency investigate elevated birth defect rates reported for Corpus Christi. After careful evaluation, ATSDR concluded that the limits of current scientific knowledge prevented the agency from identifying which, if any, hazardous waste sites or facilities contributed to the elevated birth defect rates presented in the DSHS analysis.

In December 2008, the Texas Cancer Registry (TCR) of the DSHS examined the occurrence of cancer in ZIP code 78407, Corpus Christi, in response to a request from local citizens [DSHS 2008b]. The TCR evaluated 1996–2005 incidence data and found that in both males and females, cancers of the prostate, breast, lung, colon and rectum, bladder, corpus and uterus, non-Hodgkin's lymphoma, and select leukemia subtypes were within expected ranges.

2009

In July 2009, Congressman Solomon Ortiz requested that ATSDR obtain answers for the community. ATSDR made a commitment to complete this report and to engage the community actively.

In November 2009, former National Center for Environmental Health (NCEH) and ATSDR Director Howard Frumkin, accompanied by staff, visited Corpus Christi and met with local community leaders, residents, elected officials, government partners, and industry representatives. Some of the concerns expressed to Dr. Frumkin from the community were related to the status of ATSDR's activities, the need for community involvement in all aspects of the planning effort, and the elevated birth defect rates for Corpus Christi.

In December 2009, the site team visited Corpus Christi for discussions with stakeholders, attendance at a community meeting, and a tour of the site. The trip's purpose was to

- Share the types of data and information ATSDR was then-currently reviewing and evaluating,
- Share a general timeline for public health evaluation activities,

- Talk about expectations of the evaluation,
- Determine whether any additional data or information should be considered in the evaluation, and
- Answer questions about ATSDR and NCEH work in Corpus Christi.

During the site tour, ATSDR noted the locations of ambient air monitors and observed the surrounding community.

2010

In January 2010, ATSDR began a second investigation. This was an exposure investigation (EI) to determine whether residents in Northern Corpus Christi along Refinery Row had in their bodies high levels of benzene and other petroleum-related volatile organic compounds (VOCs). On March 22–25th, ATSDR staff completed EI field activities (i.e., collected blood, urine and personal air samples, as well as some tap water samples). Overall, participants' exposures to benzene and other VOCs were no higher than those of the United States population as a whole [ATSDR 2011].

On April 28, 2010, ATSDR visited Corpus Christi to participate in a Corpus Christi Air Quality Project (AQP) advisory board meeting. ATSDR presented its public health evaluation and EI activities to the AQP advisory board and responded to questions from meeting participants. ATSDR also toured the air monitoring network with The University of Texas (UT) staff. ATSDR attended a luncheon meeting with UT and TCEQ to discuss site activities.

2011

On March 7, 2011, ATSDR participated in a Regional Health Awareness Board (RHAB) public information forum. During the forum, ATSDR and TCEQ recounted their respective site activities, and an invited guest speaker from Texas A&M commented on those activities. Both agencies also invited questions from the community, other agencies, RHAB personnel, local organizations, industry representatives, and elected officials.

From June 14–16, 2011, ATSDR worked with many local partners and held workshops in Corpus Christi to address environmental, safety and health issues of concern to the community. The workshop, entitled "It's All about Your Health," covered the following topics:

- Preventing Exposure to Hazardous Substances
- Practical Tips for a Safe and Healthy Home
- Emergency Evacuation and Safety Planning
- Oral Health for Children and Adults
- Healthy Eating on a Budget

In July 2011, ATSDR participated in the 46th Annual Health Fair in Corpus Christi. The Nueces County Medical Society and Alliance organized and sponsored the Health Fair as a public service for the Corpus Christi community and surrounding area. Each year, thousands of people attend the Health

Fair to take advantage of the free health screenings, education, training, and entertainment provided by the many exhibitors. At its booth called "Environmental Public Health," ATSDR discussed the agency's ongoing activities in Corpus Christi and elsewhere.

From July 7 to 10, 2011, and from October 5 to 7, 2011, DSHS conducted blood and urine screening for residents (children and adults) of the Dona Park, Manchester Place, and Academy Heights neighborhoods. Community members were concerned about residual metal contamination of residential soil and the potential for exposure to those contaminants from the former ASARCO facility. During both collection time periods, DSHS distributed fact sheets about metals and about ways to reduce exposure to metals, as well as other community health concerns. DSHS collected blood samples from 417 participants and urine samples from 379 participants. DSHS identified 23 persons with high levels of total arsenic in their urine and offered follow-up testing. Results from the follow-up testing indicated that very little of the total arsenic was of the harmful inorganic form. DSHS mailed letters with individual test results and an explanation of what they mean to the participants on September 15, 2011, and October 25, 2011. On November 9, 2011, DSHS released its final report on the results of the blood and urine screening [DSHS 2011]. On November 10, 2011, TCEQ, DSHS, and the U.S. Environmental Protection Agency (U.S. EPA) held a meeting to present the Dona Park biological and environmental results. Overall, this screening did not identify unusual levels of arsenic, cadmium, lead, or mercury in participants' blood or urine.

On November 18, 2011, U.S. EPA held an environmental summit in Corpus Christi. ATSDR, along with many government agencies, community groups and concerned residents, and industries, attended the summit. One result of the summit was the formation of four work groups: environmental health, environmental justice, sustainable communities and colonias, and pollution prevention. ATSDR participates on the environmental health and environmental justice work groups.

2012

On April 19, 2012, ATSDR attended the Federal Environmental Justice Interagency Working Group (EJ IWG) meeting in Corpus Christi. During the meeting, each agency made a short statement on its mission and role in ensuring inclusion of environmental justice issues in day-to-day work, activities and decision making. Attendees at the EJ IWG meeting opened up a continuing dialogue on how local, state, and the federal government might come together and work effectively with communities facing environmental justice issues.

On July 28, 2012, ATSDR participated in the 47th Annual Health Fair in Corpus Christi sponsored by the Nueces County Medical Society and Alliance. Community members had opportunities to talk with ATSDR about agency activities in the Corpus Christi community. Approximately 5,000 people attended the fair for free health testing and health information, and ATSDR was able to speak with hundreds of people throughout the day.

2013

In May 2013, ATSDR released its Community Activity Report (CAR). The interagency CAR updated residents on Corpus Christi Refinery Row activities from ATSDR, DSHS, the U.S. EPA's Office of

Environmental Justice and Tribal Affairs (OEJTA), RHAB, and TCEQ. ATSDR provided the CAR in both English and Spanish formats and mailed it to over 5,000 residences.

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Appendix D. Stationary Air Monitoring Networks and Mobile Monitoring Events

This appendix provides detailed information about the ambient (i.e., outdoor) air data the Agency for Toxic Substances and Disease Registry (ATSDR) evaluated to characterize the Refinery Row air shed. These air data are from three stationary air monitoring networks as well as mobile monitoring events. Note that ATSDR is aware that additional air data are available for the Corpus Christi area beyond those evaluated in this public health report. For example, the U.S. Environmental Protection Agency (U.S. EPA) has set national ambient air quality standards (NAAQS) for criteria pollutants such as ground-level ozone. Areas that do not meet—or that contribute to ambient air quality in a nearby area that does not meet—the NAAQS are designated "nonattainment." Areas that meet the NAAQS are designated "attainment." Areas that cannot be classified given available information are designated "unclassifiable." Because the Corpus Christi area has been designated "attainment/unclassifiable"[43] for ozone and because ozone is not emitted directly into the air by industry, ATSDR chose not to focus on ground-level ozone data in this public health evaluation.

1D. Stationary Air Monitoring Networks

For this public health evaluation, ambient air data are available from three currently operating stationary air monitoring networks in the Corpus Christi area. These three networks are operated by

- The Corpus Christi Air Quality Project (AQP),
- Industry, and
- The Texas Commission on Environmental Quality (TCEQ).

Figure 8A, Appendix A, shows the stationary air monitor locations relative to the Refinery Row facilities. Table 1B, Appendix B, provides additional details about each specific monitor.

1D.1. Corpus Christi Air Quality Project Monitoring

The Corpus Christi Air Quality Project (AQP) was designed to assess air quality along Refinery Row in Corpus Christi. The project began in October 2003. Researchers from The University of Texas (UT) at Austin's Center for Energy and Environmental Resources designed the project, with input from multiple parties. The U.S. EPA approved the project, which was funded through state funds and penalties collected in a federal lawsuit. Although this project assesses air quality along Refinery Row, it was not designed to identify specific emissions sources or initiate remedial actions [UT 2011a].

1D.1.1. Monitoring Methodology

UT installed the monitoring equipment and continues to manage the project, which includes continuous, real-time chemical level measurements, focused air sampling during periods of peak chemical levels (triggered sampling), and video surveillance of plumes originating from selected refineries. The network's principal objective is to record the concentration of specific chemicals in ambient air near Refinery Row facilities. The AQP network includes seven air monitoring stations.

[43] For ozone, U.S. EPA notes that for areas designated "attainment/ unclassifiable," states will not have to take new steps to improve air quality, but they must have programs in place, including monitoring and permitting programs, to help prevent air quality in these areas from deteriorating to unhealthy levels [USEPA 2013a].

UT initially selected the monitoring locations. The project's community advisory board advised on site accessibility, proximity of communities to industry, meteorology, and citizen complaints. Of the seven locations, three are near neighborhoods (Dona Park, Oak Park, and Solar Estates). The remaining four are closer to currently operating Refinery Row facilities. ATSDR notes both AQP and TCEQ have a monitor at the Dona Park site.

For the period 2005–2010, ATSDR compiled hydrogen sulfide, sulfur dioxide, and volatile organic compound (VOC) data from the AQP network monitors [TCEQ 2010b, 2013c; UT 2011b, 2011c, 2013]. TCEQ staff review ambient air monitoring data collected during the program. These data are available for download from TCEQ's Web site at http://www.tceq.state.tx.us/nav/data/air_met_data.html. Data are also available for download from the AQP Web site available at http://www.utexas.edu/research/ceer/ccaqp. TCEQ validated the data. ATSDR did not include rejected data in the datasets evaluated in this document.

Two general types of chemical monitoring are included in the Air Quality Project: continuous monitoring and periodic (triggered) sampling. The specific type of monitoring or sampling varies from one chemical to the next and across the monitoring stations, but is generally consistent with available monitoring technologies and convention.

- ***Sulfur Compounds.*** UT began collecting hydrogen sulfide and sulfur dioxide measurements at six of the seven monitoring sites. The only station not measuring sulfur compounds is Oak Park. Sulfur dioxide is measured using a Thermo Electron[44] (TECO) model 43-C sampler, and a similar device (model 45-C) is used for measurement of hydrogen sulfide. The continuous ambient air monitors directly measure and analyze ambient air concentrations in the field using pulsed fluorescence, without the need for laboratory analysis. Five-minute hydrogen sulfide and 5-minute sulfur dioxide samples are taken at the sampling locations. UT derives hourly average concentrations, which are reported on TCEQ's Web site. In this public health report, ATSDR compiled 2005–2010 sulfur compound data for evaluation.
- ***VOCs – Auto GC.*** At the Oak Park and Solar Estates monitoring locations, VOCs are monitored using automated gas chromatograph (Auto GC) measurement devices. The Auto GC devices directly measure ambient air concentrations of selected hydrocarbons in the field without the need for laboratory analysis of samples. The specific instrument used is a Perkin-Elmer O3 Precursor Analyzer ("Clarus-500") system. The Auto GC devices at these locations currently report concentrations for about 45 VOCs. Every hour of the day, the devices sample ambient air for 40 minutes and output the measured concentrations. The 40-minute period is judged representative of the hour in which the sample was taken. Every quarter, the principal investigators from the AQP publish annual-average concentrations for VOCs for the preceding 12-month period. Note too that because these hourly data are not available on the TCEQ Web site, for this public health evaluation TCEQ, and UT staff provided ATSDR with the hourly-average VOC concentrations for the two Auto GC locations [TCEQ 2010b, UT 2011c].
- ***VOCs – AQP Triggered Canisters.*** Triggered canister sampling events were initiated in 2005 at all seven AQP stationary locations to measure peak concentrations of VOCs during periods with higher emissions. The triggered sampling protocol was not continued after 2006 at the Oak Park

[44] Thermo Environmental Instruments, Inc. manufactures this instrument.

and Solar Estates locations because the Auto GC systems were already in place at these locations.

Note that total non-methane hydrocarbons (TNMHC) sampling was conducted using a flame ionization detector (FID) at the start of the program. Currently, five of the locations (Dona Park, JI Hailey, Off Up River Road, Port Grain Elevator, and West End Inner Harbor), continue to collect TNMHC measurements. When concentrations of TNMHC exceed 2,000 parts per billion (ppb) volume of carbon, triggered canister samples capture the chemical-specific VOC results. Note that the UT Web site uses the term "event monitoring" for the triggered-monitoring protocol.

For triggered monitoring, ATSDR compiled the chemical-specific VOC results for public health evaluation. Ambient air is collected in evacuated 400 milliliter stainless steel "mini-canisters." The UT Center for Energy & Environmental Resources Laboratory analyzes these samples with a modified version of U.S. EPA "Method TO-15"—a method that U.S. EPA developed specifically for measuring organic compounds, including many emitted from petroleum refineries [USEPA 1999a].

The original sampling protocol (2005 and early 2006) was to take 5/10/25-minute canister VOC samples (i.e., take a 5-minute sample, then a 10-minute sample, then a 25-minute sample) when triggered by a TNMHC concentration greater than 2,000 ppb volume of carbon. In addition, a separate 40-minute canister VOC sample was collected. The 5/10/25-minute samples were intended to allow for the assessment of changes in air composition during an event, while the coincident 40-minute samples were intended to provide a check of sample precision. This protocol, however, did not always function as intended: the 40-minute sample did not always start when the 5-minute sample started. Therefore, since mid-2006, only a single, 20-minute canister sample is taken when triggered by a high TNMHC concentration.

1D.1.2. Data Quality

Before the monitoring program's full implementation, UT developed a quality assurance project plan (QAPP). The U.S. District Court and multiple TCEQ representatives reviewed and signed off on the plan. The QAPP describes the proposed monitoring methods and the steps UT would take to ensure data were of a known and high quality, including chain-of-custody requirements, equipment calibrations, and audits [UT 2005]. ATSDR reviewed the QAPP and found it documented the various quality assurance measures to be applied throughout the monitoring program. As such, ATSDR found the nonrejected AQP data results were valid for public health evaluation purposes. Some additional comments regarding these data include

- ***Sulfur Compounds.*** The instruments measuring sulfur compounds have been used extensively in environmental sampling programs and generate highly reliable results. Moreover, U.S. EPA has designated the Thermo Electron model 43-C sampler as a "Reference Method" for sulfur dioxide, indicating that the method is capable of generating highly accurate and precise measurements for purposes of evaluating compliance with air quality standards [USEPA 2012].
- ***VOCs – Auto GC***. As with the sulfur compound sampling, validation of the Auto GC data is an ongoing process. The Clarus-500 system is one of several instruments used to measure ambient air concentrations of the various hydrocarbons that contribute to ozone formation [USEPA 1998]. The device is in current and wide use throughout Texas. To assess the quality of these measurements, ATSDR reviewed the many quality assurance procedures outlined in the QAPP.

In addition, UT staff performed additional validation of these Auto GC data before sending the hourly data to ATSDR for use in this public health evaluation. And to provide quantitative insights into the Auto GC data quality, ATSDR performed its own cross-network comparisons (see Section 6.2 in the main text and Section 2G in Appendix G).

- ***VOCs – Canister.*** As with the sulfur compound sampling, validation of the TNMHC data is an ongoing process. TNMHC is measured using a TECO Model 55-C sampler. While U.S. EPA does not designate “Reference Methods” for this device, it has been used successfully in many environmental monitoring programs and was selected for this program due to its relatively low measurement sensitivity. Triggered canister VOC samples are analyzed using a modified version of U.S. EPA Method TO-15. The modifications to the U.S. EPA method include use of a smaller canister and shorter sampling time than typically employed. The data are subject to the same data quality assurance process as are the samples obtained from the Auto GC VOC protocol.

1D.2. Industry-Sponsored Monitoring

Several northern Corpus Christi facilities collaborate to monitor ambient air quality along the Refinery Row corridor at six monitoring stations. The locations near operating schools (Oak Park Elementary and Tuloso Midway Middle) and former schools (Crossley Elementary and Tuloso Midway Elementary) allow ATSDR to evaluate past and current air exposures of both children and adults in the community. One location is near a neighborhood (Up River Road monitor) and one is located near the Refinery Row complex (Huisache monitor). In the past, the area surrounding the Huisache air monitor included many homes; however, the majority of homes near this monitor were bought out in the late 1990s. ATSDR notes both industry and TCEQ have monitors at the Huisache and Tuloso Midway Middle School sites. A private contractor maintains and monitors the industry network.

1D.2.1. Monitoring Methodology

ATSDR evaluated VOC data from the industry network monitors for data collected from 1996 to 2010 [ToxStrategies 2011]. On ATSDR’s request, industry provided these data electronically for use in this public health evaluation. All industry network locations use canisters to monitor VOCs except Huisache, where a continuous sampling monitor measures benzene.

- ***Benzene – Auto GC.*** Beginning in 2003, at the Huisache station industry began collecting Auto GC benzene measurements every 15 minutes. These measurements are made using an Auto-GC manufactured by SRI Instruments (Model 8610), following a sampling method developed by URS Corporation.
- ***VOCs – Canister.*** The data provided by industry included 1996–2010 canister measurements of up to 27 chemicals. Monitors collect canister samples at Crossley Elementary School, Oak Park Elementary School, Tuloso Midway Elementary School, and Tuloso Midway Middle School for 24-hour averaging periods, approximately two to six times a month, depending on the season. For example, VOCs are typically sampled four to six times a month in January, February, and March. Samples are collected in stainless steel evacuated in accordance with a modified version of U.S. EPA method TO-15.

1D.2.2. Data Quality

ATSDR learned of several quality assurance procedures incorporated into the network, such as collection of field duplicates and field blanks in approximately 10% of the sampling events, quarterly audits of the sample collection systems, and strict adherence to published methods and data validation procedures. Industry provided the following text regarding data quality:

- ***Benzene – Auto GC.*** The Auto GC instrument is calibrated across an approximate range of 1–50 ppb. Daily calibration checks are run at 10 ppb and 50 ppb with an acceptance criterion of ±30%. Daily field blanks are run with an acceptance criterion of <1 ppb. The demonstrated method detection limit is less than <0.5 ppb. The data completeness criterion is 85%. All data are fully validated and the Auto GC system is audited quarterly.
- ***VOCs – Canister.*** Samples are collected and analyzed by TestAmerica using a variation of U.S. EPA method TO-15, with the principal modification being that the laboratory uses zero humidified nitrogen in place of air for method blanks. All data are fully validated.

Nevertheless, ATSDR has not identified nor has ATSDR been provided with any reports that present quantitative data quality metrics (e.g., precision estimates from duplicate samples, accuracy estimates from audit samples). Because no data quality reports are available for review, ATSDR performed its own cross-network comparisons of the Auto GC and canister data to provide quantitative insights into the industry's data quality (see Section 6.2 in the main text and Section 2G in Appendix G).

1D.3. Texas Commission on Environmental Quality Monitoring

Over the years, Texas environmental agencies—the Texas Air Control Board (TACB), the Texas Natural Resources Conservation Commission (TNRCC), and now TCEQ—have managed the state's ambient air monitoring network. TCEQ currently operates dozens of statewide monitoring stations that serve several purposes. Much of the monitoring assesses the state's compliance with NAAQS. Additional site-specific monitoring might characterize local air quality issues and identify potential threats to public health. Such monitoring can occur for various VOCs and inorganic pollutants (e.g., metals).

TCEQ air monitoring data are on the Texas Air Monitoring Information System (TAMIS) Web interface, available at http://www5.tceq.state.tx.us/tamis/index.cfm?fuseaction=home.welcome. TAMIS allows users to generate and download predefined reports containing air quality data and associated information stored in the database. ATSDR compiled 1980s through 2010 data from 10 TCEQ monitoring stations along Refinery Row.

Four stations are currently in operation: Dona Park, Hillcrest, Huisache, and Tuloso Midway Middle School. Of these four stations, two operate near neighborhoods (Dona Park and Hillcrest), one near a school (Tuloso Midway Middle School), and one (Huisache) near the industrial area. As stated previously, in the past many homes surrounded the Huisache monitor but now there are less homes in that area. Also, in the past five stations (Fire Station #5, Navigation, Old Galveston Road, Poth Lane, and West Guth Park) operated near neighborhoods. The Poth Lane location is in the same area as Huisache, which is currently industrial without many homes. One station (Navigation Boulevard) operated on the northern section of Refinery Row, along the ship channel. As stated previously, both industry and TCEQ have monitors at the Huisache and Tuloso Midway Middle School sites.

ATSDR evaluates hydrogen sulfide, sulfur dioxide, metals, particulate matter, and VOC data from the TCEQ network monitors for data collected from 1980–2010 [TCEQ 2013a, 2013b, 2013c, 2014].

Meteorological data were also downloaded from TAMIS from Dona Park, Hillcrest, Huisache, and Tuloso Midway Middle School.

1D.3.1. Monitoring Methodology

Two general types of ambient air monitoring—continuous and semi-continuous—have occurred at the TCEQ monitoring locations. The specific type of monitoring that TCEQ conducts varies depending on the chemical and monitoring station, but is consistent with available monitoring technologies and conventions. More detailed information on TCEQ's air monitoring in Corpus Christi follows:

- ***Metals and Particulate Matter.*** ATSDR compiled particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) data from the Dona Park station for the years 2001 to 2010, the Huisache station for the years 2000 to 2010, and the Navigation station for the years 2000 to2002. Also, airborne particulate matter less than 10 microns in diameter (PM_{10}) data are available from the Dona Park (2002–2010), Fire Station #5 (1993–1996), and Navigation (1993–2002) stations.

  A 24-hour average sample is collected every 3 or 6 days according to the requirements established in Code of Federal Regulations (CFR) Title 40, Part 58. Airborne $PM_{2.5}$ are collected on Teflon filters and analyzed to determine the mass concentration following U.S. EPA's federal reference method described in 40CFR, Part 50, Appendix L. The metal content is determined using energy dispersive x-ray fluorescence (XRF), following a modified U.S. EPA Method IO-3.3. The PM_{10} data are collected on quartz filters using a high volume air sampler and analyzed with gravimetric analysis according to procedures outlined in 40CFR, Part 50, Appendix J.

  In the 1980s at the Fire Station #5, Navigation Boulevard, Old Galveston Road, and West Guth Park stations, high-volume samplers collected airborne total suspended particulates (TSP) on quartz filters. The collected samples were then sent to a laboratory for XRF metals analysis. These 24-hour average samples were also collected every 6 days. In the 1980s the Navigation station followed these same procedures, but airborne TSP was only analyzed for lead.

  Note that TCEQ analyzed particulate matter filters for over 50 metals. In this public health report, ATSDR focused its air data evaluation on 16 metals (ammonium ion, antimony, arsenic, barium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, molybdenum, nickel, selenium, vanadium, and zinc). ATSDR added chlorine to the metals analysis section because TCEQ measured chlorine as part of its particulate matter filter analysis—not as a gaseous substance. ATSDR chose these metals and chlorine based on its review of potential refinery emission sources [RTI 2011] and TRI reported releases for Nueces County [USEPA 2013].

- ***Sulfur Compounds.*** TCEQ operates continuous monitors—the monitors measure ambient air concentrations in the field without the need for additional laboratory analysis. The Huisache station continuously monitors both hydrogen sulfide and sulfur dioxide; the Tuloso Midway Middle School station continuously monitors sulfur dioxide. Teledyne Advanced Pollution Instrumentation (API) model 100E measures sulfur dioxide according to the U.S. EPA federal reference method described in 40 CFR Part 53, Appendix A-1. Teledyne API model 101E also measures hydrogen sulfide. For both parameters, measurements occur continuously and the devices record and output 1-hour average concentrations; for sulfur dioxide, concentrations are also available for 5-minute averaging periods.

- ***VOCs – Canister.*** TCEQ currently[45] conducts VOC monitoring at the Dona Park, Hillcrest, and Huisache monitoring stations and in the past conducted VOC monitoring at the Navigation and Poth Lane monitoring stations. Canister samples are collected for 24-hour averaging periods, every 6 days. TCEQ uses stainless steel canister sampling for its semi-continuous VOC monitoring. Monitoring proceeds according to modified U.S. EPA Method TO-15. By this method, ambient air is drawn into a stainless steel canister. A laboratory analyzes the canister by gas chromatography with mass spectrometry detection (GC/MS).
- ***Meteorological.*** TCEQ meteorological data (wind speed and direction) are available from 2000−2010 for three stations (Hillcrest, Huisache, and Tuloso Midway Middle School) and from 2003−2010 for one station (Dona Park). All four stations are equipped with a Rhon 25G Met Tower and the sensing equipment is a Met One F640 temperature boom and wind sensor. The stations' sensors are located at a height of 30 meters.

1D.3.2. Data Quality

As delineated in guidance and requirements specific to the objectives of the various monitoring programs, TCEQ's quality assurance (QA) program encompasses documentation, assessment, and verification. The U.S. EPA-approved quality management plan and quality assurance project plans describe the processes, procedures, and requirements needed to ensure ambient air monitoring data are scientifically valid, of known precision and bias, complete, representative, and comparable. Other guidance documentation includes standard operating procedures (SOPs) and program-specific technical guidance.

In addition, the instrumentation and methodologies TCEQ uses adhere to rigorous sampling and analytical requirements as prescribed under federal rule and U.S. EPA guidance. Part of TCEQ's comprehensive QA program includes many levels and types of QA and quality control (QC) checks. Depending on the type and purpose of individual monitors, QA/QC procedures include daily, weekly, monthly, quarterly, and annual checks. And these checks include annual performance evaluation audits conducted on each instrument by TCEQ, by U.S. EPA, by specialized contractors using independently calibrated equipment, or by a combination of the three.

ATSDR finds the TCEQ quality assured data are valid for public health evaluation purposes. Some additional comments regarding these data include

- ***Metals and Particulate Matter.*** Both the $PM_{2.5}$ and PM_{10} samples are analyzed following procedures which are well established and peer reviewed.

  Historical data collected from the 1980s might not fully represent ambient conditions. Although the 1980s data used a widely accepted sampling and analytical approach for the time, research published since 1993 suggested that XRF analyses are not appropriate for samples collected on pure quartz filters. For instance, a widely cited publication on particulate matter measurements

[45]Note that TCEQ installed the Palm Auto GC, which was activated on August 8, 2010. ATSDR's evaluation of ambient air data for Corpus Christi Refinery Row includes most available air data from the 1980s through 2010. Because, however, this monitor was not operating before 2010 and because other monitors (Hillcrest and Crossley Elementary School) have been operating for years near the Palm station, in this public health assessment ATSDR choose not to evaluate the 2010 partial year Palm Auto GC data.

does not list XRF as a compatible analytical method for particles collected on pure quartz filters [Chow 1995]. Using this and other research, U.S. EPA's Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air, first published in 1999, does not list XRF as a compatible analytical method for particles collected on pure quartz filters [USEPA 1999b]. The incompatibility results from the fact that particles can penetrate quartz filters at depths that the XRF analyses cannot resolve. Thus in recent years, when conducting laboratory analyses using XRF, other filter types (e.g., Teflon) have been more widely used.

Because of the incompatibility between the filter medium (quartz) and analytical method (XRF), ATSDR concludes that the metals data collected in the 1980s are of unknown quality and could underestimate actual ambient air concentrations. These data will be used for screening purposes and to put past metals concentrations into perspective, but ATSDR will not use them to draw definitive health conclusions.

ATSDR notes that the particulate matter data are collected for determining NAAQS compliance.

- ***Sulfur Compounds.*** Sulfur dioxide measurements use U.S. EPA-approved federal reference methods—that is, methods shown capable of generating accurate and precise air quality measurements. No federal reference method has been developed for hydrogen sulfide. The method used in Corpus Christi, however, has been successfully applied in other ambient air monitoring programs. ATSDR believes this method can generate data of a known and acceptable quality.
- ***VOCs – Canister.*** VOC canister samples that TCEQ collects in the Corpus Christi area are analyzed according to a modified U.S. EPA Method TO-15. TCEQ's analytical procedures are documented in SOPs and discuss any deviations from the U.S. EPA method. ATSDR has reviewed these deviations and has no reason to believe they affect the quality of the VOC measurements. TCEQ's SOPs document numerous VOC-sample QC checks to ensure that the VOC measurements are of a known and acceptable quality.

In addition, quantitative indicators of TCEQ's laboratory performance are available from a sampling program in which the agency collected four "split samples" analyzed both by TCEQ and by an external laboratory (TestAmerica). Using the raw data the two laboratories reported, ATSDR evaluated the differences between TCEQ's measurements and the external laboratory's measurements [TCEQ 2010a]. Across the four split samples, ATSDR computed concentration differences for the chemicals that both laboratories detected. In most cases, the two laboratories' measured concentrations differed by less than 30%, indicating acceptable agreement for this method. In 16 instances, the measured concentrations differed by more than 30%. In 13 out of 16 of these instances, however, TCEQ's laboratory measured a concentration higher than the external laboratory. This comparison suggests that the TCEQ laboratory does not have a systematic negative bias in its measurements.

Also, ATSDR performed cross-network comparisons of the TCEQ canister data to provide quantitative insight into TCEQ's data quality (see Section 6.2 in the main text and Section 2G in Appendix G).

2D. Mobile Monitoring Events

ATSDR compiled ambient air data from 24 mobile sampling events that occurred in the vicinity of Corpus Christi Refinery Row between July 1993 and March 2008 [TCEQ 2002, 2003a, 2003b, 2004, 2006, 2007, 2008; TNRCC 1994b, 1995, 1996a, 1996b, 1997, 1998a, 1998b, 1998c, 1999, 2000a, 2000b, 2000c, 2000d, 2001]. TCEQ deploys the mobile monitors to collect measurements of carbonyl compounds, sulfur compounds, semi-volatile organic compounds (SVOCs), and VOCs. The short-term mobile monitoring events allow TCEQ to monitor emission sources.

Note that in this section, ATSDR provides only general information on the types of data collected during the mobile monitoring events; the agency does not discuss each event separately. Furthermore, ATSDR compiled these data from TCEQ toxicology reports; the agency did not review the original laboratory reports or the data quality procedures. Nevertheless, for this public health evaluation, ATSDR assumed the TCEQ toxicology reports contained valid data. The following text provides some details about the mobile data:

- ***Carbonyl Compounds.*** Various carbonyl compounds were measured using 1-hour canisters for mobile events occurring between February 2002 and November 2004. Only 28 samples were collected and analyzed for 18 carbonyl compounds.
- ***Sulfur Compounds.*** Between February 1996 and March 2008, 30-minute hydrogen sulfide samples were collected using impinger tubes. In February 2002, grab samples of hydrogen sulfide and sulfur dioxide were collected with an Auto GC. Between February 1994 and February 2001, hydrogen sulfide and sulfur dioxide samples were collected using real-time gas chromatography (RTGC). RTGC samples were collected for various durations and a continuous site average, high 1-hour average, and maximum concentration were reported for each sample. Between February 1996 and March 2008, 30-minute continuous samples of both hydrogen sulfide and sulfur dioxide were measured using various sulfur dioxide analyzers and hydrogen sulfide converters. High single-point concentrations and 30-minute average concentrations were reported for each of these samples.
- ***SVOCs.*** In November 2003 and November 2004, polycyclic aromatic hydrocarbons (PAHs)—an SVOC subset—were measured using canisters of various durations. During these two mobile monitoring events, seven samples were collected and analyzed for 16 PAHs. During another March 2007 mobile monitoring event, SVOCs were measured using 3-hour canisters. During this event, five samples were collected and analyzed for 39 SVOCs, although only the 16 PAHs were detected.
- ***VOCs.*** Between 1994 and 2008, measurements of 30 VOCs were collected with RTGC. These samples were for various durations, but each sample included a continuous site average, high 1-hour average, and maximum concentration. Grab samples collected between February 2002 and February 2003 used real-time gas chromatography/mass spectroscopy to analyze for 14 VOCs. Between 1993 and 2008, canister samples of various durations were collected and analyzed for about 100 VOCs.

3D. Past Air Monitoring Investigations

ATSDR was able to obtain and review hardcopy reports from the 1990s for ambient air data in the Corpus Christi area. The VOC levels provided in these reports gave ATSDR a general understanding of past air exposure levels. These data are not summarized in Appendix B tables primarily because uncertainties exist regarding the sampling and analytical methodology from these older hardcopy data reports.

ATSDR notes that the 1980s metals data are of also of unknown quality, but the agency did summarize those data in Appendix B tables. This is because no other metals data for the 1980s exist. However, other 1990s VOC data do exist. ATSDR found that the hardcopy reports' VOC concentrations are similar to the VOC concentrations reported by the industry and TCEQ networks during the same time frame. Therefore, manually extracting the 1990s VOC data into tables for presentation in this report would not alter the agency's public health conclusions. The following text provides some basic details about the 1990s hardcopy reports.

3D.1. Corpus Christi Area Monitoring Network: March 1994–March 1996

The Corpus Christi Area Monitoring Network was an environmental initiative that included five local industrial sponsors [Radian 1996]. The program was coordinated with local and state government representatives. This monitoring network characterized airborne VOC levels in close proximity to the refineries. Between March 1994 and March 1996, the seven monitoring locations operated for different lengths of time. The hardcopy summary report contained data for a combination of 37 VOCs.

3D.2. Fence-line Benzene Monitoring: August 1993–April 1994

In the early 1990s, Coastal Refining and Marketing, Inc., and the Texas Air Control Board (TACB[46]) entered into a Consent Agreement that required ambient air monitoring of benzene. The Valero East Plant currently operates at the site of the former Coastal Refining and Marketing, Inc. facility. This program's measured benzene concentrations are documented in a series of letters from Coastal Refining and Marketing, Inc., to the Office of the Texas Attorney General [CRM 1993a, 1993b, 1993c, 1993d, 1993e, 1993f, 1993g, 1994a, 1994b, 1994c, 1994d, 1994e, 1994f, 1994g, 1994h]. These letters contain benzene results from August 1993 through April 1994 for seven monitoring stations that were both at the facility fence-line and near residential areas.

3D.3. Survey of the Oak Park Neighborhood: July 1993–November 1993

TNRCC[47] conducted continuous ambient air monitoring in the Oak Park Neighborhood of Corpus Christi as part of a special investigation in the area from the week beginning July 27, 1993 to November 22, 1993 [TNRCC 1994a]. Although ATSDR was not able to obtain a map showing the sampling location, the sampling reportedly occurred on Poth Lane, a street in close proximity to Refinery Row's easternmost area. Laboratory analyses identified various groups of hydrocarbons and individual VOCs.

[46] The Texas Air Control Board (TACB) was the Texas environmental agency that managed air quality issues up until 1993, when it merged with several other agencies to form the Texas Natural Resource Conservation Commission (TNRCC). In 2002, TNRCC officially changed names to the Texas Commission on Environmental Quality (TCEQ).

[47] In 2002, TNRCC officially changed its name to the Texas Commission on Environmental Quality (TCEQ).

4D. References

Chow J. 1995. Measurement methods to determine compliance with ambient air quality standards for suspended particles. J Air & Waste Manage. Assoc. 45:320-382.

[CRM] Coastal Refining & Marketing, Inc. 1993a. September 15th letter from Mr. Ralph G. Coker, Vice President and Plant Manager, Coastal Refining & Marketing, Inc., to Mr. Gregg Cooke, Chief, Environmental Protection Division, Office of the Texas Attorney General, containing benzene emissions and ambient air monitoring information. Corpus Christi, TX.

[CRM] Coastal Refining & Marketing, Inc. 1993b. September 24th letter from Mr. Ralph G. Coker, Vice President and Plant Manager, Coastal Refining & Marketing, Inc., to Mr. Gregg Cooke, Chief, Environmental Protection Division, Office of the Texas Attorney General, containing benzene emissions and ambient air monitoring information. Corpus Christi, TX.

[CRM] Coastal Refining & Marketing, Inc. 1993c. November 17th letter from Mr. Ralph G. Coker, Vice President and Plant Manager, Coastal Refining & Marketing, Inc., to Mr. Gregg Cooke, Chief, Environmental Protection Division, Office of the Texas Attorney General, containing benzene emissions and ambient air monitoring information. Corpus Christi, TX.

[CRM] Coastal Refining & Marketing, Inc. 1993d. November 23rd letter from Mr. Ralph G. Coker, Vice President and Plant Manager, Coastal Refining & Marketing, Inc., to Mr. Gregg Cooke, Chief, Environmental Protection Division, Office of the Texas Attorney General, containing benzene emissions and ambient air monitoring information. Corpus Christi, TX.

[CRM] Coastal Refining & Marketing, Inc. 1993e. December 8th letter from Mr. Ralph G. Coker, Vice President and Plant Manager, Coastal Refining & Marketing, Inc., to Mr. Gregg Cooke, Chief, Environmental Protection Division, Office of the Texas Attorney General, containing benzene emissions and ambient air monitoring information. Corpus Christi, TX.

[CRM] Coastal Refining & Marketing, Inc. 1993f. December 13th letter from Mr. Ralph G. Coker, Vice President and Plant Manager, Coastal Refining & Marketing, Inc., to Mr. Gregg Cooke, Chief, Environmental Protection Division, Office of the Texas Attorney General, containing benzene emissions and ambient air monitoring information. Corpus Christi, TX.

[CRM] Coastal Refining & Marketing, Inc. 1993g. December 30th letter from Mr. Ralph G. Coker, Vice President and Plant Manager, Coastal Refining & Marketing, Inc., to Mr. Gregg Cooke, Chief, Environmental Protection Division, Office of the Texas Attorney General, containing benzene emissions and ambient air monitoring information. Corpus Christi, TX.

[CRM] Coastal Refining & Marketing, Inc. 1994a. January 6th letter from Mr. Ralph G. Coker, Vice President and Plant Manager, Coastal Refining & Marketing, Inc., to Mr. Gregg Cooke, Chief, Environmental Protection Division, Office of the Texas Attorney General, containing benzene emissions and ambient air monitoring information. Corpus Christi, TX.

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[CRM] Coastal Refining & Marketing, Inc. 1994c. January 28th letter from Mr. Ralph G. Coker, Vice President and Plant Manager, Coastal Refining & Marketing, Inc., to Mr. Gregg Cooke, Chief, Environmental Protection Division, Office of the Texas Attorney General, containing benzene emissions and ambient air monitoring information. Corpus Christi, TX.

[CRM] Coastal Refining & Marketing, Inc. 1994d. March 21st letter from Mr. Ralph G. Coker, Vice President and Plant Manager, Coastal Refining & Marketing, Inc., to Mr. Gregg Cooke, Chief, Environmental Protection Division, Office of the Texas Attorney General, containing benzene emissions and ambient air monitoring information. Corpus Christi, TX.

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Appendix E. Derivation and Intended Use of Comparison Values

1E. Summary

The Agency for Toxic Substances and Disease Registry (ATSDR) has developed health and environmental guidelines to use when conducting the screening analysis and evaluating exposures to substances found at sites under investigation. The information provided in this appendix was compiled directly from ATSDR's Public Health Assessment Guidance Manual [ATSDR 2005] and other sources [ATSDR 1993, 2013; Cal EPA 2008, 2009, 2014; USEPA 2011, 2012a, 2012b, 2012c, 2013a, 2013b, 2013c, 2013d; TCEQ 2012, 2013]. The purpose of this appendix is to provide information about those health and environmental guidelines used for screening purposes in the Corpus Christi Refinery Row Public Health Assessment. For further information on ATSDR's public health evaluation process and comparison values, please refer to the ATSDR guidance manual available at http://www.atsdr.cdc.gov/hac/PHAManual/toc.html.

ATSDR, in cooperation with the U.S. Environmental Protection Agency (U.S. EPA), has developed a priority list of hazardous substances found at hazardous waste sites, as directed under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendment and Reauthorization Act of 1986 (SARA). For those substances most commonly found, ATSDR has prepared Toxicological Profiles that include an examination, summary, and interpretation of available toxicologic and epidemiologic data. Using those data, ATSDR has derived health and environmental guidelines.

- ATSDR ***health guidelines*** are substance-specific doses or concentrations derived using toxicologic information. Where adequate dose-response data exist, health guidelines are derived for both the ingestion or inhalation routes of exposure. Health guidelines include ATSDR's minimal risk levels (MRLs). No health guidelines have been developed by ATSDR for dermal exposures.
- ATSDR ***environmental guidelines*** are media-specific substance concentrations derived from health guidelines using default exposure assumptions. ATSDR environmental guidelines include environmental media evaluation guides (EMEGs) and cancer risk evaluation guides (CREGs) that are available for contact with substances in water, soil, and air. No environmental guidelines have been developed by ATSDR for contact with contaminants in food or biota.

In addition to comparison values derived by ATSDR, other federal and some state agencies have developed similar types of health-based guidelines for concentrations of substances in water, soil, air, and food. ATSDR staff may use these comparison values, when appropriate, to screen substances detected in various site media.

This appendix provides a description of comparison values available from ATSDR, as well as other sources, that were used to screen the Corpus Christi Refinery Row air data. ATSDR comparison values discussed in this appendix are MRLs, EMEGs, and CREGs. Non-ATSDR comparison values discussed in this appendix are reference concentrations (RfCs), reference exposure levels (RELs), inhalation unit risks (IURs), carcinogenic target risk screening level (SLs), and air monitoring comparison values (AMCVs). All ATSDR comparison values, as well as the aforementioned RfCs, RELs, IURs, SLs, and AMCVs, are nonenforceable health-based comparison values. ATSDR also provides information on U.S. EPA's national ambient air quality standards (NAAQS), which are enforceable standards. In addition, ATSDR provides information on U.S. workplace guidelines. ATSDR only uses these workplace values to put site-specific concentrations of contaminants into perspective for the reader, especially when no other non-occupational comparison values are available. Lastly, ATSDR provides information on air quality guidelines (AQGs) developed by the World Health Organization (WHO).

For each guideline discussed, a definition and description of the derivation and applicability or intended use are provided. When available, a website reference is also provided.

2E. ATSDR Health and Environmental Guidelines

2E.1. Minimal Risk Levels (MRLs)

ATSDR's minimal risk levels (MRLs) are an estimate of the daily human exposure to a substance that is likely to be without appreciable risk of adverse health effects during a specified duration of exposure. MRLs are based only on noncarcinogenic effects. MRLs are screening values only and are not indicators of health effects. Exposures to substances at doses above MRLs will not necessarily cause adverse health effects and should be further evaluated.

ATSDR derives MRLs when reliable and sufficient data can identify the target organ(s) of effect or the most sensitive health effects(s) for a specific duration for a given route of exposure. MRLs are set below levels that might cause adverse health effects in most people, including sensitive populations. MRLs are derived for acute (1–14 days), intermediate (15–364 days), and chronic (365 days and longer) durations. MRLs are generally based on the most sensitive chemical-induced endpoint considered relevant to humans. ATSDR does not use serious health endpoints (e.g., irreparable damage to the liver or kidneys, birth defects) as bases for establishing MRLs.

MRL Derivation

MRL = NOAEL (or LOAEL) / UF

where,

MRL	=	minimal risk level (mg/kg/day)
NOAEL	=	no-observed-adverse-effect level (mg/kg/day)
LOAEL	=	lowest-observed-adverse-effect level (mg/kg/day)
UF	=	uncertainty factor (unitless)

ATSDR derives MRLs for substances by factoring the most relevant documented no-observed-adverse-effects level (NOAEL) or lowest-observed-adverse-effects level (LOAEL) and an uncertainty factor. Inhalation MRLs are exposure concentrations expressed in units of parts per billion (ppb) for gases and volatiles, or micrograms per cubic meter ($\mu g/m^3$) for particles. Inhalation MRLs are derived for continuous, 24-hour a day exposures. The specific approach used to derive MRLs for individual substances are detailed in ATSDR's Toxicological Profile for each substance available at http://www.atsdr.cdc.gov/toxprofiles/index.asp.

Most MRLs contain a degree of uncertainty because of the lack of precise toxicologic information about the people who might be most sensitive to the effects of environmental contamination (e.g., children, elderly, those with pre-existing illnesses). ATSDR uses a conservative (i.e., protective) approach to address this uncertainty. This approach is consistent with the public health principle of prevention.

Although human data are preferred, when relevant human studies are unavailable, ATSDR bases MRLs on animal studies. In the absence of evidence to the contrary, ATSDR assumes that humans are more sensitive to the effects of hazardous substances than are animals and that certain persons might be particularly sensitive. Uncertainties are taken into account by applying "uncertainty factors" to the NOAEL. For example, an uncertainty factor of between 1 and 10 might apply for extrapolation from animal doses to human doses or to account for sensitive persons. When more than one uncertainty factor is applied, the uncertainty factors are multiplied. For example, the combined uncertainty factor of

100 could be accounted for by an uncertainty factor of 10 for the extrapolation of animals to humans and another factor of 10 to account for sensitive persons.

ATSDR derives MRLs on the assumption that exposures occur to a single substance and that only noncarcinogenic health effects might result. But hazardous waste sites might expose people to a mixture of substances. MRLs are intended to serve only as a screening tool to help ATSDR staff decide whether to evaluate more closely exposures to a substance found at a site. MRLs are not intended to define cleanup or action levels. And exposure doses above the MRL do not necessarily mean that adverse health effects will occur.

2E.2. Environmental Media Evaluation Guides (EMEGs)

ATSDR's environmental media evaluation guides (EMEGs) represent concentrations of substances in water, soil, and air to which humans might be exposed during a specified period of time (acute, intermediate, or chronic) without experiencing adverse health effects. EMEGs have been calculated for substances for which ATSDR has developed Toxicological Profiles. ATSDR uses information about the substance toxicity (MRLs) and default exposure assumptions. For exposure to substances in the air, EMEGs are expressed as air concentrations and are the same for adults and for children.

ATSDR uses EMEGs during a screening analysis, particularly when conducting an environmental guideline comparison. EMEGs help to evaluate quickly large quantities of data for a site under investigation. Substances found at concentrations below EMEGs are not expected to pose public health hazards. Substances found at concentrations above EMEGs require further evaluation before arriving at a public health conclusion. EMEGs are screening values only—they are not indicators of adverse public health effects. Substances found at concentrations above EMEGs will not necessarily cause adverse health effects, but will require further evaluation.

ATSDR makes three assumptions when deriving EMEGs: 1) exposures occur through contact with a single medium (e.g., water or air) via a single route (e.g., ingestion or inhalation), 2) exposures involve a single substance, and 3) from the exposure, only noncarcinogenic health effects might result.

EMEGs are based on toxicity information (MRLs), which consider noncarcinogenic toxic effects of chemicals, including their developmental and reproductive toxicity. MRLs do not consider potential genotoxic or carcinogenic effects of a substance. Because some substances have both noncarcinogenic and carcinogenic effects, ATSDR has derived cancer risk evaluation guides (CREGs) to consider potential carcinogenic effects of a substance.

Conversion Factor for Air

To change ppb to µg/m³, use the following equation:

$$C_{\mu g/m3} = C_{ppb} \times (MW / 24.45)$$

where,

$C_{\mu g/m3}$ = concentration in micrograms per cubic meter (µg/m³)

C_{ppb} = concentration in parts per billion (ppb)

MW = molecular weight of a substance in grams/mole

EMEGs for inhalation exposures to airborne contaminants are derived from the inhalation MRLs in the ATSDR Toxicological Profiles or ATSDR's HazDat database. The inhalation MRLs are expressed in concentration units of µg/m³ or ppb. Therefore, the air EMEG for a chemical is the same as its MRL, and no calculation is required. The same air EMEG value serves all segments of the population. For chemical substances in a vapor form at standard temperature and pressure (STP), the EMEG value is given in ppb (volume basis); for substances that are solids at STP, the value is given in µg/m³.

ATSDR MRLs are derived for continuous, 24-hour-a-day exposures. In many instances, inhalation exposures from a site are less than 24 hours per day. Air EMEGs based on MRLs provide a conservative approach for identifying air contaminants of potential health concern.

For some chemicals, experimental toxicity data based on oral administration might be available, but no data based on inhalation. The problem is that differences might occur in the chemical's toxicity for oral exposure compared to inhalation. Differences might occur in the chemical's absorption, metabolism, distribution, and site-specific toxicity. Consequently, an air EMEG is derived only from an MRL based on an inhalation study.

2E.3. Cancer Risk Evaluation Guides (CREGs)

ATSDR's cancer risk evaluation guides (CREGs) are media-specific comparison values that are used to identify concentrations of cancer-causing substances that are unlikely to result in an increase of cancer rates in an exposed population. ATSDR develops CREGs using U.S. EPA's cancer slope factor (CSF) or inhalation unit risk (IUR), a target risk level (10^{-6}), and default exposure assumptions. The target risk level of 10^{-6} represents a possible risk of one excess cancer case in a population of one million. CREGs are only available for adult exposures—no CREGs specific to childhood exposures are available.

To derive the air CREGs, ATSDR uses IURs developed by U.S. EPA. Because toxicity studies of inhalation exposures express doses as concentrations, the IURs are estimates of the possible risk of cancer associated with a carcinogen expressed in concentration units. As such, to derive CREGs for inhalation exposure, no exposure parameters are needed for intake rate or body weight. Nevertheless, ATSDR assumes that exposure is continuous—occurring for 24 hours a day, every day.

Derivation of a CREG for Inhalation

$$CREG = TR / IUR$$

where,

CREG = cancer risk inhalation guide (µg/m^3)

TR = target risk level (10^{-6})

IUR = inhalation unit risk [(µg/m^3)$^{-1}$]

In developing the CREGs, ATSDR assumes that 1) exposures occur through contact to a single medium, (2) exposures occur to a single substance, and 3) from the exposure only cancer health effects will result. CREGs serve as a screening tool for evaluating concentrations of carcinogens during an environmental guideline comparison. CREGs are based on possible estimates of cancer risk. Therefore, CREGs should serve only as a screening tool and not that cancer is indicated, expected, or predicted.

3E. Non-ATSDR Health and Environmental Guidelines

3E.1. Reference Concentrations (RfCs)

U.S. EPA developed chronic reference concentrations (RfCs) for inhalation. These are estimates of daily exposures to a substance likely without a discernible risk of adverse effects to the general human population (including sensitive subgroups) during a lifetime of exposure. On December 5, 2003, the U.S. EPA Office of Superfund Remediation and Technology Innovation (OSRTI) revised its hierarchy of human health toxicity values for Superfund risk assessments, establishing three tiers as the new hierarchy. RfCs for this hierarchy used to screen the Corpus Christi Refinery Row data are:

5. ***RfC – I***: Reference concentrations based on information contained in the Integrated Risk Information System (IRIS). Prepared and maintained by the U.S. EPA's National Center for Environmental Assessment (NCEA), IRIS represents the first tier. It is an electronic database, and

it contains information on human health effects that might result from exposure to more than 550 chemical substances in the environment. IRIS includes information on RfCs, as well as other reference guidelines. IRIS assessments have undergone external peer review and a U.S. EPA consensus review process [USEPA 2013a, 2013c]. IRIS is available at http://www.epa.gov/iris/index.html.

6. ***RfC – P***: Reference concentrations based on information from the Provisional Peer Reviewed Toxicity Values (PPRTV) electronic library. PPRTV, prepared and developed by U.S. EPA's OSRTI, represents the second tier. PPRTV information has not undergone the multi-program review and consensus required for toxicity values to be placed in IRIS [USEPA 2013b]. PPRTV is available at http://hhpprtv.ornl.gov/.
7. ***RfC – H***: Reference concentrations based on information from the Health Effects Assessment Summary Tables (HEAST). Prepared by or for the NCEA, HEAST represents the third tier. HEAST information is provisional, meaning the toxicity values have had some limited form of agency or external review but do not have the extensive documentation or formal review process required for IRIS inclusion [USEPA 2011]. HEAST is available at http://epa-heast.ornl.gov/.

RfCs are derived from the NOAEL or LOAEL, or benchmark concentration, or from categorical regression. The derivation process includes application of uncertainty factors and additional modifying factors based on a professional judgment of the chemical's entire database. To ensure that the potential for health effects is not underestimated, U.S. EPA includes uncertainties sometimes spanning orders of magnitude.

RfCs assume that certain toxic effects have thresholds, such as for cell death or organ damage. RfCs also assume exposure to a single substance in a single media. RfCs are derived for the noncarcinogenic health effects of compounds that are also carcinogens. Doses less than the RfC are not expected to be associated with health risks. But doses less than the RfC are not necessarily "acceptable," and doses in excess of the RfC are not necessarily "unacceptable."

For this public health evaluation, ATSDR compiled RfC values from the "Residential Air Supporting" table on U.S. EPA's Mid-Atlantic Risk Assessment Web site and available at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm.

3E.2. Reference Exposure Levels (RELs)

The California EPA (Cal. EPA) Office of Environmental Health Hazard Assessment (OEHHA) develops acute, 8-hour, and chronic reference exposure levels (RELs) for use in risk assessments conducted under California's Air Toxics Hot Spots and Toxic Air Contaminants programs. RELs are concentrations of a chemical at or below which adverse noncancer health effects are not anticipated to occur for a specified exposure duration, including sensitive subgroups (e.g., infants and children) exposed to that concentration for a specified duration [Cal EPA 2008].

OEHHA methodology for REL development is similar to other agencies undertaking public health risk assessments. REL derivation consists of identification of a point of departure, such as an exposure level in an animal experiment or an epidemiological study at which no adverse effects (or at least minimal adverse effects) are observed. Or REL derivation could involve a benchmark dose (a statistical estimate of a low response rate, typically 5%, in the dose response curve for the chemical of concern.) Extrapolation from this point of departure to a health protective level for the target human population is by means of explicit models where possible, but more often by means of uncertainty factors [Cal EPA 2008].

RELs are health guidance values designed to protect against the noncancer health effects of exposure to airborne chemicals. In some cases, a carcinogenic chemical can cause noncancer health effects and thus have both health value types. The acute RELs are designed to protect against a 1-hour exposure duration occurring infrequently (e.g., no more than once every two weeks.) Chronic RELs are designed to protect against long-term exposure for 24 hours a day and are used in the Air Toxics Hot Spots risk assessments to evaluate exposures anywhere from about 9 years to a lifetime [Cal EPA 2008].

For this public health evaluation, ATSDR compiled acute and chronic REL values from Cal. EPA's OEHHA Web site, available at http://www.oehha.ca.gov/air/allrels.html.

3E.3. Inhalation Unit Risks (IURs)

U.S. EPA uses a two-step process to evaluate the potential carcinogenicity of a substance and to define the relationship between dose and the likelihood of a possible increase in cancer cases in a population: 1) a qualitative weight-of-evidence approach, and 2) a quantitative assessment.

As a result of its qualitative evaluation of information relevant to carcinogenicity and the quality of that information, U.S. EPA assigns cancer classifications to suspected carcinogenic substances. For known or possible air carcinogens, U.S. EPA uses inhalation unit risks (IURs) as a quantitative indication of the substance's carcinogenicity. An IUR is an estimate of possible increases in cancer cases in a population expressed in concentration units [$(\mu g/m^3)^{-1}$] to allow for comparison with site-specific air concentrations.

IURs are usually derived from animal experiments that involve exposures to a single substance by a single route of exposure (i.e., inhalation). U.S. EPA extrapolates IURs from experimental data of increased tumor incidences at high doses to estimate possible cancer rate increases at low doses. The experimental data often represent exposures to chemicals at concentrations orders of magnitude higher than concentrations found in the environment.

Historically, U.S. EPA has used mathematical models to derive IURs. Models can incorporate a number of uncertainties and conservative assumptions, can manipulate experimental data, and can extrapolate possible health outcomes from high doses to low doses. Models assume cancer effects have no thresholds (or low dose linearity)—a single carcinogen molecule can assumedly cause cancer.

As scientists learn more about how carcinogens produce tumorigenic responses in animals and humans (i.e., the mechanism of action), they find that some carcinogens do exhibit thresholds. In light of the evolving science, U.S. EPA's more recent guidelines call for more emphasis on analyzing the dose-response data before invoking low-dose linear defaults as described above. The new guidelines call for closer examination of substance-specific modes and mechanisms of action. This procedure invokes a two-step dose-response process to "weigh" the available evidence: 1) model the observed data to the "point of departure" and (2) extrapolate to lower doses. When data are sufficient, nonlinear extrapolation may be considered. In the absence of adequate data showing nonlinear dose-response, the guidelines call for defaulting to linear assumptions.

U.S. EPA develops IURs as a result of a quantitative evaluation of a suspected carcinogenic substance. IURs are combined with information about exposure doses to estimate a possible increase in cancer cases in a population. One example is using U.S. EPA's IURs to derive ATSDR's CREGs (see section 2E.3).

3E.4. Carcinogenic Target Risk Screening Levels (SLs)

U.S. EPA provides carcinogenic target risk screening levels (SLs) for inhalation. The agency considers SLs protective for humans (including sensitive groups) over a lifetime of exposure to a carcinogen. As stated previously, the U.S. EPA's OSRTI revised its hierarchy of human health toxicity values in 2003, establishing three tiers as the new hierarchy. SLs for this hierarchy are

1. ***SL – I***: Carcinogenic target risk screening levels developed using U.S. EPA's IURs, which are contained in IRIS. As stated previously, IRIS represents the first tier because its assessments have undergone both external peer review and an U.S. EPA consensus review process [USEPA 2013a, 2013c]. IRIS is available at http://www.epa.gov/iris/index.html.
2. ***SL – P***: Carcinogenic target risk screening levels developed using U.S. EPA's provisional IURs, which are contained in the PPRTV electronic library. As stated previously, PPRTV information represents the second tier because it has not undergone the multi-program review and consensus required for toxicity values to be placed in IRIS [USEPA 2013b]. PPRTV is available at http://hhpprtv.ornl.gov/.
3. ***SL – C***: Carcinogenic target risk screening levels developed using Cal. EPA's cancer potency factors used by Cal. EPA to protect the public against the cancer-causing effects of carcinogenic chemicals. Cal. EPA information represents the third tier. Weighting factors are used in calculating cancer risks from exposures of infants, children, and adolescents to reflect their anticipated special sensitivity to carcinogens. All the Cal. EPA values undergo public comment and external peer review [Cal EPA 2009].

SLs correspond to a 10^{-6} risk level for carcinogens. For this public health evaluation, ATSDR compiled SL values from the "Residential Air Supporting" table on U.S. EPA's Mid-Atlantic Risk Assessment Web site and available at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm.

3E.5. Air Monitoring Comparison Values (AMCVs)

Because of significant differences between air permit reviews and the various forms of ambient air monitoring data, Texas' TCEQ now uses "air monitoring comparison values" (AMCVs) to describe air monitoring data health-effect evaluations [TCEQ 2012]. AMCV is a collective term that describes chemical-specific air concentrations used to evaluate air monitoring data set to protect human health. Data concerning acute health effects underlie short-term AMCVs, while data concerning chronic health effects support long-term AMCVs.

AMCVs include

- Acute and chronic inhalation reference values (ReVs) derived for human health hazards associated with threshold dose-response relationships, and
- Chronic inhalation unit risk factor (URF) values derived from hazards associated with nonthreshold dose-response relationships.

In other words, the derivation of a ReV or URF is dependent on whether the adverse effect is associated with (or assumed to have) a nonthreshold or threshold dose-response relationship, not with the classification of the effect as carcinogenic or noncarcinogenic.

An AMCV designated "final" indicates that the AMCV was updated using the revised TCEQ's RG-442. "Under review" indicates that the AMCV is currently being reviewed by the Toxicology Division. "Interim" indicates that the AMCV is current and will be reviewed by the Toxicology Division at a later date. Also, interim AMCVs can be updated pending the release of updated toxicity information or odor data.

For this public health evaluation, ATSDR compiled AMCVs from the "Air Monitoring Comparison Values" Excel tables available at http://www.tceq.texas.gov/toxicology/AirToxics.html#list.

3E.5.1. Inhalation Reference Values (ReVs)

An inhalation reference values (ReV) is an estimate of an inhalation exposure concentration for a given duration to the human population (including susceptible subgroups) likely to be without an appreciable risk of adverse effects. ReV values are based on the most sensitive adverse health effect relevant to humans reported in the scientific literature. ReV values are derived by adjusting an appropriate point of departure (POD) with uncertainty factors (UFs) to reflect data limitations and to derive a value below levels where health effects would be expected to occur. Examples of PODs include the benchmark concentration lower confidence limit (BMCL) and the NOAEL.

Acute ReVs are health-based exposure concentrations used in assessing health risks of short-term chemical exposures. They are typically derived from acute or subacute human or animal studies, or from short-term reproductive/developmental toxicity studies conducted on animals. Occasionally, information is available from epidemiology or occupational studies. Acute ReVs are typically derived for a 1-hour (hr) exposure duration, although those based on reproductive/ developmental effects may be derived for exposure durations other than 1 hr. If other short-term exposure durations are needed to evaluate air monitoring data, then acute ReVs may be developed using other averaging times.

Chronic inhalation ReV values are health-based exposure concentrations used in assessing health risks of long-term (i.e., lifetime) chemical exposures. Chronic toxicity factors are derived from chronic human epidemiology studies, chronic animal studies, or well-conducted subchronic human or animal studies. Chronic ReV values are derived for a lifetime exposure duration.

ReV values are designed to protect the most sensitive persons in a population, such as children, pregnant women, and the elderly, in part by inclusion of UFs. ReVs, however, might not protect persons who exhibit rare or idiosyncratic responses that cannot be predicted based on typical animal toxicity studies or human health effects studies. While the default UF for intrahuman variability is generally considered protective, the true range of variability among the population for a response to a given chemical is often unknown. The TCEQ attempts to identify specific sensitive subgroups for each substance from the available scientific literature, but might not identify all conditions that result in adverse health effects following exposure to chemicals.

That said, UFs account for differences between study animal species and humans, variability within the human species, and uncertainties related to the applicability and completeness of the available data. Because UFs are incorporated to address data gaps, variability, and other uncertainties, exceeding the ReV does not necessarily indicate that an adverse health effect would occur. In addition, if a useable study in a population known to be sensitive through data or mode-of-action or other chemical-specific information is available, dose-response data from that study will be used to derive the ReV.

Note that TCEQ uses the ReV for air monitoring whereas the health-based effects screening level (ESL), which is 70% lower than the ReV, is used for air permitting. If a ReV has not yet been developed for a chemical, the original short-term and long-term ESLs are used in both program areas [TCEQ 2012].

3E.5.2. Inhalation Unit Risk Factors (URFs)

For chronic adverse effects found associated with nonthreshold dose-response relationships in the low-dose region, the TCEQ adopts or derives inhalation unit risk factor (URF) values. This determination is based on data or science policy default assumptions. Typically, the effects associated with nonthreshold dose-response relationships are carcinogenic and are from chronic exposures.

For adverse effects associated with a nonthreshold dose-response, the assumption is that an effects threshold does not exist. Therefore, a linear extrapolation from the POD to the origin of the dose-response curve estimates excess lifetime risk at lower doses. Excess risk is estimated risk above background morbidity or mortality rates. The slope of the line from this linear extrapolation is the URF. The URF is generally defined as the upper-bound excess risk estimated to result from continuous lifetime exposure to an agent at a concentration of 1 $\mu g/m^3$ in air (i.e., risk estimate per $\mu g/m^3$). But in certain circumstances, the central estimate as opposed to the upper-bound estimate may be used. A biologically based model, if available, may also be used. The no-significant excess risk level is defined at 1×10^{-5} risk (one in 100,000.)

URF values could also be developed for chronic noncarcinogenic effects, which exhibit a nonthreshold dose-response relationship. For chronic adverse effects determined to be associated with nonthreshold dose-response relationships in the low-dose region, the TCEQ adopts or derives inhalation URF values. This determination is based on data or science policy default assumptions. Typically, the effects associated with nonthreshold dose-response relationships are carcinogenic and are from chronic exposures [TCEQ 2012].

4E. National Ambient Air Quality Standard (NAAQS)

Unlike the other nonenforceable health-based comparison values used for screening purposes, U.S. EPA's national ambient air quality standards (NAAQS) are enforceable standards. The Clean Air Act, last amended in 1990, requires U.S. EPA to set NAAQS for wide-spread pollutants from numerous and diverse sources considered harmful to public health and the environment. The Clean Air Act established two types of national air quality standards:

- Primary standards set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly.
- Secondary standards set limits to protect public welfare, including protection against visibility impairment, damage to animals, crops, vegetation, and buildings.

U.S. EPA has set NAAQS for six principal "criteria" pollutants. These criteria pollutants are carbon monoxide, lead, nitrogen oxides, ozone, particulate matter, and sulfur dioxide. The Clean Air Act requires periodic review of the science on which the standards are based and the standards themselves.

U.S. EPA must designate areas as meeting (attainment) or not meeting (nonattainment) the standard. The Clean Air Act requires states to develop a general plan to attain and maintain the NAAQS in all areas of the country and a specific plan to attain the standards for each area designated nonattainment for a NAAQS. These plans, known as State Implementation Plans, are developed by state and local air quality management agencies and submitted to U.S. EPA for approval [USEPA 2012a].

For technical information related to setting the national air quality standards for the six criteria pollutants, see U.S. EPA's Web site available at http://epa.gov/air/criteria.html [USEPA 2012b, 2012c]. For this public health evaluation, ATSDR compiled NAAQS values from this same Web site link.

5E. Workplace Guidelines

5E.1. Permissible Exposure Limits (PELs) and Short-term Exposure Limit (STELs)

OSHA's permissible exposure limits (PELs) were developed to provide safe and healthful working conditions, as mandated by Occupational Safety and Health Act of 1970. PELs are maximum exposure limits for certain airborne contaminants in the workplace, based on health criteria and technical feasibility. They are designed to ensure, to the extent feasible, that no employee suffers impairment of health or functional capacity even if regularly exposed to a substance throughout his/her working life. Further information on PELs is available at https://www.osha.gov/dsg/topics/pel/index.html.

PELs are usually listed as 8-hour time weighted averages (TWA). The level may be exceeded at points in time, but the sum of the exposure levels averaged over 8 hours must not exceed the limit. In some cases, ceiling and peak levels are listed in place of, or in addition to, the 8-hour TWA. Ceiling values cannot be exceeded at any time. During a designated time period, substance concentrations may reach, but never exceed, a peak level.

OSHA's short-term exposure limit (STEL) is a 15-minute TWA which should not be exceeded at any time during a workday even if the 8-hour TWA is within the PEL. Exposures at the STEL should not exceed 15 minutes and should not be repeated more than four times per day. There should be at least a 60-minute interval between successive exposures at the STEL. A STEL is recommended only in cases in which toxic effects have been reported from high short-term exposures in either animals or humans. It is not a separate, independent exposure limit, but rather a supplement to the PEL.

PELs and STELs are enforceable regulatory standards for contaminants in the workplace and are revised as new information becomes available. If an employee is exposed to an OSHA-regulated substance at a level exceeding the PEL or STEL, the employer must comply with the substance-specific health standards listed in 29 CFR part 1910 to reduce the exposure.

It is important to understand that PELs and STELs apply to healthy adult employees working 40-hour weeks and not to the general population—including children, the elderly, and the sick—who may be subject to continuous environmental exposure. As such, ATSDR only uses these values to put site-specific concentrations of contaminants into perspective for the reader, especially when no other non-occupational comparison values are available.

5E.2. Recommended Exposure Limits

Under the authority of OSHA of 1970, NIOSH develops and periodically revises its recommended exposure limits, which are exposure limits for potentially hazardous substances or conditions in the workplace. Recommended exposure limits, as well as PELs, can be found in the *NIOSH Pocket Guide to Chemical Hazards*, which is available at http://www.cdc.gov/niosh/npg/npg.html.

Recommended exposure limits are available for airborne contaminants in the workplace. These limits are developed as 8- or 10-hour TWAs or ceiling levels, as discussed under the definition and use of PELs. Recommended exposure limits are published and transmitted to OSHA and the Mine Safety and Health Administration for use in promulgating legal standards.

Similar to PELs and STELs, recommended exposure limits apply to healthy adult employees working 40-hour weeks and not to the general population, who may be subject to continuous environmental exposure. As with PELs and STELs, ATSDR only uses recommended exposure limits to put site-specific concentrations of contaminants into perspective for the reader, especially when no other non-occupational comparison values are available.

5E.3. Threshold Limit Values (TLVs)

The American Conference of Government Industrial Hygienists (ACGIH) is an organization concerned with industrial health and occupational health and safety (further information about ACGIH is available at http://www.acgih.org/home.htm). ACGIH has developed threshold limit values (TLVs), which are airborne concentrations of substances that are not believed to cause harmful effects in workers exposed regularly. ACGIH develops and updates TLVs based on toxicity information from industrial exposures, animal studies, and human studies, if available. ACGIH stresses that TLVs for individual substances may be based on different toxicologic studies and endpoints.

TLVs are developed as a TWA for exposures 8 hours a day during a 40 hour work week and as TWA for short-term (15 minute) exposures, and as ceiling levels that should never be exceeded. TLVs are intended only as guidelines for protecting worker safety and do not represent an enforceable standard or finite level of toxicity.

Similar to the OSHA and NIOSH values, TLVs apply to healthy adult employees working 40-hour weeks and not to the general population, who may be subject to continuous environmental exposure. ATSDR only uses TLVs to put site-specific concentrations of contaminants into perspective for the reader, especially when no other non-occupational comparison values are available.

6E. Air Quality Guidelines (AQGs)

The World Health Organization (WHO) develops air quality guidelines and drinking-water quality guidelines. The WHO air quality guidelines (AQGs) are designed to offer guidance in reducing the health impacts of air pollution. First produced in 1987 and updated in 1997, these guidelines are based on expert evaluation of current scientific evidence. Given the wealth of new studies on the health effects of air pollution that have been published in the scientific literature since the completion of the second edition of the *Air quality Guidelines for Europe*, including important new research from low-and middle-income countries where air pollution levels are at their highest, WHO reviewed the accumulated scientific evidence and considered its implications for its air quality guidelines. These guidelines are intended to inform policy-makers and to provide appropriate targets for a broad range of policy options for air quality management in different parts of the world. The new information included in the 2005 update relates to four common air pollutants: particulate matter, ozone, nitrogen dioxide, and sulfur dioxide [WHO 2006]. In the main text of this document, ATSDR mentions the particulate matter guidelines from WHO (see Section 7.8).

The WHO AQGs are intended for worldwide use but have been developed to support actions to achieve air quality that protects public health in different contexts. Air quality standards, on the other hand, are set by each country to protect the public health of their citizens and as such are an important component of national risk management and environmental policies. National standards will vary according to the approach adopted for balancing health risks, technological feasibility, economic considerations and various other political and social factors, which in turn will depend on, among other things, the level of development and national capability in air quality management. The guideline values recommended by WHO acknowledge this heterogeneity and, in particular, recognize that when formulating policy targets, governments should consider their own local circumstances carefully before adopting the guidelines directly as legally based standards [WHO 2006].

7E. References

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Appendix F. Refinery Row Data Screening Results

During the public health evaluation process, the Agency For Toxic Substances and Disease Registry (ATSDR) typically reviews large volumes of environmental data and evaluates these data in the context of the site-specific exposure pathway assessment. This screening analysis process enables ATSDR to sort through data in a consistent manner and identify chemicals that might need closer evaluation. This screening process compares measured chemical concentrations with health-based comparison values (CVs) [ATSDR 2005].

As stated in Section 4.1 of the main text and Appendix D, ATSDR compiled available ambient (i.e., outdoor) air data from the following Refinery Row stationary air monitoring programs:

- Corpus Christi Air Quality Project (AQP) network from 2005–2010,
- Industry network from 1996–2010, and
- Texas Commission on Environmental Quality (TCEQ) network from 1980–2010.

ATSDR also compiled ambient air data from 24 Refinery Row-area mobile monitoring events that occurred between July 1993 and March 2008. To help with its evaluation, ATSDR organized the air data into these seven groups:

- Automated gas chromatograph (Auto GC),
- TCEQ canisters,
- Industry canisters,
- AQP Triggered canisters,
- Mobile monitoring,
- Metals and particulate matter, and
- Sulfur compounds.

ATSDR screened the Refinery Row data with CVs from ATSDR, California Environmental Protection Agency (Cal. EPA), U.S. Environmental Protection Agency (U.S. EPA), and Texas Commission on Environmental Quality (TCEQ) [ATSDR 2013; Cal EPA 2014; USEPA 2012, 2013; TCEQ 2013]. Selecting the environmental guidelines most appropriate and applicable to site-specific conditions is of critical importance in conducting public health evaluations. Exposures identified at a site should closely approximate the exposure assumptions used to derive the environmental guidelines [ATSDR 2005]. For example, including an air contaminant for further evaluation based on a few maximum detections that exceed a long-term CV might be inappropriate if the maximum concentrations are below short-term CVs, and the mean concentration is below long-term CVs. Section 4.3 of the main text describes ATSDR's initial and refined screening approach.

1F. Results

The following text provides the results of ATSDR's Refinery Row screening evaluation for each of the seven groups.

1F.1. Auto GC

Based on initial screening step 2, 11 chemicals had maximum detected concentrations that exceeded long-term CVs and eight chemicals had no long-term CVs (see Table 3B, Appendix B). These 19 chemicals were retained for refined screening.

Table 11B, Appendix B, contains the refined screening results. Based on its refined screening analysis, ATSDR finds only benzene's maximum concentrations are above short-term CVs. Benzene and 1,3-butadiene mean, lower confidence limit (LCL), and upper confidence limit (UCL) concentrations exceed long-term CVs.

Overall, of the 19 chemicals that passed the initial screening process for the Auto GC group, refined screening resulted in the selection of 10 chemicals

benzene	t-2-butene	c-2-pentene
1,3-butadiene	ethane	propane
1-butene	1-pentene	
c-2-butene	t-2-pentene	

for public health evaluation.

1F.2. TCEQ Canisters

Based on initial screening step 2, 20 chemicals had maximum detected concentrations that exceeded the available long-term CVs and nine chemicals had no long-term CVs (see Table 4B, Appendix B).

ATSDR split the TCEQ canister data into two time frames[48]: pre-2005 and 2005–2010. Table 12B, Appendix B, contains the refined screening results for the pre-2005 dataset, and Table 13B, Appendix B, contains the refined screening results for the 2005–2010 dataset.

For both the pre-2005 and 2005–2010 datasets, only benzene's maximum concentrations are above short-term CVs. Six chemicals (benzene, 1,3-butadiene, carbon tetrachloride, chloroform, 1,2-dichloroethane, and trichloroethylene) have at least one value (mean, LCL or UCL) that exceeds long-term CVs in one or both datasets. ATSDR could not calculate any mean concentrations for six infrequently detected chemicals (chloroprene, 1,2-dibromoethane, 1,2-dichloropropane, 1,1,2,2-tetrachloroethane, 1,1,2-trichloroethane, and vinyl chloride) and these six chemicals have method reporting limits that exceed their long-term CVs.

Overall, of the 29 chemicals that passed the initial screening process for the TCEQ canisters group, 21 chemicals

benzene	chloroprene	c-2-pentene
1,3-butadiene	1,2-dibromoethane	t-2-pentene
carbon tetrachloride	1,2-dichloroethane	propane

[48] In general, two time periods were used to group data for calculations—chemical data available before 2005 and those from 2005–2010. Because the AQP network did not begin sampling activities until 2005, ATSDR chose to separate the industry and TCEQ data into two time periods (pre-2005 and 2005–2010) to facilitate comparison between networks and time periods.

chloroform	1,2-dichloropropane	1,1,2,2-tetrachloroethane
1-butene	ethane	1,1,2-trichloroethane
c-2-butene	2-methyl-2-butene	trichloroethylene
t-2-butene	1-pentene	vinyl chloride

are selected for public health evaluation based on the refined screening results.

1F.3. Industry Canisters

Based on initial screening step 2, the maximum detected concentration of 13 chemicals exceeded that chemical's long-term CV and one chemical had no long-term CV (see Table 5B, Appendix B). ATSDR split the industry canister data into two time frames: pre-2005 and 2005–2010. Table 14B, Appendix B, contains the refined screening results for the pre-2005 dataset, and Table 15B, Appendix B, contains the refined screening results for the 2005–2010 dataset.

In the pre-2005 dataset, no maximum concentrations of any chemical exceed short-term CVs. In the 2005–2010 dataset, only benzene's maximum concentration in one sample is above short-term CVs. Four chemicals (benzene, 1,3-butadiene, carbon tetrachloride, and naphthalene) have at least one value (mean, LCL or UCL) that exceeds long-term CVs in one or both datasets. ATSDR could not calculate any mean concentrations for two infrequently detected chemicals (1,2-dichloroethane in the pre-2005 dataset and trichloroethylene in the 2005–2010 dataset) and these two chemicals have detection limits that exceed their long-term CVs.

Overall, of the 14 chemicals that passed the initial screening process for the industry canisters group, seven

benzene	carbon tetrachloride	trichloroethylene
1,3-butadiene	1,2-dichloroethane	
1-butanol	naphthalene	

are selected for further public health evaluation based on the refined screening results.

1F.4. AQP Triggered Canisters

Based on initial screening step 1, the maximum detected concentration of four chemicals exceeds the short-term CV for that chemical (see Table 6B, Appendix B). These chemicals were benzene, carbon tetrachloride, 1,2-dibromoethane, and isoprene. Three chemicals (dodecane, propane, and propylene) do not have a short-term CV. Thus, ATSDR retains seven chemicals for public health evaluation.

1F.5. Mobile Monitoring

Of the seven samples collected and analyzed for 16 polycyclic aromatic hydrocarbons (PAHs), none of the detections exceed short-term CVs. Similarly, of the five samples collected and analyzed for 38 semi-volatile organic compounds (SVOCs), none of the detections exceed short-term CVs. Of the 28 samples collected and analyzed for 18 carbonyl compounds, none of the detections for 17 of the carbonyls exceed short-term CVs. One carbonyl (furfural) did not have a short-term CV.

During mobile monitoring, the maximum detected concentration of six volatile organic compounds (VOCs) exceeded the short-term CV for that chemical (see Table 7B, Appendix B). These chemicals were benzene, carbon tetrachloride, chloroform, 1,2-dibromoethane, isoprene, and toluene. Four VOCs do not have a short-term CV. Also, Table 10B, Appendix B, shows mobile monitoring events detected both hydrogen sulfide and sulfur dioxide above these chemicals' respective short-term CVs.

Based on the mobile monitoring datasets, ATSDR selects 13 chemicals

benzene	ethane	propylene
carbon tetrachloride	furfural	sulfur dioxide
chloroform	hydrogen sulfide	toluene
chloroprene	isoprene	
1,2-dibromoethane	propane	

for public health evaluation.

1F.6. Metals and Particulate Matter

Based on initial screening step 2, the maximum concentration of airborne particulate matter less than 2.5 microns ($PM_{2.5}$) exceeded its long-term CV and particulate matter less than 10 microns in diameter (PM_{10}) does not have a long-term CV (see Table 8B, Appendix B). Table 19B, Appendix B, contains the refined $PM_{2.5}$ and PM_{10} screening results for the pre-2005 dataset and Table 20B, Appendix B, contains the 2005–2010 dataset. Maximum airborne $PM_{2.5}$ levels exceed the short-term CV in the pre-2005 dataset.

Based on initial screening step 2 for the Dona Park metals dataset, the maximum detected concentration of five metals exceeded that compound's long-term CV (see Table 8B, Appendix B). The five metals were arsenic, cadmium, chromium, cobalt, and nickel. Table 16B, Appendix B, contains the Dona Park refined screening results for the pre-2005 metals dataset and Table 17B, Appendix B, contains the Dona Park refined screening results for the 2005–2010 metals dataset. For the pre-2005 dataset, maximum concentrations are not above short-term CVs for any metals. For the 2005−2010 dataset, one cadmium detection and one lead detection are above short-term CVs. Arsenic and chromium have at least one chronic value (mean, LCL, or UCL) that exceeds long-term CVs in one or both datasets. ATSDR could not calculate mean concentrations for two infrequently detected chemicals (cadmium and cobalt) and these two chemicals have method detection limits that exceed their long-term CVs.

Based on initial screening of the 1980s metals dataset[49], the maximum detected concentration for six metals exceeded the long-term CV for that metal (see Table 9B, Appendix B). These metals were arsenic, barium, cadmium, chromium, nickel, and vanadium. Table 17B, Appendix B, contains the 1980s stationary air monitor refined data screening results. The maximum concentrations of four metals (barium, cadmium, chromium, and lead) are above short-term CVs. Barium and chromium have at least one chronic value (mean, LCL, or UCL) that exceeds long-term CVs. For this 1980s metals dataset, ATSDR could not calculate mean concentrations for two infrequently detected chemicals (arsenic and nickel) in the 1980s metal dataset and these two chemicals have method detection limits that exceed their long-term CVs; ATSDR notes, however, mean nickel concentrations for both the pre-2005 and 2005–2010 Dona Park datasets were below the nickel long-term CV. Cobalt was not detected, but because its

[49] Because the metals data collected in the 1980s are of unknown quality, ATSDR compiled these data separately from the Dona Park metals datasets.

detection limit was above its long-term CV, cobalt might actually have been present in the air at levels above CVs.

For the all metals datasets, ATSDR notes a long-term CV is not available lead and no CVs are available for chlorine as a particulate. Overall, eight compounds

arsenic	chlorine	lead
barium	chromium	$PM_{2.5}$
cadmium	cobalt	

are selected for public health evaluation.

1F.7. Sulfur Compounds

Based on initial screening step 2, routine monitoring at the Huisache stationary air monitor showed the maximum 1-hour hydrogen sulfide level, which was 365 parts per billion (ppb) and exceeded its long-term CV (1.4 ppb). Tuloso Midway Middle School had the maximum 1-hour sulfur dioxide level; sulfur dioxide does not have a long-term CV.

Table 21B, Appendix B, provides the stationary air monitor refined screening results for hydrogen sulfide and sulfur dioxide. Maximum hydrogen sulfide levels exceed its short-term CV at two air monitoring stations. Sulfur dioxide exceeds its short-term CV at all eight stationary air monitoring stations. In the past, hydrogen sulfide's mean, LCL, and UCL concentrations at Huisache exceeded the long-term CV.

Therefore, hydrogen sulfide and sulfur dioxide are selected for public health evaluation based on the refined screening results.

2F. References

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Appendix G. Data Analysis Approach and Trends Discussion

In Section 4.1 of the main text, the Agency for Toxic Substances and Disease Registry (ATSDR) provides information on the three currently operating stationary networks along Refinery Row. These three network operators are

- The Corpus Christi Air Quality Project (AQP),
- Industry, and
- The Texas Commission on Environmental Quality (TCEQ).

In general, the stationary air monitoring data from the three networks were validated using procedures appropriate to the methods used for the sampling. Data rejected because of validation procedures were not included in the datasets evaluated in this public health report.

For its stationary air monitor data analyses, ATSDR used R[50] version 3.1.1 [R Core Team 2014], with package "NADA" [Lee 2013]. The R packages "openair" [Carslaw and Ropkins 2014] and "ggplot2" [Wickham 2014] provided visualization and analysis capabilities. ATSDR used R package "mgcv" [Wood 2006, 2014] to perform generalized additive modeling for showing smooth trends of data. Bootstrapping was performed using R packages "boot" [Canty and Ripley 2014] and "meboot" [Vinrod and López-de-Lacalle 2009]. These analyses allowed ATSDR to

1. Estimate a mean concentration for comparison with long-term comparison values (CVs) in its refined screening analysis.
2. Perform cross-network comparisons of one monitoring network to the others for the same chemicals to provide further insight into data quality.
3. Describe the temporal, seasonal, and geographic trends that influence chemical air levels along Refinery Row.

1G. Calculating Mean Chemical Concentrations

Initially, ATSDR screens data with conservative, health-based CV guidelines. Section 4.3.1 of the main text and Appendix F describe ATSDR's initial screening approach and initial screening results. For the chemicals retained based on initial screening, the data were summarized by rate of exceedence by monitoring station and period. In general, two periods were used to group data for calculations—chemical data available before 2005 and chemical data from 2005–2010. Because the AQP network did not begin sampling activities until 2005, ATSDR chose to separate the industry and TCEQ data into two time periods (pre-2005 and 2005–2010) to facilitate comparison between networks and time periods.

ATSDR estimated chemical means and approximate 95% confidence intervals for the two periods. A 95% confidence interval for the mean is expected to contain the true mean over repeated samples approximately 95% of the time, and it is an indicator of the estimate's precision [Helsel and Hirsch 2002]. Wider confidence intervals indicate imprecise estimates, while narrow confidence intervals indicate more precise estimates. Two-sided confidence intervals (i.e., upper and lower confidence intervals) were used because they facilitated comparison between stations and between periods. Estimates of the mean can also be biased—that is, influenced higher or lower relative to the true value.

[50] R is a free software programming language and software environment for statistical computing and graphics.

Both the bias and precision of the estimates can be influenced by unique features in the datasets. Broadly speaking, these data features were:

- **Censoring** —Censored observations occur when there are levels of chemicals in the sample that are below the laboratory's detection or reporting limit (which ATSDR refers to broadly as a censoring limit) [Helsel 2012]. The level of the chemical is somewhere between zero and the censoring limit. Data below a censoring limit provide some information about the means and trends. Different approaches for including censored data have advantages over others. Some methods are simple, such as substituting ½ the censoring limit for censored data, while other methods of incorporating censored data use more sophisticated methods. The method of incorporating the censored values can introduce biases and imprecisions in the estimates of the mean [Helsel 2012].
- **Sampling design** — Sampling design describes the frequency, location, and duration of sample collection over time. For instance, some of the data were collected using a stratified sampling design, which had greater collection frequency during a few months of the year, depending on the season. Such sampling designs are routine in environmental sampling, and offer the benefit of increasing precision with a reduction of needed samples collected [Gilbert 1987]. With a stratified design, more samples are collected during periods when the chemical concentration is more variable and fewer samples are collected when concentrations are less variable. This approach should maximize the information provided by each sample. Because, however, samples have different collection frequency over a given period, each sample should have a different weight in estimating the mean concentration.

  Also, monitoring results for different durations are not directly comparable—samples from different networks are collected over different durations; directly comparing these data will result in one set appearing more or less variable than the other.
- **Correlation structure** — Chemical concentration measurements can be related to each other in time or space. For example, the data can be related to each other in time (*temporal autocorrelation*), where a result at one sampling interval is correlated to the previous sampling intervals, generally with decreasing correlation as the time separation increases. In addition, a sampling location's data can also be associated with another station nearby (*spatial autocorrelation*), with the strength of the association generally becoming weaker with distance. Individual air chemical levels can be expected to be correlated with each other if they are emitted from the same process or are influenced by similar environmental variables that affect the movement and mixing in the atmosphere (*chemical correlation*). Temporal autocorrelation can result in overly precise estimates of the mean. Assuming independence (no correlation) between spatially correlated stations or correlated chemicals might likewise lead to overly imprecise estimates of the mean.
- **Seasonality** — Chemical concentrations can display consistent changes day-to-day and season-to-season. In Corpus Christi, the wind direction and wind speed change with season. This will lead to changes in chemical levels, depending on the location of the monitor relative to the source. Temperature and cloudiness changes will lead to changes in turbulence in the atmosphere and consequent increases or decreases in chemical levels. Likewise, chemical concentrations will change depending on the cycles that generate them. Chemicals related to automobile traffic emissions will have daily cycles, as well as weekday

and weekend patterns. Production patterns for industry-generated compounds will also influence chemical levels. Not adjusting for seasonality can lead to imprecise mean estimates. Seasonality can also bias estimates if a sample over or under represents a particular season.

Each of the three monitoring networks presented unique features that influenced bias and precision of estimated means. They each required different approaches to calculating the mean and estimating the confidence intervals. The following text provides further information specific to ATSDR's mean chemical level calculations for each network.

Auto GC. Two AQP automated gas chromatograph (Auto GC) stations in Refinery Row reported hourly air values for volatile organic compounds (VOCs). The industry Auto GC station at Huisache reported 15-minute values for benzene only. These sampling intervals introduce a high correlation between observations over time. The measured chemicals in the datasets also have a high degree of correlation (see Figures 50A and 51A, Appendix A).

Detection limits for VOCs were given as parts per billion carbon (ppb-C) for the AQP Auto GC's. Results in parts per billion (ppb) were calculated by multiplying the ppb-C detection limit by the number of carbon atoms in each VOC molecule. For benzene, the industry Auto GC detection limit was reported as 0.2 ppb. Both the AQP and the industry data reported chemical measurements below these reported detection limit values.

Although values reported below the detection limit were considered imprecise, they were considered generally accurate for calculating a long-term mean. For values reported as zero, the multiple imputation method was used. And the imputation values were from values taken from the empirical cumulative distribution of values below the detection limit of each compound. In this approach, the empirical distribution of the reported values below the detection limit is assumed to approximate the zero-valued distribution of the non-zero nondetects. Ten imputations were performed for each of the chemicals. Sensitivity using the multiple imputation method was estimated, at maximum, 0.3%.

For chemicals whose maximum value exceeded either a short-term or long-term comparison value, daily average values were calculated for each of the 10 imputations (with a minimum required data availability of 75% per day). These daily averages were then used to calculate the mean concentration from 2005 through 2010. Maximum entropy bootstrapping was used to calculate 95 percent confidence intervals of the mean as implemented in R package "meboot 1.4-3" [Vinrod and López-de-Lacalle 2014]. Maximum entropy bootstrapping creates bootstrap replicates of the time series, which preserves the data's autocorrelational structure and the seasonality. As maximum entropy bootstraps do not assume stationarity, they are resistant to structural changes in the air quality of the Corpus Christi air shed (e.g., implementation of pollution control devices, reductions in emissions from lowered production). Maximum entropy bootstrapping does not impose any parametric assumptions on the data.

TCEQ Canisters. Five TCEQ monitoring stations collected integrated 24-hour air samples analyzed for over 90 VOCs. The sampling frequency was generally every 6 days, with two notable exceptions.

1. Until 2006 at the Huisache air monitor, samples were collected more frequently (usually every day) from mid-November through mid-May. At other times of the year, the data were collected mostly every 6 days. To address the stratified sampling scheme, ATSDR calculated a weight for each concentration that corresponded to the amount of time it represented. ATSDR calculated weights by weighing each sample by the number of days between the sample and its previous

and next sample, with half the time from the difference between the sample and its previous sample, and half the time from the sample and the next sample. Beginning and ending samples only received weights equal to half the time between the next and previous samples, respectively.

2. At the Hillcrest air monitor, in addition to the 1-in-6 day sampling scheme, VOC samples were collected on days when the technician believed that winds would be such that the monitoring site would be influenced by Refinery Row facilities. This led to duplicate samples being collected at this location on the same day, as well as to the period varying between sampling days. Similar to the stratified data, ATSDR weighed the sample results according to the number of days between the sampling periods, after—when duplicate results for a given day were available—selecting the maximum concentration. Although the effects of sample weighting are expected to be less important with other three TCEQ air monitors, ATSDR also used a weighted scheme because the sampling periods were not always exactly 6 days (e.g., missing days, make up sample days).

To estimate the mean chemical concentrations for long-term screening analysis, ATSDR used robust regression on order statistics (ROS) (Lee and Helsel 2005; Helsel 2012) as implemented in the R package “NADA”. ROS was used for chemicals when at least 20% of the samples were not censored. Gilliom and Helsel (1986) demonstrated that when censoring levels were at 80%, expected errors from ROS approached a level that exceeded the parameter values being estimated. Errors would be expected to increase when censoring exceeded that level. ROS was chosen in favor of the Kaplan-Meier (KM) method because the single reporting limit in the data would result in effectively substituting the reporting limit for the nondetected data (see Helsel 2012, page 93).

An important feature with the TCEQ data is that many reported values are below what is termed the *detection limit*, a value high enough for a 99% confidence that it does not include zero. TCEQ reports in its TAMIS database values less than the detection limit and uses these data in summary statistical calculations (after replacing zeros with half the 0.01 ppb reporting limit). But individually, TCEQ states the results should be qualified as uncertain [TCEQ 2008]. The substitution method (such as substituting half the detection limit for censored data) has been shown to perform poorly [USEPA 2006] in comparison with other methods such as ROS . ATSDR elected to use the reporting limit (0.01) for the TCEQ data that were reported as zero, which is most consistent with statements of TCEQ regarding their censoring of canister parameters [TCEQ 2008].

ATSDR computed means with 2-sided 95% confidence limits using the ROS imputed values and the nonparametric percentile bootstrap intervals. In the bootstrap ATSDR used percentile methods recommended by Helsel (2012) and used 1,999 sample replicates.

Industry Canisters. The canister air data from five industry stationary air monitors used a stratified sampling design. The VOC measurements were collected two to six times per month, depending on the season, for 24-hours per day. To calculate time-weighted average (TWA) concentrations, ATSDR calculated a weight for each chemical concentration that corresponded to the amount of time it represented. ATSDR calculated weights by the number of days between the sample and its previous and next sample, with half the time from the difference between the sample and its previous sample, and half the time from the sample and the next sample. Beginning and ending samples only received weights equal to half the time between the next and previous samples, respectively.

Industry provided ATSDR with information on nondetects in the dataset. In the dataset, however, these nondetects were substituted with ½ limit of detection. ATSDR calculated the limit of detection in the industry dataset by doubling the substituted value.

Because the data are both censored and of varied sampling frequencies, ATSDR used a combination of KM statistics and weighted bootstrapping to obtain a weighted mean sample value. Each sampling station and chemical reported values. These values were multiplied by the calculated weights and divided by the average weight. Where the nondetection rate did not exceed 80%, ATSDR then calculated time weighted concentrations using KM statistics [Helsel 2012]. To obtain confidence limits for the TWA concentration, ATSDR used percentile bootstrap confidence limits. But to maintain sample weighting, ATSDR used the unweighted sample values. For each sample in the bootstrap, ATSDR set the sampling probabilities proportionate to the sample weights.

Metals and Particulate Matter. From 2001 to 2010, for a 24-hour period about every sixth day, the TCEQ Dona Park air monitoring station collected airborne particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) and analyzed for metals content. In the 1980s, for a 24-hour period every sixth day, four TCEQ air monitors generally collected airborne total suspended particulates (TSP) and analyzed for metals. At the Navigation station, airborne TSP was analyzed for lead. Because only a single detection limit was used, ATSDR used ROS to calculate mean concentrations with percentile bootstrapping to estimate 95% confidence intervals (using time weighting).

Individual detection limits were reported for much of the TCEQ $PM_{2.5}$ data. Therefore, ATSDR elected to use the KM estimates to calculate the sample mean [Lee and Helsel 2007] as implemented in NADA. Multiple censoring limits were present in the data, and KM estimates do not assume that the dataset fits a known distribution shape (e.g., normal, log-normal). Instead, to estimate a mean, KM methods use the probabilities that the data are above or below a given value (a mean, by definition, is the sum of possible values multiplied by their probabilities). To address the uncertainty of our estimated mean, ATSDR computed 2-sided 95% percentile bootstrap confidence limits using time weighting.

Three TCEQ stations (Dona Park, Huisache, and Navigation) reported $PM_{2.5}$ measurements. Daily $PM_{2.5}$ data were used to calculate annual mean concentrations, along with 98th percentile concentrations. The data were uncensored. To assess statistical uncertainty, ATSDR calculated daily means and used maximum entropy bootstrapping to calculate 2-sided 95% confidence intervals of these statistics.

Data for airborne particulate matter less than 10 microns in diameter (PM_{10}) were available from the Dona Park, Fire Station #5, and Navigation stations. ATSDR used daily PM_{10} measurements to calculate annual means and derived time weighted, percentile bootstraps to calculate 2-sided 95% confidence intervals.

Sulfur Compounds. At seven stationary air monitoring stations (Dona Park, Huisache, JI Hailey, Off Up River Road, Port Grain Elevator, Solar Estates, and West End Inner Harbor), hydrogen sulfide and sulfur dioxide measurements are collected continuously every day, 24-hours a day. In addition, continuous sulfur dioxide monitoring has occurred at the Tuloso Midway Middle School. ATSDR used multiple imputation to calculate mean hourly hydrogen sulfide and sulfur dioxide measurements and used maximum entropy bootstraps to estimate 2-sided, 95% confidence intervals.

2G. Cross-network Data Analysis Approach and Results

The three stationary air monitoring networks measure air quality throughout Refinery Row, and some monitoring stations are in close proximity to each other. For its cross-network comparisons, ATSDR compared the benzene measurements made by one network with measurements made by another. ATSDR used Kendall's Tau rank correlation coefficient as implemented in NADA. Kendall's Tau was chosen over other methods because 1) most of the data contain censoring in both sets of variables, 2) Kendall's Tau is resistant to the effects of outliers, and 3) Kendall's Tau is resistant to monotonic transformations of the data (such as log transformation) [Helsel 2005].

For its cross-network comparison figures, ATSDR shows comparisons with a line of equality to indicate a relationship that would exist if both compared monitors produced identical data. Data points from sites that have similar data will fall roughly equally on either side of the line. Data predominantly to the right or left of this line of equality indicate that one of the monitoring sites had higher concentrations than the other site.

The following text provides additional procedures ATSDR followed to complete its cross-network analysis.

2G.1. Canister Benzene Data Comparisons

ATSDR merged data from three pairs of geographically comparable industry and TCEQ sites by date, and calculated correlation coefficients for the sites. Because the monitoring schedules were slightly different, depending on season, not all data could be compared. Nonetheless, over the course of several years there were a sufficient number of days in which both industry and TCEQ monitoring occurred together, thus allowing a comparison of the networks.

Figure 9A, Appendix A, shows the three pairs of canister sites that were cross-compared:

Graph A. Dona Park (TCEQ) and Up River Road (industry). Benzene results from Dona Park and Up River Road were similar. A significant correlation exists between the benzene measurements at these two stations with a Kendall's Tau of 0.58 and $p < 0.001$[51].

Graph B. Huisache (TCEQ) and Oak Park Elementary School (industry). Huisache resulted in consistently higher benzene levels than Oak Park Elementary School, an expected result given that Huisache is closer to Refinery Row facilities. A significant correlation was found between the Huisache and Oak Park Elementary School benzene data (Kendall's Tau = 0.63, $p < 0.001$). Both sites had higher benzene levels when winds were from a northerly direction.

Graph C. Hillcrest (TCEQ) and Crossley Elementary School (industry). Benzene data for Hillcrest and Crossley Elementary School fall close to the line of equality, indicating similar results at both sites, with Hillcrest—which is closer to the Refinery Row facility boundary than Crossley Elementary School—having slightly higher benzene concentrations. A significant correlation

[51] ATSDR considered $p < 0.05$ to be statistically significant. The p-value is the probability of the particular Kendall's Tau statistic (or greater) if there was not a relationship between the stations data. Using $p < 0.05$, one would expect to find a significant relationship due to chance alone when there was not a relationship 5% of the time or less.

exists between these two stations (Kendall's Tau = 0.6, $p < 0.001$). Both Hillcrest and Crossley Elementary School benzene levels were higher when winds were from a northerly direction.

Overall, the relationships of the monitoring sites were statistically significant, meaning the different measurement devices and analytical methods used by industry and TCEQ showed similar benzene levels for concurrent time periods. Additionally, the relationships were clearly affected by some sites' proximity to Refinery Row and by wind direction.

2G.2. Auto GC Benzene Data Comparisons

The industry automatic gas chromatograph (Auto GC) at the Huisache air monitoring site reports benzene results every 15 minutes. Because these data were compared with hourly measurements of benzene at the AQS Auto GC Oak Park air monitoring site, ATSDR performed averaging for each hour at Huisache using the following algorithm:

1. For each hour, ATSDR first summed the detected values for each hour, and used the detection limit for any values below the detection limit (0.2 ppb).
2. ATSDR then divided by the number of 15-minute observations in that hour to obtain that hour's average concentration.
3. Average hourly concentrations calculated from 15-minute periods below the detection limit were considered censored (i.e., less than the average of the results).
4. Any hour's data at Huisache that had fewer than 3 observations (censored or uncensored) was considered "missing" for the comparison to the Oak Park Auto GC station.

Overall, wind direction strongly influenced the relationship of benzene measured at one Auto GC station relative to the other Auto GC station (see Figure 10A, Appendix A).

Computationally, calculation of an exact Kendall's Tau exceeded the computation capabilities available to ATSDR. As an estimator, for each wind direction, 1,000 observations were randomly sampled 30 times and the Kendall's Tau calculated. Table 32B, Appendix B, shows results of the comparisons. Regardless of wind direction, there was a significant relationship between the Oak Park and Industry auto GC data. However, the strength of that relationship (as measured by Kendall's Tau) varied by wind direction. Higher Kendall Tau values (which indicate closer agreement between the two stations) occurred when the winds were from the west by southwest, west by northwest, west, and north by northwest.

2G.3. Auto GCs and 24-hour Canisters Benzene Data Comparisons

For its cross-network comparisons of AQP, industry, and TCEQ benzene data, ATSDR also compared Auto GC data to 24-hour canister data for concurrent timeframes. After averaging the continuous Auto GC data to a 24-hour time period (with a minimum of 75% data availability), ATSDR calculated Kendall's Tau statistics comparing the 24-hour canister data available from each of the three networks to the Auto GC data available from AQP and industry. Overall, ATSDR found significant correlations between the networks, each of which showed similar benzene measurements on concurrent days despite different devices and analytical methods. ATSDR further describes its findings below.

- Industry's Huisache Auto GC Compared with Industry's and TCEQ's Canister Benzene Data (see Figures 11A and 12A, Appendix A).

All benzene measurements were correlated to a degree, with canister data locations more remote from industry's Huisache Auto GC site having lower Kendall's Tau statistics than did the nearer sites. As expected, the most significant and strongest correlation existed between industry's Huisache Auto GC and TCEQ's Huisache canister benzene data. Considering wind direction, in general winds that were more northerly weakened the relationship between the Auto GC site and the more distant eastern canister monitoring locations.

- AQP's Oak Park Auto GC Compared with Industry's and TCEQ's Canister Benzene Data (see Figures 13A and 14A, Appendix A).

The AQP Oak Park Auto GC station is located south of Refinery Row. The AQP Oak Park Auto GC site had a strong correlation with industry's Oak Park Elementary School canister site (Kendall's Tau = 0.8), which is only 0.2 miles away. The AQP Oak Park Auto GC benzene data were moderately correlated with canister data from industry's Tuloso Midway Middle School, Tuloso Midway Elementary School, and Up River Road sites, and were weakened whenever the winds were from the north. Unlike the more westerly industry canister sites, the correlation between AQP's Oak Park and industry's Crossley Elementary School was slightly higher, and was not as strongly affected by changes in wind direction.

While on a similar longitude to TCEQ's Huisache canister site, I-37 separates the AQP Oak Park station from Refinery Row. The AQP Oak Park Auto GC measured generally lower levels of benzene than the TCEQ canister sites, even when the winds were out of the south. For the TCEQ canister sites, the AQP Oak Park Auto GC had the highest correlation coefficients with Hillcrest and Huisache. Oak Park's correlation was affected by wind direction, with more northerly winds resulting in higher benzene concentrations at Huisache and, relative to Oak Park, lower concentrations at Dona Park.

- AQP's Solar Estates Auto GC Compared to Industry's and TCEQ's Canister Data (see Figures 15A and 16A, Appendix A).

The AQP Auto GC station located at Solar Estates is the most westerly Auto GC station in the network. The two nearest canister sites, which are industry's Tuloso Midway Middle School and Tuloso Midway Elementary School, showed good agreement with the AQP Solar Estates Auto GC benzene concentrations. The data correlated with all industry and TCEQ sites, with the strength of the association decreasing as the sites become more remote to Solar Estates. Even the industry canister sites at the eastern end of Refinery Row (Crossley Elementary School and Oak Park Elementary School) show significant correlation. The more distant TCEQ canister sites (Huisache, Oak Park, and Hillcrest) had higher benzene concentrations when the winds were from the north.

3G. Chemical Trends

ATSDR used bivariate polar plots to analyze how concentrations of a given chemical vary by wind speed and wind direction. Using the *openair* package function polarPlot, the data are plotted in polar coordinates indicating the wind direction. The distance from center indicates the wind speed. The use of bivariate polar plots is discussed in Carslaw *et al.* (2006) and in Westmoreland *et al*. (2007). The statistic plotted was the conditional probability function (CPF), which is used to show the probability that the concentration is within a given interval when the winds are from a given direction and speed [Uria-Tellaetxe and Carslaw 2014].

The main advantage of using CPF within the polar plot is that it will resolve other potential sources when large sources of a chemical are present near smaller sources. Polar plots utilizing the CPF are not as likely to suffer from the effects of outliers or require summarizing data that are censored into summary statistics. If nearby emission sources are similar, or vary in time for the data-collection period the polar plot covers, then the CPF polar plot features can potentially appear smeared or unclear. Polar plots will only reveal influences of nearby sources, and do not account for back trajectories (see Carslaw 2014 pages 124—136 for full discussion of polar plots). ATSDR only created polar plots for 2005–2010 or 2006–2010 (depending on data availability) to cover more recent trends in exposure in several compounds of interest (benzene, hydrogen sulfide, particulate matter, and sulfur dioxide).

The majority of ATSDR's chemical trend analysis is contained in Section 6.4 of the main text. The following text provide additional information for benzene, hydrogen sulfide, and sulfur dioxide.

3G.1. Benzene

In Section 6.4.1 of the main text, ATSDR notes Figures 26A and 27A, Appendix A, show benzene data scatter plots. The text here provides additional observations regarding these figures that were not provided in the main text.

Figure 26A, Appendix A, shows TCEQ canister sampling for benzene. The highest concentrations (and highest variability in concentrations) occurred at Huisache. Dona Park benzene concentrations were the lowest of the TCEQ canister sampling data. Hillcrest benzene concentrations were higher and more variable than Dona Park. Navigation Boulevard had slightly higher levels than Dona Park, but these samples were collected during an earlier period than those in Dona Park. In fact, the Navigation Boulevard data are the earliest (1993) benzene dataset in the entire TCEQ Refinery Row canister dataset. Poth Lane, which was geographically located closer to the refineries than Hillcrest, had less than two years of data. But for the period that samples were collected, the levels were on the same order of magnitude as the early Hillcrest data.

Industry canister sampling for benzene represents the longest period for which benzene was sampled at single locations in ATSDR's analysis (1996–2010). Figure 27A, Appendix A, shows the scatter plot for benzene data for the five industry stations. Because of the duration of the sampling program, long-term trends in the data are more apparent than in other sets. At all industry monitoring sites, the benzene concentrations decreased over time (see Table 34B, Appendix B). Oak Park Elementary School typically had the highest concentrations of benzene and the highest variance (as measured by the spread of the data on the log plot, as well as the lowest Kendall's Tau value) of the industry sites.

3G.2. Hydrogen Sulfide

ATSDR notes the agency only analyzed trends in the 2000–2010 data for hydrogen sulfide. Analysis of previous years revealed that the data were too highly censored and possibly substituted in cases of nondetect, which made analysis of dates before 2000 problematic. Section 6.4.2 of the main text provides the hydrogen sulfide trend information, with a few additional observations mentioned here.

There was an anomaly in the hydrogen sulfide data at Huisache (see Figure 33A, Appendix A). On Sunday mornings, the concentration quantiles drop precipitously, only to return to the previous hour's levels later in the morning.

Figure 33A, Appendix A, also shows the monthly pattern in hydrogen sulfide concentrations at Huisache and its two nearby monitoring sites across the ship channel, JI Hailey and Port Grain Elevator, oppose each other (see Graph C of this figure). But this opposition is consistent with the seasonal wind patterns and the polar plots analysis. That is, during the winter, when winds are more variable, Huisache tends to measure higher hydrogen sulfide levels relative to other periods. But during summer, when the winds are more southerly, Port Grain Elevator and JI Hailey sites measure higher hydrogen sulfide levels than in other months. Dona Park and Up River Road generally showed higher levels of hydrogen sulfide during autumn, appearing highest in September.

3G.3. Sulfur Dioxide

With regard to long-term temporal trends, ATSDR reviewed sulfur dioxide trends from 2000 through 2010. As with hydrogen sulfide, analysis of previous years revealed the data were too highly censored and, cases of nondetect, possibly substituted. Such data defects made analysis of periods before 2000 problematic. Section 6.4.4 of the main text provides the sulfur dioxide trend information, with a few additional observations mentioned here.

ATSDR noted increased sulfur dioxide concentrations occurred at Solar Estates from October 2006 until March 2007, when the winds were from the southeast. ATSDR developed polar plot analyses of the top 99^{th} percentile sulfur dioxide concentrations (i.e., those greater than 5 ppb). Figure 52A, Appendix A, shows these analyses by wind direction for each season and year.

For October 1, 2006, through March 1, 2007, the positive effect of wind speed on the concentration profile of sulfur dioxide at Solar Estates is remarkable (see Figure 53A, Appendix A). This wind speed effect would be inconsistent with nearby low-elevation plumes, which would be expected to produce an inverse relationship between high wind speed and concentration [Carlsaw 2014].

Figures 54A and 55A, Appendix A, show the temporal variation of sulfur dioxide from October 1, 2006, through March 1, 2007. Elevated levels occurred during the weekdays and are sharply elevated during the morning and late afternoon hours. Combined with the previous observations of the relationship to wind speed, it would appear that during this time an anthropogenic source possibly generated sulfur dioxide from a location approximately 150 degrees from the Solar Estates monitor (e.g., a few degrees north of south by southeast).

For the eastern end of the Refinery Row area, The University of Texas (UT) noted periods of elevated sulfur dioxide concentrations at Solar Estates in late 2006 through early 2007, which was consistent with wind directions between 135 and 180 degrees, with the highest concentration coming from 156 degrees [UT 2013]. UT's conclusion was that a high probability source occurred from the southeast at wind speeds greater than 10 knots during the fall of 2006 through winter of 2006/2007. UT concluded that this source was unlikely to be associated with actual sulfur dioxide and more likely attributable to some instrument interference [UT 2014].

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Appendix H. Toxics Release Inventory Emission Observations

In addition to reviewing the site-specific air monitoring data collected in the Refinery Row area, the Agency for Toxic Substances and Disease Registry (ATSDR) also provides general observations about reported air emissions by the Refinery Row facilities. These observations are from information in the U.S. Environmental Protection Agency's (EPA's) Toxics Release Inventory (TRI) database. TRI provides estimates of the annual air emissions of many chemicals (see http://www.epa.gov/triexplorer/).

According to the TRI database, nine industries in the Refinery Row area are classified as "petroleum" or "petroleum bulk terminals." In addition, two facilities not related to the petroleum industry emit chemicals of concern (e.g., benzene) to the air. These 11 industries are

BTB Refining	Flint Hills East
CITGO Deep Sea Terminal	Flint Hills West
CITGO East	Martin Operating LP
CITGO West	Valero West
Elementis Chromium	Valero East
Equistar	

1H. Toxics Release Inventory Data Review

ATSDR first reviewed the TRI data to determine which facilities reported releases of the chemicals identified in this public health evaluation. For comparison purposes, ATSDR downloaded data from the TRI system for the years 2000, 2005, and 2010 [USEPA 2012a]. The TRI database revealed that several Refinery Row facilities reported quantifiable point source (i.e., stack) and fugitive air emission releases[52] of chemicals such as benzene.

ATSDR searched the TRI database for information on emissions of many chemicals of potential concern in the Refinery Row area. For example, during 2000, 2005, and 2010 no facilities in the Refinery Row area reported to TRI point source and fugitive air emission releases of 1,2-dibromoethane, 1,2-dichloroethane, arsenic, arsenic compounds, cadmium compounds, carbon tetrachloride, and chloroform. Flint Hills West was the only Refinery Row facility that reported air emissions of trichloroethylene, but it reported only fugitive emissions—not stack emissions. In addition, during these years some chemicals such as hydrogen sulfide, isoprene, and sulfur dioxide were not regulated chemicals. Thus they were not chemicals listed in the TRI data and downloadable by ATSDR. Overall, ATSDR decided to focus its TRI review on 1,3-butadiene, benzene, chlorine and chromium compounds.

For these four chemicals, ATSDR noted the U.S. rank for the regulated facilities in the Refinery Row area based on total air emission releases (i.e., point source and fugitive combined) as reported to TRI [USEPA 2012a]. See Table 24B, Appendix B. ATSDR makes these general observations:

- According to the TRI database, in 2010 Equistar was ranked 27th of 179 U.S. facilities for total 1,3-butadiene air emissions. In 2005, Equistar was ranked 44th of 188 facilities. For total 1,3-butadiene air emissions, no other Refinery Row area facility was ranked in the top 50.

[52] Fugitive air emissions are all releases to air that are not released through a confined air stream like a stack. Fugitive emissions include equipment leaks, evaporative losses from surface impoundments and spills, and releases from building ventilation systems.

- In 2010, Flint Hills West was ranked 21st of 736 U.S. facilities for total benzene air emissions, and Valero East was ranked 24th. Flint Hills West was ranked 31st of 836 facilities in 2000 and ranked 8th of 793 facilities in 2005. Valero East was also ranked in the top 50 facilities during 2000 and 2005. Overall, eight facilities in the Refinery Row area reported benzene emissions to TRI.
- In 2005, Valero West ranked 33rd and CITGO West ranked 50th of 596 U.S. facilities for total chlorine air emissions. Although Flint Hills West did not report air emissions of chlorine in 2005 and 2010, in 2000 it ranked 47th of 749 facilities.
- Elementis Chromium ranked in the top 25 U.S. facilities for total chromium compound air emissions during 2000, 2005, and 2010.

For total air emission releases of 1,3-butadiene, benzene, chlorine, and chromium compounds, ATSDR also noted the U.S. rank of Nueces County for the years 2000, 2005, and 2010 [USEPA 2012b]. See Table 25B, Appendix B. ATSDR makes these general observations:

- For 1,3-butadiene total air emissions from 2000 to 2010, Nueces County steadily increased in rank for U.S. counties from 45th to 13th.
- Benzene total air emissions for Nueces County ranked in the top 10 in the U.S. counties, steadily increasing during 2000–2010 from 9th to 4th.
- From 2005 to 2010, chlorine total air emissions for Nueces County dropped in U.S. county rank from 17th to 120th.
- From 2005 to 2010, chromium compounds total air emissions for Nueces County dropped in U.S. county rank from 16th to 28th.

In addition, because benzene air emissions in Nueces County were ranked in the top 10 in the United States, ATSDR compiled benzene information for each facility reporting to TRI for 2000, 2005 and 2010 [USEPA 2012a]. In addition to the eight Refinery Row area facilities in Nueces County that reported benzene emissions to TRI, another facility outside the Refinery Row area in Nueces County also reported benzene emissions. Table 26B, Appendix B, provides the total benzene emissions reported in pounds for facilities in Nueces County. ATSDR makes these general observations:

- In 2005, Flint Hills West reported the maximum total benzene emissions (76,153 pounds).
- In 2005, CITGO Deep Sea Terminal reported the minimum total benzene emissions (22 pounds).

For comparison purposes, ATSDR calculated the percent each facility contributed to Nueces County total benzene air emissions for the years 2000, 2005, and 2010 [USEPA 2012a]. Figure 40A, Appendix A, graphically depicts this information. ATSDR makes these general observations:

- For 2000, 2005, and 2010, Flint Hills West and Valero East together contributed to more than 50% of the Nueces County total benzene air emissions reported to TRI.
- For these same years, Equistar's contributions to the total benzene air emissions reported to TRI for Nueces County steadily increased from 2.6% to 18%.
- For these same years, Flint Hills East's contributions to Nueces County total benzene air emissions reported to TRI steadily decreased from 9.5% to 3.9%.

ATSDR also reviewed TRI information for total benzene air emissions for 1988 to 2010 for Nueces County, the State of Texas, and the United States to determine any notable trends [USEPA 2012c]. Figure 41A, Appendix A, depicts total benzene information about Nueces County. Overall,

- Nueces County total benzene air emissions showed a 55% drop from year 1988 levels to year 2010 levels.
- In 1992, the maximum total benzene air emission level was reported (300,718 pounds), with the sharpest drop between 1992 and 1994.
- Except for years 2006 and 2010, Nueces County fugitive benzene emissions have exceeded point source benzene emissions.

Figure 42A, Appendix A, depicts the State of Texas total benzene air emissions, which showed an 82% drop from 1988 levels to 2010 levels. The maximum total benzene air emission level was in 1998 (7,299,830 pounds), with the sharpest drop between 1988 and 1989. Since 1995, fugitive benzene emissions in Texas have been lower than point source benzene emissions.

Figure 43A, Appendix A, depicts the U.S. total benzene air emissions, which showed an 88% drop from 1988 levels to 2010 levels. The maximum total benzene air emission level was in 1988 (32,340,125 pounds), with the sharpest drop between 1990 and 1992. Since 1995, fugitive benzene emissions have been lower than point source benzene emissions in the U.S.

Over the years, awareness has increased of the potential health effects of chemicals released into the environment. Accordingly, through environmental regulation and advances in air emissions control technology, releases of chemicals into the environment have greatly reduced.

2H. Toxics Release Inventory Review Limitations

ATSDR reviewed the TRI data to gain a general overview of potential air releases of regulated facilities in the Refinery Row area. But note the TRI dataset's limitations:

- Only certain industries are required to disclose to the TRI database releases for specific hazardous chemicals. Thus the TRI database does not cover all industries or all chemicals of concern. For example, although TRI data typically capture large stationary sources of emission releases, the database does not capture smaller stationary sources. These smaller stationary sources could include offices and residences, gasoline stations, and dry cleaners.
- The TRI data do not represent measured concentrations. Rather, the data represent industry-reported estimates of air emissions. The accuracy of these air emissions estimates is unknown.
- TRI data do not include mobile sources, such as automobiles, trucks, buses, and motorcycles. Several chemicals of concern in this public health evaluation are associated with motor vehicle emissions, such as benzene and 1,3-butadiene.
- Long-term trends in air emissions data can reflect actual changes in emissions as well as changes in the TRI reporting requirements. For example, beginning with the 1998 reporting year, some industry sectors, including petroleum bulk storage/terminals, were required to report for the first time. These industries are included for analyses for any period beginning with 1998 or later, but not for periods before 1998.

- Most importantly, TRI data do not represent a direct measure of exposure. Air emission estimates are not appropriate for evaluation of the potential for harmful human health effects.

Despite these limitations, ATSDR did make some general observations about facility-reported air emissions.

3H. References

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Appendix I. Toxicological Evaluation

In this appendix, the Agency for Toxic Substances and Disease Registry (ATSDR) describes the key points of its site-specific analysis of the chemicals chosen for public health evaluation. Table 2 in Section 4.3.3 of the main text lists these compounds.

As part of its public health evaluation, ATSDR again looked at the environmental guidelines sources to check for updates to chemicals with no health-based comparison values (CVs) because every few months agencies update their CVs. During this review, ATSDR noted that in March 2014 the Texas Commission on Environmental Quality (TCEQ) assigned long-term CVs to three chemicals previously without them[53] [TCEQ 2014]. These three chemicals were 1-butene, c-2-butene, and t-2-butene. ATSDR reviewed the concentrations of these chemicals in Refinery Row air. Maximum concentrations of these three chemicals in the available datasets were below each chemical's newly assigned TCEQ long-term CV. Thus, ATSDR did not retain these three chemicals for further public health evaluation.

During its CV review, ATSDR also noted that although ethane and propane do not have short-term and long-term CVs, and propylene does not have a short-term CV, these three chemicals are simple asphyxiants. Simple asphyxiants displace the oxygen in air and cause a serious risk of suffocation in confined areas; confined space is not an exposure pathway of concern for this public health evaluation. Because the measured ethane, propane, and propylene concentrations were in outdoor air and not indoors or other confined space areas, ATSDR did not retain these chemicals for further public health evaluation[54].

For the remaining compounds, ATSDR evaluates short-term exposure, long-term noncancer exposure, and cancer risk, as appropriate. Overall, ATSDR found the air levels of eight compounds (benzene, cadmium, chromium, 1,2-dibromoethane, hydrogen sulfide, naphthalene, particulate matter, and sulfur dioxide) to be of potential health concern and describes its evaluation of these eight compounds in Sections 7.1–7.8 of the main text. This appendix contains a description of ATSDR's evaluation of the remaining chemicals chosen for public health evaluation.

1I. Arsenic

Arsenic is a metal that occurs naturally in soil and in many kinds of rock, especially in minerals and ores that contain copper or lead. Arsenic is an alloying element in ammunition and in solders, is an anti-friction additive to metals used for bearings, and strengthens lead-acid storage battery grids. In the past, inorganic arsenic compounds were in pesticides, but this use is no longer permitted. In the more recent past, inorganic arsenic was a wood preservative; it made wood resistant to rotting and decay. In 2003, however, arsenic-containing wood preservatives were phased out for certain residential uses such as play structures, picnic tables, decks, fencing, and boardwalks. Arsenic wood preservatives are still used in industrial applications [ATSDR 2007a].

California EPA (Cal. EPA) has an acute reference exposure level (REL) of 0.2 micrograms per cubic meter (µg/m^3) and a chronic REL of 0.015 µg/m^3. TCEQ has a short-term air monitoring comparison value (AMCV) of 9.9 µg/m^3. The U.S. Department of Health and Human Services (DHHS), the International

[53] ATSDR originally screened the air data with TCEQ CVs last modified in September 2013.

[54] For perspective, ATSDR also notes that the maximum ethane and propane levels in Refinery Row outdoor air were two to three orders of magnitude below levels healthy workers could breathe indoors, day after day, for a working lifetime. Propylene's maximum concentrations were over an order of magnitude below the available propylene long-term CV.

Agency for Research on Cancer (IARC), and the U.S. Environmental Protection Agency (U.S. EPA) have designated arsenic as a human carcinogen. ATSDR has a cancer risk evaluation guide (CREG) of 0.00023 $\mu g/m^3$, U.S. EPA has a carcinogenic target risk screening level (SL) of 0.00057 $\mu g/m^3$, and TCEQ has a carcinogenic-based long-term AMCV of 0.067 $\mu g/m^3$.

Short-term exposure: None of the arsenic levels were above short-term CVs. Thus ATSDR does not expect that short-term exposure to the arsenic concentrations in Refinery Row air would cause harmful health effects.

Long-term noncancer exposure: ATSDR was able to calculate a mean concentration for the pre-2005 Dona Park dataset following the procedures described in Appendix G. This mean concentration of 0.00108 $\mu g/m^3$ is more than an order of magnitude below the Cal. EPA REL. Thus ATSDR does not expect that long-term exposure to the arsenic concentrations in Refinery Row air would cause harmful noncancer health effects.

Cancer risk: Several human studies have shown that arsenic inhalation exposures can cause lung cancer [ATSDR 2007a; USEPA 1998b]. The U.S. EPA inhalation unit risk (IUR) of 4.3×10^{-3} $(\mu g/m^3)^{-1}$ is based on four occupational studies that found arsenic exposure to cause an increase in respiratory cancer mortality [USEPA 1998b; Brown and Chu 1983; Enterline and Marsh 1982; Lee-Feldstein 1983; Higgins et al. 1982]. Because each of the studies calculated similar IURs, the U.S. EPA IUR is the geometric mean of the individual studies. The cancer risks associated with various concentrations of arsenic are in Table 27B, Appendix B.

The arsenic mean (0.00108 $\mu g/m^3$) is above its U.S. EPA carcinogenic SL. As part of its evaluation, ATSDR calculated cancer risk estimates for chemical carcinogens selected for further consideration. To calculate estimates, each chemical's mean concentration is multiplied by its U.S. EPA IUR (see Table 28B, Appendix B). These cancer risk estimates are expressed as a probability; that is, the proportion of a population that might be affected by a carcinogen during a lifetime of exposure (24 hours/day, 365 days/year, for 70 years). Using the highest arsenic mean (0.00108 $\mu g/m^3$) and its U.S. EPA IUR results in an additional cancer risk of 4.6 in 1,000,000, a risk that ATSDR considers very low.

2I. Barium

Barium is a silvery-white metal found in barite ores containing mixtures of elements. Compounds form when barium combines with other chemicals such as sulfur or oxygen. These compounds are in paint, bricks, ceramics, glass, rubber, and other products. Oil and gas industries use barium compounds to make drilling mud, which helps rock drilling by keeping the drill bit lubricated [ATSDR 2007b].

According to U.S. EPA 1996 cancer assessment guidelines, barium is classified as not likely to be carcinogenic to humans via oral exposure, but its carcinogenic potential via inhalation cannot be determined. The U.S. EPA reference concentration (RfC) is 0.5 $\mu g/m^3$. TCEQ has a short-term (5 $\mu g/m^3$) and long-term (0.5 $\mu g/m^3$) AMCV.

Short-term exposure: Few studies have clearly documented the effects of barium inhalation. In extreme cases of occupational exposure, barium inhalation caused adverse respiratory, cardiovascular, musculoskeletal, and metabolic effects [Doig 1976; Essing et al. 1976; Zschiesche et al. 1992]. Still, these concentrations were much higher than those encountered in ambient (outdoor) air. And such extreme cases generally have been of small sample size and have lacked reproducibility and consistency in their health effects.

Barium was measured in samples from three periods: the 1980s, pre-2005, and 2005–2010. The maximum concentration of barium measured in Refinery Row air, which was found in a sample from the 1980s, was 6.335 µg/m^3. For the pre-2005 and 2005–2010 Dona Park datasets, the maximum concentration was 0.374 µg/m^3.

As stated in Section 4.1.5 of the main text, the 1980s data are of unknown quality—ATSDR therefore cannot draw definitive health conclusions from them. But to put these levels in perspective, ATSDR notes only 1 of 184 samples (0.5%) exceeded the TCEQ short-term AMCV (5 µg/m^3), which is based on a threshold limit value (TLV) time weighted average (TWA) developed by the American Conference of Government Industrial Hygienists (ACGIH). The barium TLV of 500 µg/m^3 is considered protective for healthy workers exposed regularly during a conventional workday of 8 hours/day and 40 hours/week.

In the pre-2005 and 2005–2010 Dona Park datasets, the maximum concentrations did not exceed the short-term CV. Thus ATSDR does not expect that short-term exposure to barium concentrations in Refinery Row air would result in harmful health effects.

Long-term noncancer exposure: While no studies are available on the human health effects from chronic inhalation barium exposure, one subchronic study observed respiratory and cardiovascular effects in rats exposed to 3,600 µg/m^3 barium 4 hours/day, 6 days/week for 4 months [Tarasenko et al. 1977]. At Refinery Row, barium was detected above the reporting limit in 84 of 184 (46%) samples from stationary air monitors in the 1980s, with the highest mean at 0.54 µg/m^3. For those older 1980s data of unknown quality, ATSDR notes that the highest mean was about equal to the U.S. EPA RfC and TCEQ long-term AMCV and was over three orders of magnitude below documented health effect levels. For the pre-2005 and 2005–2010 Dona Park datasets, the maximum and mean concentrations were all below these long-term CVs. Thus using the Dona Park datasets, ATSDR does not expect that long-term exposure to barium concentrations in Refinery Row air would result in harmful noncancer health effects.

3I. 1,3-Butadiene

1,3-Butadiene is a colorless gas with a mild, gasoline-like odor. Automobile exhaust from internal combustion engines is a constant source of 1,3-butadiene air emissions. Other sources of 1,3-butadiene include cigarette smoke and wood fire smoke. Forest fires are a natural source of 1,3-butadiene. About 60% of manufactured 1,3-butadiene is used to make rubber, which is then used mostly for car and truck tires [ATSDR 2012]. 1,3-Butadiene is also used to make certain types of plastics, such as acrylics. While large amounts of 1,3-butadiene are released into the air from industrial sources, releases to water and soil are relatively low. In the atmosphere, 1,3-butadiene is expected to undergo photo-initiated destruction, with a half-life of approximately 6 hours. In the general population, smokers, persons exposed to secondhand smoke, and persons inhaling smoke from wood fires are likely to be exposed to elevated levels of 1,3-butadiene [ATSDR 2012]. ATSDR has a CREG value of 0.015 parts per billion (ppb), while the U.S. EPA has an RfC (0.9 ppb) and carcinogenic SL of 0.037 ppb. TCEQ has a short-term AMCV of 1,700 ppb, a noncancer-based long-term AMCV of 15 ppb, and a carcinogenic-based long-term AMCV of 9.1 ppb for 1,3-butadiene in air.

Short-term exposure: Maximum concentrations of 1,3-butadiene in Refinery Row air are more than an order of magnitude below the short-term AMCV of 1,700 ppb. Therefore, ATSDR does not expect that short-term exposure to 1,3-butadiene concentrations in Refinery Row air would result in harmful health effects.

Long-term noncancer exposure: None of the means at any location exceeds the U.S. EPA RfC and TCEQ noncancer-based AMCV, which are protective of chronic health effects. Therefore, ATSDR does not expect that long-term exposure to 1,3-butadiene concentrations in Refinery Row air to cause harmful noncancer health effects.

Cancer risk: Although the ATSDR CREG is 0.015 ppb, for 1,3-butadiene concentrations to exceed this carcinogenic screening value is not uncommon. According to ATSDR's Toxicological Profile for 1,3-Butadiene [ATSDR 2012], mean concentrations of 1,3-butadiene in the air in cities and suburban areas range from 0.04–1 ppb, with an estimated average background concentration of 0.059 ppb.

The U.S. EPA IUR of 3×10^{-5} $(\mu g/m^3)^{-1}$ is based on a study by Health Canada that used occupational data on leukemia in rubber production workers to develop a relative rate model to predict cancer incidence [USEPA 2002; Health Canada 1998]. The cancer risks associated with various concentrations of 1,3-butadiene, based on this IUR, are in Table 27B, Appendix B.

In all, 1,3-butadiene exceeded its CREG in 64% of the samples. But as stated previously, it is not unusual for 1,3-butadiene concentrations to exceed the CREG. According to U.S. EPA's 2005 National-Scale Air Toxics Assessment (NATA) [USEPA 2011c], the CREG is lower than the estimated average concentrations for the United States, for Texas, and for Nueces County (see Table 1J, Appendix J). Overall, the highest mean at any location was 0.076 ppb, which corresponds to an additional cancer risk of 5.0 per 1,000,000 persons, which ATSDR considers a very low risk (see Table 28B, Appendix B).

4I. 1-Butanol

1-Butanol is a colorless liquid with a rancid, sweet, wine-like odor. It is a common product of mold metabolism and releases naturally from forests, grasslands, and orchards. 1-Butanol has a range of applications as a solvent and is in a variety of products ranging from cosmetics to brake fluid. The Food and Drug Administration (FDA) considers 1-butanol generally recognized as safe (GRAS) for use as a flavoring agent, and FDA lists it as an inert ingredient approved for prescription drugs [WHO 1987; ACGIH 2013]. Although ATSDR and U.S. EPA have not developed air CVs for 1-butanol, U.S. EPA has a chronic oral reference dose (RfD) of 0.1 milligrams per kilogram per day (mg/kg/day). An oral RfD is a daily lifetime ingestion dose of a chemical that is not likely to cause people harm. As to human carcinogenicity, U.S. EPA deemed 1-butanol as "not classifiable" based on a lack of human and animal carcinogenicity data.

Short-term exposure: Short-term exposure to 1-butanol can cause skin, eye, and upper respiratory tract irritation. In some studies, eye irritation—the most sensitive endpoint—occurred at concentrations as low as 10 parts per million (ppm) (or 10,000 ppb). But other studies found no effect at concentrations as high as 100 ppm (or 100,000 ppb) [ACGIH 2013]. ACGIH has a TLV of 20 ppm (or 20,000 ppb), the Occupational Safety and Health Administration (OSHA) has a permissible exposure limit (PEL) of 100 ppm (or 100,000 ppb) and the National Institute for Occupational Safety and Health (NIOSH) has a recommended exposure limit ceiling of 50 ppm (or 50,000 ppb). These worker guidelines apply to healthy adult employees working 40-hour weeks, not to the general population—including children, the elderly, and the sick—who might be subject to continuous environmental exposure. As such, ATSDR only uses these values to put site-specific concentrations of contaminants into perspective, especially when no other nonoccupational comparison values are available.

The ACGIH 1-butanol TLV is the lowest worker-guideline value. This guideline is intended to protect workers from eye irritation, although ACGIH does state that workers unfamiliar with 1-butanol might endure a passing irritation due to odor at levels below the TLV. 1-Butanol was only analyzed for in industry canisters before 2005. The maximum Refinery Row air concentration of 1-butanol measured (61.4 ppb) is greater than two orders of magnitude below levels documented to cause health effects and is well within the worker guidelines. Thus ATSDR expects that short-term exposure to 1- butanol concentrations in Refinery Row air would not cause harmful health effects.

Long-term noncancer exposure: Using the U.S. EPA assumptions of breathing rates (16 cubic meters per day (m^3/day) and 10 m^3/day for adults and children, respectively) and body weights (80 kilograms (kg) and 10 kg for adults and children, respectively), the oral RfD corresponds to air concentrations of 165 ppb for adults and 33 ppb for children. The highest measured mean (9.6 ppb) is greater than three orders of magnitude below levels documented to cause health effects and would result in a dose below the RfD. Thus ATSDR expects that long-term exposure to 1- butanol concentrations in Refinery Row air would not cause harmful noncancer health effects.

5I. Carbon Tetrachloride

Carbon tetrachloride is a synthetic chemical formerly used in many applications, such as refrigeration and aerosol cans. In recent decades, most industrial and commercial uses of the chemical have been phased out because of concerns about how carbon tetrachloride affects the ozone layer [ATSDR 2005]. Carbon tetrachloride can affect the kidney, liver, and nervous system. Generally, unless exposure has caused severe damage to the organs, health effects from acute exposures will dissipate after exposure ceases. Liver damage caused by carbon tetrachloride exposure has been observed to be worse in people who consume alcohol. ATSDR has a CREG of 0.026 ppb and chronic environmental media evaluation guide/minimal risk level (EMEG/MRL) of 30 ppb. U.S. EPA has a chronic RfC (16 ppb) and carcinogenic SL (0.065 ppb). TCEQ has a short-term (20 ppb) and long-term (2 ppb) AMCV for carbon tetrachloride in air.

Short-term exposure: Studies have found acute inhalation and oral exposures to high levels of carbon tetrachloride damages the liver (swollen, tender liver, changes in enzyme levels, and jaundice) and kidneys (nephritis, nephrosis, proteinurea); this damage occurs at levels of exposure greater than 63,000 µg/m^3 (or 10,000 ppb) [USEPA 2010], which is the no-observed-adverse-effect-level (NOAEL) for humans and the lowest-observed-adverse-effect-level (LOAEL) for rats. Depression of the central nervous system has also been reported. Acute exposure symptoms in people include headache, weakness, lethargy, nausea, and vomiting [USEPA 2010], but these symptoms were quantified at exposures of nearly 252,000 µg/m^3 (or 40,000 ppb) [ATSDR 2005]. The TCEQ short-term AMCV of 20 ppb for carbon tetrachloride is based on a NIOSH recommended exposure limit of 2 ppm (or 2,000 ppb) averaged over a 1-hour period [NIOSH 1976]. To achieve the short-term AMCV, the NIOSH value is divided by a safety factor of 100.

In the Refinery Row area, the carbon tetrachloride short-term CV was not exceeded during routine sampling (TCEQ canisters and industry canisters groups). For episodically collected samples, the short-term CV was exceeded in two samples from the AQP triggered canisters group at two separate locations. The measured concentrations of 47.62 ppb in 2010 and 34.43 ppb in 2008 were found in 1 of 13 samples and 1 of 14 samples, respectively. Although the short-term CV was exceeded twice, these exceedences were not in neighborhood areas. The short-term CV was also exceeded in 0.83% of the samples from mobile monitoring, and the maximum concentration (130 ppb) was detected in 2001. This concentration is almost two orders of magnitude less than the concentrations documented to cause acute effects in people. Because the short-term CV was not exceeded during routine monitoring, because of the low incidence of exceeding the short-term CV during episodic monitoring, and because of an absence of documented health effects near the maximum concentrations detected, ATSDR does not expect that short-term exposure to the carbon tetrachloride levels in Refinery Row air would cause harmful health effects.

Long-term noncancer exposure: None of the sample means from the TCEQ canisters or industry canisters exceeded the ATSDR, U.S. EPA, and TCEQ chronic noncancer CVs. The highest mean from any sampling location was 0.11 ppb. Thus ATSDR does not expect that long-term exposure to the carbon tetrachloride levels measured in Refinery Row air would cause harmful noncancer health effects.

Cancer risk: Because significant quantities of other airborne chemicals complicate occupational (i.e., worker) exposures, studies have not linked carbon tetrachloride exposures directly to cancer in people [USEPA 2010]. Liver cancer has been reported in laboratory animals exposed chronically to carbon tetrachloride at air concentrations of 157,500 $\mu g/m^3$ (or 25,000 ppb), but not liver cancer in people [ATSDR 2005].

While ATSDR has a CREG of 0.026 ppb, it is not unusual for carbon tetrachloride concentrations to exceed this CV. According to the 2005 NATA [USEPA 2011c], the CREG value is lower than the estimated average carbon tetrachloride concentrations for the United States, Texas, and Nueces County (see Table 1J, Appendix J).

The U.S. EPA IUR of 6×10^{-6} $(\mu g/m^3)^{-1}$ is based on two separate studies that found an increased incidence in pheochromocytoma (i.e., tumors of the adrenal gland) in mice that had a cancer effect level (CEL) of 25 ppm (or 25,000 ppb) [Nagano et al. 2007; JBRC 1998]. The cancer risks associated with various concentrations of carbon tetrachloride based on this IUR are in Table 27B, Appendix B.

Overall, carbon tetrachloride was detected in 91% of the samples from TCEQ canisters and industry canisters groups. The CREG was exceeded in 87% of the TCEQ canister samples from pre-2005 and 2005–2010. It was also exceeded in 99.6% of the pre-2005 industry canister samples. The highest sample mean (0.11 ppb) was measured at multiple locations and corresponds to an additional cancer risk of 4.2 per 1,000,000 people, which ATSDR considers very low (see Table 28B, Appendix B).

6I. Chlorine

Few studies have examined the health effects of inhalation exposure to particulate chlorine. The available recommended health-based comparison values are for chlorine gas. Chlorine gas is very different from the solid-phase chlorine found in particulate matter, such as that found in the sampling of particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) conducted at the Dona Park monitoring site. Chlorine gas has a defined chemical formula, while particulate chlorine can be attached to a variety of substituents, and is thus without a defined chemical formula.

The varying chemical structures of particulate chlorine can result in various health effects. One study documented a likely association of diabetes with particulate chlorine $PM_{2.5}$ exposure at concentrations of 14 $\mu g/m^3$ [Reis et al. 2009]. In this study, organochlorine pesticides were found to dominate the chlorine particulate. Another study analyzed $PM_{2.5}$ data from the TCEQ Dona Park monitor and estimated the likely sources and content of ambient $PM_{2.5}$ [Karnae and John 2011]. Using data from July 2003 to December 2008, Karnae and John concluded that much of the chlorine associated with $PM_{2.5}$ was fresh and aged sea salt, a common area constituent given Refinery Row's proximity to the Gulf of Mexico. Sea salt is predominantly sodium chloride (table salt) and is much less toxic than chlorine gas.

Although sodium chloride does not have any inhalation comparison values, U.S. EPA allows more than 62 times the amount of sodium chloride in water by weight than it allows chlorine.

This public health evaluation is only based on the chlorine content, not the unknown components associated with the chlorine compounds in the $PM_{2.5}$. Although the assumption that all particulate chlorine is as equally toxic as the more reactive chlorine gas will likely overestimate particulate, chlorine-specific toxicity, it is also possible that some portion of the toxicity from the chlorine concentration may be underestimated because of the unknown identity and toxicity of the chlorine substituents.

ATSDR has an acute (170 µg/m^3), intermediate (5.8 µg/m^3), and chronic (0.15 µg/m^3) EMEG/MRL for chlorine gas, but particulate chlorine has no ATSDR CVs. Neither the U.S. EPA, the IARC, nor DHHS classify chlorine as a carcinogen.

Short-term exposure: Several studies have documented respiratory and ocular effects in humans (burning and irritation of the nose, eyes, and throat) following acute exposure to chlorine gas at concentrations as low as 1,000 ppb (or 2,900 µg/m^3) [ATSDR 2010]. For the Dona Park datasets, the highest concentration of particulate chlorine measured was 2.73 µg/m^3. This concentration did not exceed the ATSDR acute or intermediate EMEG/MRLs for chlorine gas. Thus ATSDR does not expect that short-term exposure to chlorine concentrations in Refinery Row air would result in harmful health effects.

Long-term noncancer exposure: Chronic and acute chlorine gas exposure have similar effects. Health effects data for chronic inhalation exposure are limited to animal studies. One study observed changes to monkey nasal epithelial cells—the most sensitive endpoint—at concentrations as low as 100 ppb (or 290 µg/m^3) [Klonne et al. 1987]. This study was the basis of the ATSDR chronic EMEG/MRL. The EMEG/MRL was derived from a model adjusted to reflect a human equivalent benchmark concentration, lower bound (BMCL)[55] of 1.36 ppb (or 3.9 µg/m^3), to which ATSDR applied an uncertainty factor of 30 (3 for use of an animal study with dosimetric adjustment and 10 for human variability).

Chlorine was measured above the reporting limit in 439 of 572 $PM_{2.5}$ samples (77%) at Dona Park. The pre-2005 samples had a mean of 0.104 µg/m^3, but the 2005−2010 samples had a statistically higher mean of 0.276 µg/m^3, which could indicate an increasing trend.

Although the 2005−2010 chlorine mean exceeds the chlorine gas chronic EMEG/MRL, it is about two orders of magnitude below the most sensitive endpoint level of 290 µg/m^3. ATSDR also notes that the 2005−2010 chlorine mean is more than an order of magnitude lower than the particulate chlorine level of 14 µg/m^3 associated with diabetes. Further, the chlorine dose based on this mean is expected to be lower, given the likelihood that sodium chloride constitutes most of this chlorine. Sodium chloride is less toxic than both chlorine gas and the particulate chlorine dominated by organochlorine pesticides. Thus ATSDR does not expect that long-term exposure to chlorine concentrations in Refinery Row air would result in harmful noncancer health effects.

7I. Chloroform

Chloroform is a colorless liquid with a pleasant, nonirritating odor and a slightly sweet taste. Industrial uses are the most common source of the chloroform found in the environment [ATSDR 1997a].

[55] BMCL or benchmark dose level (BMDL) is a statistical lower confidence limit on the dose or concentration at the benchmark concentration (BMC) or benchmark dose (BMD), respectively.

Chloroform is in chlorinated water and consumer products such as air deodorizers and cleaning products. It is also in some foods such as soft drinks, dairy products, and grains. Chloroform can cause harmful effects to the kidney and liver. It can also affect the nervous system at higher concentrations. Generally, harmful effects from acute exposures will dissipate after exposure ceases unless that exposure has severely damaged the organs. The amount of chloroform normally expected in the air ranges from 0.02–0.05 ppb in areas not affected by chloroform emissions [ATSDR 1997a]. ATSDR has chronic (20 ppb) and acute (100 ppb) EMEG/MRLs for noncancer effects, and a CREG of 0.0089 ppb. The U.S. EPA carcinogenic SL for chloroform is 0.023 ppb. TCEQ has a short-term (20 ppb) and long- term (2 ppb) AMCV for chloroform in air.

Short-term exposure: In the past, acute chloroform exposure most often occurred through its use as a medical anesthetic; people were commonly exposed to extremely high doses of 12–73 grams per cubic meter (or 2.46×10^6–1.5×10^7 ppb). Using chloroform as an anesthetic was discontinued because of its association with deaths due to heart and breathing failures. And many people who survived the anesthesia experienced a number of neurological and liver symptoms including nausea, vomiting, prostration, jaundice, and coma due to liver dysfunction. Respiratory effects and liver damage have been documented in mice after acute exposures to concentrations as low as 10 ppm (or 10,000 ppb) [ATSDR 1997a; Larson et al. 1994].

The TCEQ short-term AMCV for chloroform of 20 ppb is based on an OSHA PEL of 2 ppm (or 2,000 ppb) averaged over a 1-hour period [NIOSH 1974]. This PEL is designed to prevent adverse effects and reduce the risk of cancer from occupational exposure to chloroform (up to a 10-hour workday and 40 hour workweek). The PEL is divided by a safety factor of 100 to achieve the short-term AMCV. The ATSDR acute EMEG/MRL of 100 ppb is based on an acute study that found a NOAEL of 3 ppm (or 3,000 ppb) in mice for changes in the liver cells [Larson et al. 1994]. ATSDR applied an uncertainty factor of 30 (3 for animal to human extrapolation and 10 for human variability) to the NOAEL to achieve the acute EMEG/MRL.

Chloroform was measured in the TCEQ canisters and mobile monitoring groups. Chloroform exceeded the short-term AMCV in 2 of 480 mobile monitoring samples, but did not exceed this CV in any of the samples during routine TCEQ canister monitoring. Although the maximum measured concentration (110 ppb) exceeded the TCEQ short-term AMCV, this maximum concentration is only slightly above the ATSDR acute EMEG/MRL and is over an order of magnitude below the NOAEL in animals. Thus, ATSDR does not expect that short-term exposure to chloroform concentrations measured in Refinery Row air would cause harmful health effects.

Long-term noncancer exposure: Because mean chloroform levels for the TCEQ canisters group did not exceed the ATSDSR chronic EMEG/MRL or the TCEQ long-term AMCV, ATSDR does not expect that long-term exposure to chloroform levels in Refinery Row air would cause harmful noncancer health effects.

Cancer risk: DHHS has designated chloroform as a reasonably anticipated carcinogen; IARC has designated chloroform as possibly carcinogenic to humans. U.S. EPA developed its chloroform IUR of 2.3×10^{-5} $(\mu g/m^3)^{-1}$ in 1987 and classified chloroform as a *probable human carcinogen*, based on "sufficient evidence" of carcinogenicity in animals. Using more recent cancer assessment guidelines, U.S. EPA updated its carcinogenicity assessment to state the following [USEPA 2001]:

> Chloroform is *likely to be carcinogenic to humans by all routes of exposure* under high-exposure conditions that lead to cytotoxicity and regenerative hyperplasia in susceptible tissues [USEPA 1998c, 1998d]. Chloroform is *not likely to be*

carcinogenic to humans by any route of exposure under exposure conditions that do not cause cytotoxicity and cell regeneration.

The cancer risks associated with various concentrations of chloroform, using the U.S. EPA IUR, are in Table 27B, Appendix B. For the TCEQ canisters group, chloroform was detected in 31% of the samples, which were all above the CREG. However, it is not unusual for chloroform concentrations to exceed this CV. According to the 2005 NATA [USEPA 2011c], the CREG value is lower than the estimated average chloroform concentration for the United States, Texas, and Nueces County (see Table 1J, Appendix J).

The highest chloroform mean, 0.017 ppb, corresponds to an additional cancer risk of 1.9 per 1,000,000 persons. ATSDR considers this a very low risk (see Table 28B, Appendix B).

8I. Chloroprene

Chloroprene is a colorless liquid used almost exclusively in the manufacture of neoprene (polychloroprene), a synthetic rubber in wire and cable covers, gaskets, automotive parts, adhesives, caulks, flame-resistant cushioning and other applications requiring chemical, oil, and weather resistance or high gum strength [NTP 1998a]. Workers can be occupationally exposed to chloroprene by the inhalation or dermal route [USEPA 1985]. DHHS reasonably anticipates chloroprene is carcinogenic, IARC deems it possibly carcinogenic to humans, and U.S. EPA says chloroprene is likely carcinogenic to humans. ATSDR has a CREG (0.00091 ppb), while U.S. EPA has an RfC (5.5 ppb) and a carcinogenic SL (0.0022 ppb).

Short-term exposure: In studies of occupationally exposed workers, chloroprene has reportedly caused respiratory, eye, and skin irritation, chest pains, temporary hair loss, dizziness, insomnia, headache, and fatigue [Nystrom 1948]. Acute exposure might damage the liver, kidneys, and lungs. And chloroprene might affect the circulatory system and immune system, depress the central nervous system (CNS), irritate the skin and mucous membranes, and cause dermatitis and respiratory difficulties in humans [USEPA 1985].

Chloroprene was measured in samples from the TCEQ canisters and mobile monitoring groups. Chloroprene has no acute CV. To determine the likelihood of harmful acute health effects, ATSDR compares the chloroprene ambient air data with the long-term noncancer U.S. EPA RfC (5.5 ppb), which is health-protective for a lifetime of continuous exposure. Chloroprene did not exceed the RfC in any TCEQ canister samples, nor any mobile monitoring canister samples. However, chloroprene exceeded the RfC in 2 of 69 (2.9%) real-time GCMS samples from mobile monitoring, with a maximum concentration of 14.9 ppb.

The RfC was derived from a study that found a LOAEL of 12.8 ppm (or 12,800 ppb) for non-neoplastic lesions in multiple organ systems in rats [NTP 1998a]. EPA adjusted the LOAEL to a human equivalent concentration and applied benchmark dose (BMD) modeling to multiple endpoints to achieve a benchmark dose level (BMDL) of 550 ppb. To achieve the 5.5 ppb RfC, EPA treated the BMDL with an uncertainty factor of 100 (10 for human variability, 3 for intra species variation, and 3 for database inadequacies). Although two samples exceeded the RfC, the majority of the chloroprene data (1,917 TCEQ canister samples; 196 mobile monitoring canister samples; and 67 mobile monitoring real-time GCMS samples) indicate levels well below the long-term U.S. EPA RfC. Furthermore, the maximum measured chloroprene concentration is an order of magnitude lower than the level documented to cause health effects [Sanotskii 1976]. Therefore, ATSDR does not expect that short-term exposure to chloroprene concentrations in Refinery Row ambient air would cause harmful health effects.

Long-term noncancer exposure: None of the TCEQ canister sampling locations detected chloroprene over 20% of the time, and the mean could not be calculated by the methods described in Appendix G. Furthermore, because this chemical was detected in fewer than 5% of the samples at each location, the 95th percentile represents a nondetect value. As a result, ATSDR uses the reporting limit of VOCs in TCEQ canisters (0.01 ppb) divided by the square root of two as the concentration for the evaluation of the potential for long-term noncancer health effects and cancer risk. The resulting 0.007-ppb concentration is below the RfC (5.5 ppb).

In addition, NATA estimated that the concentration of chloroprene in Nueces County, where Refinery Row is located, was 2.20×10^{-6} ppb—over six orders of magnitude below the RfC [USEPA 2011c]. Both the NATA modeled estimate and the measured TCEQ canister data suggest average concentrations below the RfC. Thus ATSDR does not expect that long-term exposure to chloroprene concentrations in Refinery Row ambient air would cause harmful noncancer health effects.

Cancer risk: The U.S. EPA IUR of 3×10^{-4} $(\mu g/m^3)^{-1}$ is based on the same study as the RfC, which also found increased carcinomas in a variety of organs with a CEL of 12.8 ppm (or 12,800 ppb) [NTP 1998a]. Using the NATA estimated 2005 concentration (2.20×10^{-6} ppb), the cancer risk is 2.4×10^{-9}, which ATSDR considers insignificant. The cancer risks associated with various concentrations of chloroprene are in Table 27B, Appendix B.

As stated previously, the TCEQ canister stationary air monitors detected chloroprene in only 2 out of 1,917 samples. Because of the very low detection rate, ATSDR used the reporting limit divided by the square root of 2 (or 0.007 ppb) to assess cancer risk. Using this value results in an additional cancer risk of 7.6 in 1,000,000, a risk ATSDR considers very low (see Table 28B, Appendix B).

9I. Cobalt

Elemental cobalt is a hard, silvery grey metal usually found in the environment combined with other elements such as oxygen, sulfur, and arsenic. Small amounts of these chemical compounds are in rocks, soil, plants, and animals. Cobalt is not currently mined in the United States, but was mined in the past. The United States now obtains cobalt and its other chemical forms from imported materials and from recycling cobalt-containing scrap metal. Cobalt metal is usually mixed with other metals to form alloys, which are hard and resist wear and corrosion. Industry uses these alloys in a number of military and industrial applications such as aircraft engines, magnets, and grinding and cutting tools. The alloys also appear in artificial hip and knee joints. And cobalt compounds are used as colorants in glass, ceramics, and paints, catalyze chemical reactions, and help to dry paint [ATSDR 2004]. Small amounts of cobalt might release into the atmosphere from coal-fired power plants and incinerators, vehicular exhaust, industrial activities relating to the mining and processing of cobalt-containing ores, and the production and use of cobalt alloys and chemicals [ATSDR 2004].

ATSDR has a chronic inhalation EMEG/MRL of 0.10 $\mu g/m^3$ for cobalt in air. U.S. EPA has an RfC of 0.006 $\mu g/m^3$ and a carcinogenic SL of 2.7×10^{-4} $\mu g/m^3$. TCEQ has a short-term (0.2 $\mu g/m^3$) and long-term (0.02 $\mu g/m^3$) AMCV for cobalt in air. IARC has designated cobalt as possibly carcinogenic to humans, albeit based on limited human evidence and less than sufficient evidence in animals.

Short-term exposure: Cobalt was not detected above the reporting limit in any of the samples from the 1980s. In all, the Dona Park datasets show that cobalt was detected in 18 of 756 samples (2.4%). The maximum concentration measured was 0.00112 $\mu g/m^3$—more than two orders of magnitude below the TCEQ short-term AMCV, designed to protect people from acute health effects. Thus ATSDR does not expect that short-term exposure to the cobalt concentrations in Refinery Row air would cause harmful health effects.

Long-term noncancer exposure: Because in the Refinery Row area cobalt was detected in less than 20% of the samples, mean values could not be calculated following the procedures outlined in Appendix G, ATSDR used the highest 95th percentile (0.00068 µg/m^3), generally a more conservative value than the mean, to estimate long-term noncancer exposure risk. The 95th percentile of the data is below the ATSDR chronic EMEG/MRL, U.S. EPA RfC, and TCEQ long-term AMCV, all of which are designed to protect people from long-term noncancer health effects. Thus ATSDR does not expect that long-term exposure to cobalt concentrations in Refinery Row air would cause harmful noncancer health effects.

Cancer Risk: Studies of the carcinogenic potential of inhaled cobalt in rats and mice have shown increased incidence of alveolar/bronchiolar tumors, pheochromocytomas and hemangiosarcomas [Bucher et al. 1999; NTP 1998b]. Due to a higher and more consistent response across species, U.S. EPA used the increase in alveolar/bronchiolar tumors to derive its provisional IUR 9.0×10^{-3} (µg/m^3)$^{-1}$. The cancer risks associated with various concentrations of cobalt are in Table 27B, Appendix B. Calculation based on the cadmium 95th percentile (0.00068 µg/m^3) at Refinery Row and the U.S. EPA IUR results in an additional cancer risk of 6.1 in 1,000,000, which ATSDR considers very low (see Table 28B, Appendix B).

10I. 1,2-Dichloroethane

1,2-Dichloroethane is a manufactured chemical not found naturally in the environment. The most common use of 1,2-dichloroethane is in the production of vinyl chloride, which is used to make a variety of plastic and vinyl products including polyvinyl chloride (PVC) pipes, furniture and automobile upholstery, wall coverings, housewares, and automobile parts. 1,2-Dichloroethane is also a solvent and is added to leaded gasoline to remove lead [ATSDR 2001].

At high exposures, 1,2-dichloroethane affects the central nervous system, liver, and kidneys. Few researchers have studied people exposed to 1,2-dichloroethane; most of what is known comes from intentional or accidental poisoning by ingestion of the pure chemical. In those instances, the exposed persons died from circulatory system failure [ATSDR 2001; NRC 2008]. 1,2-Dichloroethane has been detected in urban air at levels ranging from 0.1–1.5 ppb [ATSDR 2001]. The U.S. EPA considers 1,2-dichloroethane as a probable human carcinogen. ATSDR has a chronic EMEG/MRL (600 ppb) and a CREG (0.0095 ppb), while U.S. EPA has a carcinogenic SL of 0.023 ppb. TCEQ has a short-term (40 ppb) and long-term (1 ppb) AMCV for 1,2-dichloroethane in air.

Short-term exposure: The highest measured 1,2-dichloroethane concentrations were 0.67 ppb (TCEQ canisters), 0.65 ppb (industry canisters), and 22 ppb (mobile monitoring). None of the 1,2-dichloroethane levels exceed the TCEQ short-term AMCV (40 ppb). Thus ATSDR does not expect that short-term exposure to the 1,2-dichloroethane concentrations measured in Refinery Row air would cause harmful health effects.

Long-term noncancer exposure: The highest mean concentration of 0.011 ppb at any sample location was below both the ATSDR chronic EMEG/MRL and the TCEQ long-term AMCV. Thus ATSDR does not expect that long-term exposure to the 1,2-dichloroethane concentrations measured in Refinery Row air would cause harmful noncancer health effects.

Cancer risk: No available studies have identified a relationship between inhaling 1,2-dichloroethane and cancer in humans. Some studies, however, indicate that animals dosed with 1,2-dichloroethane on their skin or by gavage (i.e., orally, directly into their stomachs) have developed cancerous tumors on their skin and in many places in their bodies (e.g., stomach, circulatory system, mammary (breast) tissue, lung, liver, and kidneys) [ATSDR 2001; NRC 2008]. The U.S. EPA bases its IUR of 2.6×10^{-5} $(\mu g/m^3)^{-1}$ on a 78-week oral exposure study in which Osborne-Mendel rats and B6C3F1 mice developed various adenomas and carcinomas [NCI 1978a]. Reitz et al. (1982) found the major urinary metabolites in rats that ingested and inhaled 1,2-dichloroethane to be identical and generated in the same relative amounts, which validates the use of the oral study to estimate inhalation carcinogenicity. The cancer risks associated with various concentrations of 1,2-dichloroethane, using the U.S. EPA IUR, are in Table 27B, Appendix B.

Only 2005–2010 TCEQ canister samples detected 1,2-dichloroethane in enough samples to calculate mean concentrations. These means ranged from 0.0091–0.011 ppb—similar to the 0.0095-ppb CREG. The highest mean (0.011 ppb) corresponds to an additional cancer risk of 1.2 per 1,000,000 persons, a risk ATSDR considers very low (see Table 28B, Appendix B).

11I. 1,2-Dichloropropane

1,2-Dichloropropane is a colorless, volatile liquid with a chloroform-like odor. A wholly manufactured chemical, 1,2-dichloropropane is currently used in the United States in research and industry. Before the early 1980s, 1,2-dichloropropane was used in farming as a soil fumigant and was found in some paint strippers, varnishes, and furniture finish removers. Most of the 1,2-dichloropropane released into the environment ends up in the air or groundwater. The half-life of 1,2-dichloropropane in air is not exactly known, but it is longer than 23 days, which means that 1,2-dichloropropane can spread to areas far from where it is released [ATSDR 1989a].

Inhalation and ingestion studies have shown 1,2-dichloropropane causes effects in humans similar to those in animals. Exposure effects include [ATSDR 1989a]

- Irritation of the eyes, skin, and throat;
- Dizziness, headache, and nausea;
- Injury to the liver and kidneys;
- Anemia, coma and, ultimately, death.

ATSDR has a 1,2-dichloropropane acute (50 ppb) and intermediate (7 ppb) EMEG/MRL. U.S. EPA has an RfC (0.87 ppb) and Cal. EPA has a carcinogenic SL (0.052 ppb). TCEQ has a short-term (100 ppb) and long-term (10 ppb) AMCV. IARC designates 1,2-dichloropropane as not classifiable as a carcinogen.

Short-term exposure: 1,2-Dichloropropane was measured in the TCEQ canisters, AQP triggered canisters, and mobile monitoring groups with a maximum concentration of 26.1 ppb (triggered canisters). This maximum concentration was below the ATSDR acute EMEG/MRL (50 ppb) and TCEQ short-term AMCV (100 ppb). Thus, ATSDR does not expect that short-term exposure to the 1,2-dichloropropane concentrations in Refinery Row air would cause harmful health effects.

Long-term noncancer exposure: Because none of the sampling locations detected 1,2-dichloropropane over 20% of the time, ATSDR could not calculate means by the methods described in Appendix G. The highest 95th percentile for the TCEQ canisters group was 0.03 ppb. This 95th percentile is below the U.S.

EPA RfC and TCEQ long-term AMCV, considered health-protective for effects from long-term exposures. Thus ATSDR does not expect that long-term exposure to the 1,2-dichloropropane concentrations in Refinery Row air would cause harmful noncancer health effects.

Cancer Risk: Although no available reports have documented that 1,2-dichloropropane exposure produces cancer in humans, long-term oral exposure has produced evidence of liver cancer in mice and breast cancer in female rats. The Cal. EPA bases its IUR of 1.0×10^{-5} $(\mu g/m^3)^{-1}$ on an oral exposure study that observed an increased incidence of liver tumors in mice [NTP 1986]. A linear mathematical model was applied to the data to achieve a cancer potency factor of 0.072 $(mg/kg/day)^{-1}$. This value was converted to the IUR using exposure assumptions for inhalation rate (16 m^3/day) and body weight (80 kg). The cancer risks associated with various concentrations of 1,2-dichloropropane in air are in Table 27B, Appendix B. The highest 1,2-dichloropropane 95th percentile (0.03 ppb) results in an additional cancer risk of 1.4 in 1,000,000, which ATSDR considers very low (see Table 28B, Appendix B).

12I. Dodecane

The U.S. EPA considers dodecane a high production volume (HPV) chemical and over 1 million pounds are produced annually. Dodecane is a solvent in paint manufacturing and is also a component of various fuels [USEPA 1998a]. Neither ATSDR, U.S. EPA, ACGIH, OSHA, nor NIOSH has derived comparison or regulatory values for dodecane. The World Health Organization (WHO) has developed an RfD of 0.1 mg/kg/day for aliphatics with 9−16 carbons—a group of straight chain, unsubstituted hydrocarbons that includes dodecane [WHO 2008]. Using the U.S. EPA assumptions for breathing rate and body weight, the reference dose corresponds to air concentrations around 72 ppb for adults and 14 ppb for children [USEPA 2011a].

Dodecane was also included in the Voluntary Childrens Chemical Evaluation Program (VCCEP). In this program, U.S. EPA asked several companies to provide health effects information on manufactured or imported chemicals which, based on its intended use, could come in contact with children. The VCCEP summary describes only two relevant inhalation subchronic (90 day exposure) studies on rats. The first found a LOAEL of 1,600 ppm (or 1,600,000 ppb) for increased body weight. The second found an increase in body weight and white blood cells with a LOAEL of 540 ppm (or 540,000 ppb) [USEPA 2007]. Dodecane exposure, grouped with decane and undecane because of their similar structure and properties, was determined to be highest in occupations involving painting or Air Force base workers refueling aircraft. Dodecane has a short half-life in air (9.2 hours) and has not been deemed persistent in ambient air. Thus the VCCEP only addressed exposure scenarios that involved either indoor air pollution from new paint or occupational exposures related to painting and refueling operations. In the VCCEP summary, ambient air exposure from dodecane was considered unlikely.

Dodecane was only measured in a total of 22 triggered samples. The maximum measured concentration was 1.92 ppb at the Port Grain Elevator monitoring site in 2010. This concentration would result in total doses to adults (0.00268 mg/kg/day) and children (0.0134 mg/kg/day)—less than the WHO RfD for the class of chemicals that includes dodecane. And this measurement is several orders of magnitude below the LOEALs observed from inhalation studies in the VCCEP. Thus ATSDR does not expect that short-term and long-term exposures to the dodecane concentrations in Refinery Row air would cause harmful health effects.

13I. Furfural

Furfural is a clear, colorless liquid that is only slightly soluble in water. Furfural is a precursor to several chemicals and is used in numerous industrial processes. Due to furfural's formation during the thermal decomposition of carbohydrates, furfural is found in numerous processed food and beverage products including [Maga 1979]:

- Cocoa, coffee, tea, beer, wine, milk products;
- Fruits: grapes, cranberries, mangoes, oranges, pineapples;
- Vegetables: asparagus, broccoli, cabbage, onions, peppers;
- Potato products;
- Bread; and
- Many other food items.

Although a few studies have investigated the effects of furfural inhalation, they are limited in scope. Thus neither ATSDR, Cal. EPA, U.S. EPA nor TCEQ has developed inhalation CVs. IARC has designated furfural as not classifiable as a carcinogen.

But sufficient studies are available that investigate the effects of furfural ingestion. U.S. EPA bases its current RfD on a subchronic study of rats that observed changes in liver cells with oral doses of furfural [NTP 1981]. Using this study, U.S.EPA derived an RfD of 0.003 mg/kg/day. Given the U.S. EPA exposure assumptions of adult body weight (80 kg) and inhalation rate (16 m^3/day), the RfD corresponds to an air concentration of 15 µg/m^3 (or 3.8 ppb) [USEPA 2011a]. The same dose for children, assuming a body weight of 10 kg and an inhalation rate of 10 m^3/day, would correspond to a concentration of 3 µg/m^3 (or 0.76 ppb). This same [NTP 1981] study evaluated carcinogenicity in mice and found that oral exposure to furfural increased the incidence of liver tumors.

During mobile monitoring, furfural was detected in 2 of 18 samples, with a maximum concentration of 0.38 ppb. This corresponds to a dose of 0.0003 mg/kg/day for adults and 0.0015 mg/kg/day for children. Although children will have the highest exposure, this dose is still half of the U.S. EPA RfD. Because furfural was detected at low concentrations and in only 2 of 18 samples, ATSDR does not expect that short-term and long-term exposures would cause harmful noncancer or cancer health effects.

14I. Isoprene

Isoprene is a colorless, volatile, flammable liquid used largely in the manufacture of synthetic rubber. Isoprene has been detected in tobacco smoke, is the principal unit of natural rubber, and of naturally occurring terpenes and steroids. Isoprene is also the major endogenous hydrocarbon exhaled in human breath. In heavily forested areas, natural isoprene emissions from vegetation can reach 5 times those sourced to human activities [Wiedinmyer et al. 2001].

Studies on the health effects of isoprene inhalation are limited in humans, but animal (rat and mouse) studies observed genetic toxicity in bone marrow cells, degeneration of nasal, blood, reproductive , and hepatic cells, and increased proliferation of forestomach epithelial cells [Bogaards et al. 2001; Hurst 2007]. Developmental effects such as decreased mouse fetal body weights have also been documented [Mast et al. 1989]. TCEQ has a short-term AMCV of 20 ppb and long-term AMCV of 2 ppb.

Short-term exposure: In the Refinery Row area, isoprene did not exceed the TCEQ short-term AMCV in routine sampling from the Auto GC and TCEQ canisters groups. For episodically collected samples, two AQP triggered canister samples at two separate locations exceeded the short-term CV. The measured concentrations of 77.89 ppb in 2007 and 76.17 ppb in 2006 were found in 1 of 59 samples and 1 of 29 samples, respectively. Isoprene also exceeded the short-term CV in various mobile monitoring measurements. In 2004, isoprene exceeded the short-term CV the most often in mobile monitoring Auto GC measurements (16% of the samples), with a maximum value of 330 ppb and a 1-hour average value of 130 ppb.

The National Toxicology Program (NTP) conducted a study on the effects of isoprene inhalation on rats and mice for up to 6 months exposure. These inhalation studies showed that isoprene caused toxic effects in the testis of rats and at multiple organ sites in mice. The lowest noncancer NOAEL (found in mice) was 70 ppm (or 70,000 ppb) for nonresponsive reduction of red blood cells, decreased hind limb grip strength, nasal cell degeneration, and reductions in sperm cells [NTP 1994].

While some of the triggered canister and mobile monitoring samples exceeded the short-term CV, the isoprene concentrations measured in Refinery Row are more than two orders of magnitude below documented, noncancer effect levels [NTP 1994]. Due to the low prevalence of detection and the proximity of measured concentrations to the CV, ATSDR does not expect that short-term exposure to isoprene in Refinery Row air would cause harmful health effects.

Long-term noncancer exposure: Mean concentrations for the Auto GC and TCEQ canisters groups were more than an order of magnitude below the long-term CV. Thus ATSDR does not expect that long-term exposure to isoprene in Refinery Row air would cause harmful noncancer health effects.

Cancer Risk: The NTP isoprene study described previously also provides clear evidence of isoprene carcinogenicity in mice, particularly in the liver, lung, forestomach, and harderian gland [NTP 1994]. A separate study found also found similar carcinogenic evidence with a CEL of 70 ppm (or 70,000 ppb) [Placke et al. 1996]. While U.S. EPA and ATSDR have not developed any isoprene cancer screening values, TCEQ has developed a cancer unit risk factor (URF) of 8.1×10^{-7} $(ppb)^{-1}$, based on the 1996 Placke study.

The cancer risks associated with various isoprene concentrations, based on the TCEQ URF, are in Table 27B, Appendix B. Using the TCEQ URF and the highest site-specific mean (0.086 ppb), ATSDR calculated a 7.0×10^{-8} additional cancer risk, which is considered insignificant and below the ATSDR level of concern (see Table 28B, Appendix B).

15I. Lead

Lead is a naturally occurring, bluish-gray metal found in the earth's crust, albeit in small amounts. Various industries mine and process lead for use in batteries, ammunition, ceramic glazes, medical equipment, scientific equipment, and military equipment. At one time, lead was an additive in gasoline and paint [ATSDR 2007c].

For the general population, lead exposure occurs primarily via the oral route, with some contribution from the inhalation route. Occupational exposure is primarily by inhalation, with some contribution by the oral route. The toxic effects of lead are the same regardless of the route of entry into the body. U.S. EPA offers the following summary of health effects from lead [USEPA 2012]:

> Depending on the level of exposure, lead can adversely affect the nervous system, kidney function, immune system, reproductive and developmental systems, and the cardiovascular system. Lead exposure also affects the oxygen carrying capacity of the blood. The lead effects most commonly encountered in current populations are neurological effects in children and cardiovascular effects (e.g., high blood pressure and heart disease) in adults. Infants and young children are especially sensitive to even low levels of lead, which may contribute to behavioral problems, learning deficits, and lowered IQ.

The nervous system is the most sensitive lead exposure target. There may be no lower threshold for some of the adverse neurological effects of lead in children [USEPA 2013]. Because of the absence of any clear threshold for some of lead's more sensitive health effects, ATSDR has not established guidelines for a low or no risk lead intake dose. The Centers for Disease Control and Prevention (CDC) currently recommends taking action to reduce exposure in children with blood lead levels (BLLs) higher than 5 micrograms per deciliter (µg/dL), the 97.5th percentile for the distribution of blood lead levels of U.S. children 1–5 years old [CDC 2012].

In 1978, U.S. EPA set the NAAQS for lead in outdoor air at 1.5 µg/m^3 (as a quarterly average); but in 2008 the lead NAAQS changed to 0.15 µg/m^3 (as a rolling 3 month average). Using animal studies, the IARC has designated lead as possibly carcinogenic to humans, and the U.S. EPA has designated lead as a probable human carcinogen. DHHS considers lead to be reasonably anticipated to be a carcinogen. Cal. EPA has a carcinogenic SL of 0.03 µg/m^3 for lead acetate in air.

Short-term exposure: Lead was measured in samples from three time periods: the 1980s, pre-2005, and 2005–2010. In all, lead was detected in 579 of 1,272 samples (46%). The maximum concentration (3.03 µg/m^3) was measured in September 1980. From the pre-2005 and 2005–2010 Dona Park datasets, the maximum concentration was 0.174 µg/m^3.

As stated in Section 4.1.5 of the main text, the 1980s data are of unknown quality; thus ATSDR cannot draw definitive health conclusions from them. The OSHA PEL, NIOSH recommended exposure limit, and ACGIH TLV are all 50 µg/m^3, which is a level not believed to cause harmful effects in regularly exposed workers. To put the 1980s lead levels into perspective, ATSDR notes only that lead was detected frequently in this dataset (470 of 700 samples or 67%), and the maximum concentration detected—although above the current and previous NAAQS for lead—was an order of magnitude below the worker guideline level.

The maximum concentration from the pre-2005 and 2005–2010 Dona Park datasets (0.174 µg/m^3) is similar to the current NAAQS value (0.15 µg/m^3) and more than two orders of magnitude below the worker guideline level. The NAAQS is a rolling, 3-month average designed to protect against the most sensitive effects from lead exposure, which are neurological effects in children, including neurocognitive and neurobehavioral effects. Although the maximum value slightly exceeded the NAAQS, this occurred only once in 572 samples, which means that the rolling 3-month average is likely below the NAAQS. Thus ATSDR does not expect that short-term exposure to the lead concentrations detected in Refinery Row air would elevate BLLs.

Long-term noncancer exposure: The 1980s dataset had the highest mean (0.26 µg/m^3), which was still below the NAAQS (1.5 µg/m^3) in effect during that period. From the pre-2005 and 2005–2010 Dona Park datasets, the highest mean was 0.00243 µg/m^3—below the current NAAQS. Thus ATSDR does not expect that chronic exposure to the Refinery Row airborne lead concentrations would elevate BLLs.

Cancer Risk: Almost all of the information regarding lead exposure and cancer in humans is derived from studies of lead workers exposed to inorganic lead. These studies offer conflicting evidence and do not show definitively that lead causes cancer in humans [ATSDR 2007c]. More consistent data on lead carcinogenicity following ingestion by laboratory animals indicates lead is carcinogenic, and although the tumor location in animals might vary, the most common are renal tumors [Azar et al. 1973; Koller et al. 1985; Van Esch and Kroes 1969]. Cal. EPA has developed an IUR for lead acetate of 8.0 x 10^{-5} ($\mu g/m^3)^{-1}$. The cancer risks associated with various concentrations of lead based on this IUR are in Table 27B, Appendix B.

For the Refinery Row-Dona Park datasets, the highest mean measured (0.00243 $\mu g/m^3$) is more than an order of magnitude below the carcinogenic SL. In addition, NATA predicts that the concentration of lead in Nueces County, where Refinery Row is located, is 0.000086 ppb (or 0.00073 $\mu g/m^3$) (see Table 1J, Appendix J) [USEPA 2011c]. Calculations using the highest mean and Cal. EPA IUR result in an additional cancer risk of 1.9 in 10,000,000, which ATSDR considers insignificant (see Table 28B, Appendix B).

16I. Pentene Isomers (1-pentene, c-2-pentene, t-2-pentene, 2-methyl-2-butene, 3-methy-1-butene)

Pentene isomers are generally part of hydrocarbon mixtures and rarely purified for individual use. As a byproduct of the petroleum industry, pentenes might be present in various fuels. 1-Pentene, c-2-pentene, t-2-pentene, and 2-methyl-2-butene all have a TCEQ short-term AMCV of 2,600 ppb. The only pentene isomer measured with a long-term CV is 3-methyl-1-butene, which has a TCEQ short-term (8,000 ppb) and long-term (800 ppb) AMCV. Very few studies have investigated the long-term effects of the other pentene isomers. Thus other, similar chemicals with known toxicity data serve as surrogates for pentene-specific toxicity data.

WHO recommends assessing health effects from petroleum hydrocarbons by grouping together a range of similar hydrocarbons based on the number of carbons and on chemical structure [WHO 2008]. Isomers and similar chemicals might have varying toxicity levels. For a conservative risk assessment, the most toxic isomer or chemical in the group often represents the whole. WHO states the following in its assessment of petroleum oils in drinking water [WHO 2008]:

> In general terms, alkanes have relatively low toxicity, but those with five or more carbons have strong narcotic properties, particularly following inhalation exposure to high concentrations, and exposure to high concentrations of n-hexane may lead to irreversible effects on the nervous system. Alkenes exhibit little toxicity other than weak anesthetic properties.

Pentenes are alkene hydrocarbons with five carbons and one double bond. Using the fractions of hydrocarbons described in the WHO guidelines for drinking water, pentenes would be grouped with aliphatic (i.e., straight chain) hydrocarbons with 5−8 carbons [WHO 2008]. WHO based the toxicity of this group of compounds on that of commercial n-hexane, which is the most toxic compound in this group. Commercial n-hexane is actually a mixture of hexane isomers and contains 53% n-hexane. The ATSDR chronic EMEG/MRL for n-hexane is 600 ppb, and the U.S. EPA RfC is 200 ppb. TCEQ has a short-term (1,800 ppb) and long-term (190 ppb) AMCV for n-hexane in air.

1-Hexene is also a similar compound to 1-pentene which, using the WHO fractions, would be grouped with 1-pentene. Of all of the compounds in this group, 1-hexene has the lowest CVs, which results in the most conservative risk assessment. TCEQ has a short-term (500 ppb) and long-term (50 ppb) AMCV for 1-hexene in air.

In this public health evaluation, ATSDR sums together the concentrations of the following pentene isomers (when available) to estimate the potential health effects due to exposure to all pentenes: 1-pentene, c-2-pentene, t-2-pentene, 2-methyl-2-butene, and 3-methyl-1-butene.

Short-term exposure: The sum of the maxima of the pentene isomers was highest in the AQP triggered canister samples (387.37 ppb), despite the fact that only 1-pentene and 2-methyl-2-butene were measured. The maxima of both of these isomers occurred at the JI Hailey monitoring site, away from residential areas, on the same day in 2007—possibly indicating a fugitive release in the area. In the TCEQ canister and mobile monitoring groups, the only groups in which all isomers were measured, the sums of the maxima were 115.74 ppb and 268.7 ppb, respectively. The mobile monitoring maxima were measured at different times, thus offering a conservative value for the maximum concentration of pentenes in air that someone might encounter in Refinery Row.

The highest sum of the maxima for all pentene isomers (387.37 ppb) is below the 2,600-ppb TCEQ short-term AMCV for 1-pentene, c-2-pentene, t-2-pentene, and 2-methyl-2-butene and below the 8,000-ppb short-term AMCV for 3-methyl-1-butene. This highest sum is also below the more conservative 1,800-ppb short-term AMCV for n-hexane and the 500-ppb short-term AMCV for 1-hexene. Thus ATSDR does not expect that short-term exposure to pentene isomer concentrations in Refinery Row air would cause harmful health effects.

Long-term noncancer exposure: For the TCEQ canisters group, the highest sum of the pentene isomers means is 2.68 ppb. That highest sum of the means is over two orders of magnitude below the less conservative, long-term 800-ppb AMCV for 3-methyl-1-butene. ATSDR also compares the highest sum of the means with the more conservative long-term CVs for n-hexane and 1-hexene, which are more toxic and should allow for a more conservative risk estimation. The highest sum of the pentene means is more than an order of magnitude below the n-hexane chronic EMEG/MRL (600 ppb), RfC (200 ppb), and long-term AMCV (190 ppb), as well as the 1-hexene long-term AMCV (50 ppb). Thus ATSDR does not expect that long-term exposure to pentene isomer concentrations in Refinery Row air would cause harmful noncancer health effects.

Cancer Risk: Available human or animal studies data are insufficient to show the potential for any of the pentene isomers to cause cancer. Furthermore, U.S. EPA considers information regarding n-hexane—one potential surrogate for pentene toxicity—inadequate to assess carcinogenic potential. Thus ATSDR does not expect that concentrations of pentene isomers in Refinery Row air would increase the risk of cancer.

17I. 1,1,2,2-Tetrachloroethane

1,1,2,2-Tetrachloroethane is a synthetic, colorless, dense liquid that does not burn easily. It has a penetrating, sweet odor similar to chloroform. In the past, industry used large amounts of 1,1,2,2-tetrachloroethane to produce other chemicals and as an industrial solvent. 1,1,2,2-Tetrachloroethane was also used to separate fats and oils from other substances, to clean and degrease metals, and in paints and pesticides. Because less toxic chemicals are now available, 1,1,2,2-tetrachloroethane is no longer commercially produced on a large scale. It remains in use as a chemical intermediate, but information is limited about this use. Present sources are largely attributable to fugitive emissions or discharges when 1,1,2,2-tetrachloroethane is generated as a byproduct and to emissions or discharges stemming from its production and use as a chemical intermediate [ATSDR 2008].

Most 1,1,2,2-tetrachloroethane released into the environment eventually moves into the air or groundwater. Although data from human studies are limited, animal studies have shown that after inhalation or oral exposure or both, the central nervous system and liver are the most sensitive targets of 1,1,2,2-tetrachloroethane toxicity. TCEQ has a short-term (10 ppb) and long-term (1 ppb) AMCV, and Cal. EPA has a carcinogenic SL of 0.0061 ppb.

Short-term exposure: Maximum 1,1,2,2-tetrachloroethane values are one to two orders of magnitude below the TCEQ short-term AMCV of 10 ppb. Thus ATSDR does not expect that short-term exposure to 1,1,2,2-tetrachloroethane levels in Refinery Row air would result in harmful health effects.

Long-term noncancer exposure: Because 1,1,2,2-tetrachloroethane was detected in less than 20% of the samples at any TCEQ canister sampling location, mean values could not be calculated following the procedures outlined in Appendix G. The highest 1,1,2,2-tetrachloroethane 95th percentile value from TCEQ stationary air monitors is 0.01 ppb, which is generally a higher estimate than the mean. The 1,1,2,2-tetrachloroethane 95th percentile value of 0.01 ppb is two orders of magnitude below the TCEQ long-term AMCV. Thus ATSDR does not expect that long-term exposure to concentrations of 1,1,2,2,-tetrachloroethane in Refinery Row air would cause harmful noncancer health effects.

Cancer risk: Although the U.S. EPA determined that 1,1,2,2-tetrachloroethane is likely a human carcinogen, the IARC determined its human carcinogenicity potential is not classifiable. Thus far, only Cal. EPA has developed an IUR for 1,1,2,2-tetrachloroethane: 5.8×10^{-5} $(\mu g/m^3)^{-1}$. Inhalation exposure has been documented to cause noncancer effects, but the database lacks a study that shows a dose-related carcinogenic effect level following subchronic or chronic 1,1,2,2-tetrachloroethane inhalation exposure. The Cal. EPA based its IUR on a 1978 National Cancer Institute (NCI) study that found oral exposure to significantly increase the incidence of hepatocellular carcinomas in mice [NCI 1978b]. Using the Cal. EPA IUR, the cancer risks associated with various concentrations of 1,1,2,2-tetrachloroethane, are in Table 27B, Appendix B. The 95th percentile of the TCEQ canister samples, 0.01 ppb, exceeds the Cal. EPA carcinogenic SL of 0.0061 ppb. The 95th percentile results in 4.0 additional cases of cancer per 1 million persons, a risk that ATSDR considers very low (see Table 28B, Appendix B).

18I. Toluene

Toluene is a clear, colorless liquid with a distinctive smell. Toluene is a good solvent; that is, a substance that dissolves other substances. Toluene occurs naturally in crude oil and in the tolu tree. It is produced in the process of making gasoline and other fuels from crude oil, in making coke from coal, and as a by-product in the manufacture of styrene. Toluene is used in making paints, paint thinners, fingernail polish, lacquers, adhesives, and rubber and in some printing and leather tanning processes [ATSDR 2000]. Toluene does not stay in the environment for long [ATSDR 2000].

ATSDR has an acute (1,000 ppb) and chronic (80 ppb) EMEG/MRL, while U.S. EPA has an RfC (1,300 ppb). TCEQ has a short-term (4,000 ppb) and long-term (1,100 ppb) AMCV. IARC deems toluene unclassifiable as a carcinogen. U.S. EPA has determined that available information is inadequate to assess toluene's carcinogenicity.

Short-term exposure: Short-term toluene exposure effects include irritation of the eyes and nose, as well as headaches, dizziness, and intoxication-like feelings. The ATSDR acute EMEG/MRL is based on a human study that observed adverse neurological effects such as dizziness, headaches and intoxication with a LOAEL of 100 ppm (or 100,000 ppb) and a NOAEL of 40 ppm (or 40,000 ppb) [Andersen et al. 1983]. ATSDR adjusted the NOAEL to reflect continuous exposure (9.5 ppm) then divided by an uncertainty factor of 10 for human variability to achieve the acute EMEG/MRL of 1 ppm (or 1,000 ppb).

Toluene was measured in five groups—Auto GC, TCEQ canister, industry canister, AQP triggered canister, and mobile monitoring. Toluene did not exceed the acute EMEG/MRL in any samples from the first four groups, but did exceed this CV in 3 of 1,519 samples from mobile monitoring (0.2%), with a maximum detected concentration of 1,300 ppb. Although three values exceed the ATSDR acute EMEG/MRL, they are below and equal to the RfC, which U.S. EPA considers a concentration to which a person can be exposed for a lifetime without adverse effects. All toluene levels are below the TCEQ short-term AMCV. Because toluene rarely exceeded the acute EMEG/MRL, did not exceed the RfC or short-term AMCV, and was more than an order of magnitude below the NOAEL, ATSDR does not expect that short-term exposure to toluene concentrations in Refinery Row ambient air would result in harmful health effects.

Long-term noncancer exposure: In the Auto GC and industry canisters groups, toluene was detected in almost 100% of the samples, with 4.5 ppb as the highest mean. But that highest mean did not exceed the ATSDR chronic EMEG/MRL (80 ppb), the U.S. EPA RfC (1,300 ppb), or the TCEQ long-term AMCV (1,100 ppb), all of which are intended to be protective over a lifetime of exposure. Thus ATSDR does not expect that long-term exposure to toluene concentrations in Refinery Row ambient air would cause harmful noncancer health effects.

19I. 1,1,2-Trichloroethane

1,1,2-Trichloroethane is a colorless, sweet-smelling liquid mostly used as a solvent. Information is largely unknown about how much industry manufactures and how it is used. 1,1,2-Trichloroethane possibly forms in landfills when 1,1,2,2-tetrachloroethane breaks down. When 1,1,2-trichloroethane releases into the environment, most of it ends up in the air; some, however, might enter groundwater. Breakdown is slow in both the air and groundwater. In the air, half the 1,1,2-trichloroethane is expected to breakdown in 49 days, so before breakdown, it is likely to spread far from where it released [ATSDR 1989b].

Because industries that produce or use 1,1,2-trichloroethane often recycle or burn their waste, releases of 1,1,2-trichloroethane from these industries should not be a major pollution source. Surveys of industrial wastewater show that some of the industries that discharge 1,1,2-trichloroethane are the timber products industry, plastics and synthetics industry, and laundries.

ATSDR has a 1,1,2-trichloroethane CREG value of 0.011 ppb. U.S. EPA has an RfC (0.037 ppb) and a carcinogenic SL of 0.027 ppb. TCEQ has a short-term (100 ppb) and long-term (10 ppb) AMCV for 1,1,2-trichloroethane. Although the IARC designates 1,1,2-trichloroethane as unclassifiable as a carcinogen, U.S. EPA using limited animal studies deems 1,1,2-trichloroethane a possible human carcinogen.

Short-term exposure: In the Refinery Row area, the chemical was measured in the TCEQ canisters and mobile monitoring groups. The highest measured concentration was 3.5 ppb (mobile monitoring)—below the TCEQ short-term AMCV (100 ppb), which is considered protective against health effects from short-term exposures. Thus ATSDR does not expect that short-term exposure to 1,1,2-trichloroethane concentrations in Refinery Row air would cause harmful health effects.

Long-term noncancer exposure: Because none of the sampling locations detected 1,1,2-trichloroethane over 20% of the time, means could not be calculated by the methods described in Appendix G. And because this chemical was detected in fewer than 5% of the samples at each location, the 95th percentile represents a nondetected value. Thus ATSDR used the reporting limit of VOCs in TCEQ canisters (0.01 ppb) divided by the square root of 2 as the concentration by which to assess long-term noncancer health effects and cancer risk. The resulting 0.007-ppb concentration is below the 0.037-ppb RfC.

In addition, NATA models predict the 1,1,2-trichloroethane concentration in Nueces County, where Refinery Row is located, is 2.38 x 10^{-5} ppb (see Table 1J, Appendix J) [USEPA 2011c]. Both the NATA modeled data and the measured TCEQ canister data suggest average concentrations below the RfC. Thus ATSDR does not expect that long-term exposure to 1,1,2-trichloroethane concentrations in Refinery Row ambient air would cause harmful noncancer health effects.

Cancer Risk: Although mice chronically exposed most of their lives to high doses of 1,1,2-trichloroethane by mouth developed liver cancer, human cancer effects have not been documented. U.S. EPA based its IUR of 1.6 × 10^{-5} $(\mu g/m^3)^{-1}$ on a chronic oral study that found an increase in liver cancer in mice given 1,1,2-trichloroethane via gavage for 78 weeks [USEPA 1991; NCI 1978c]. The cancer risks associated with various concentrations of 1,1,2-trichloroethane in air are in Table 27B, Appendix B.

As previously stated, because of the very low rate of detection, to assess cancer risk ATSDR used the reporting limit divided by the square root of 2 (0.007 ppb). This value results in an additional cancer risk of 6.1 in 10,000,000, which ATSDR considers insignificant (see Table 28B, Appendix B). The additional risk using the NATA-predicted concentration would be 3.8 x 10^{-10}, which ATSDR also considers insignificant.

20I. Trichloroethylene

Trichloroethylene is a solvent used to remove grease from metals, and in paint removers, adhesives, and spot removers [ATSDR 2003]. The background levels of trichloroethylene in indoor air range from nondetect to a maximum of 134 ppb, with the 95 percentile range from 0.104–0.61 ppb [USEPA 2011b]. Trichloroethylene is a volatile chemical and easily evaporates when exposed to air. Once the vapors are in the air, within a week about half break down [ATSDR 1997b]. For this chemical, TCEQ has a short-term (100 ppb) and long-term (10 ppb) AMCV, ATSDR has a chronic EMEG/MRL of 0.40 ppb and CREG value of 0.045 ppb, and the U.S. EPA has a chronic RfC of 0.37 ppb and carcinogenic SL of 0.08 ppb.

Short-term exposure: For the TCEQ canisters, industry canisters and mobile monitoring groups, none of the detected samples were above the TCEQ short-term AMCV of 100 ppb. Thus ATSDR does not expect that short-term exposure to trichloroethylene concentrations in Refinery Row air would result in harmful health effects.

Long-term noncancer exposure: In all, 13.6% of the TCEQ canister samples contained trichloroethylene, as did 15% of the industry canister samples. The highest trichloroethylene mean was 0.055 ppb at Navigation (a neighborhood area), which is almost an order of magnitude below the ATSDR EMEG/MRL and U.S. EPA RfC. As such, ATSDR does not expect that long-term exposures to the trichloroethylene levels detected in the air along Refinery Row would result in harmful noncancer health effects.

Cancer risk: Using limited evidence of carcinogenicity from human studies, sufficient evidence of carcinogenicity from experimental animals studies, and information from carcinogenesis mechanism studies, DHHS reasonably anticipates that trichloroethylene is a human carcinogen [NTP 2011]. U.S. EPA uses increased risks of kidney cancer, with more limited evidence for non-Hodgkin lymphoma and liver cancer, to classify trichloroethylene as carcinogenic to humans [USEPA 2011d]. The U.S. EPA IUR is 4.1×10^{-6} $(\mu g/m^3)^{-1}$. The cancer risk associated with various concentrations of trichloroethylene are in Table 27B, Appendix B. The highest, 0.055-ppb mean concentration slightly exceeds the ATSDR CREG value of 0.045 ppb. ATSDR's calculated cancer risk estimate results in 1.2 additional cancer cases per 1,000,000 persons, a risk which ATSDR considers very low (see Table 28B, Appendix B).

21I. Vinyl Chloride

Vinyl chloride is anthropogenic; that is, vinyl chloride is purely of human origin. It is typically a sweet-smelling, colorless gas used in the manufacture of PVC products. A variety of plastic products incorporate PVC including pipes, wire and cable coatings, and packaging materials. Other uses include furniture and automobile upholstery, wall coverings, housewares, and automotive parts. At one time, vinyl chloride was used as a coolant, as a propellant in spray cans, and in some cosmetics. Since the mid-1970s, however, vinyl chloride has been used mostly in PVC manufacture [ATSDR 2006]. Vinyl chloride can also be formed in the environment when, under anaerobic (i.e., oxygen-poor) conditions, certain microorganisms break down other manufactured substances, such as trichloroethylene, trichloroethane, and tetrachloroethylene in groundwater [Smith and Dragun 1984; Vogel et al. 1987].

ATSDR has an acute (500 ppb) and intermediate (30 ppb) EMEG/MRL, and a CREG value (0.044 ppb) for vinyl chloride. U.S. EPA has an RfC (39 ppb) and a carcinogenic SL (0.063 ppb). TCEQ has a short-term (26,000 ppb), a noncancer long-term (23 ppb), and a carcinogenic long-term (0.45 ppb) AMCV for vinyl chloride. DHHS, IARC and U.S. EPA have all designated vinyl chloride as a human carcinogen.

Short-term exposure: Vinyl chloride was measured in the TCEQ canisters and mobile monitoring groups. The highest measured concentration was 11.6 ppb (mobile monitoring)—well below the ATSDR acute EMEG/MRL and TCEQ short-term AMCV. Thus ATSDR does not expect that short-term exposure to vinyl chloride concentrations in Refinery Row air would cause harmful health effects.

Long-term noncancer exposure: Because none of the TCEQ sampling locations detected vinyl chloride over 20% of the time, ATSDR could not calculate means by the methods described in Appendix G and instead used the highest 95th percentile from the TCEQ canisters (0.059 ppb) to assess the potential for chronic health effects. The highest 95th percentile did not exceed the U.S. EPA RfC and TCEQ's noncancer, long-term AMCV. Thus ATSDR does not expect that long-term exposure to vinyl chloride concentrations in Refinery Row air would cause harmful noncancer health effects.

Cancer Risk: Occupational studies of vinyl chloride workers in the 1970s [Creech and Johnson 1974; Heath et al. 1975; Fox and Collier 1977] demonstrated a link between chronic occupational exposure to high vinyl chloride levels in the air in an enclosed environment (estimated vinyl chloride concentrations of several thousand parts per million) and the development of hepatic angiosarcoma, a rare and fatal form of liver cancer. Additional occupational studies in the vinyl chloride industry indicated less conclusively any association between exposures to high vinyl chloride vapor levels or PVC dust and the development of cancers of the brain, lungs, and digestive tract [Wagoner et al. 1980; Wong et al. 1991]. The U.S. EPA IUR of 8.8×10^{-6} $(\mu g/m^3)^{-1}$ is based on studies that observed various cancers of the liver in female rats following inhalation of vinyl chloride [Maltoni et al. 1981, 1984; USEPA 2000]. The cancer risks associated with various concentrations of vinyl chloride in air are in Table 27B, Appendix B. The highest 95th percentile from the TCEQ canisters (0.059 ppb) exceeds the CREG and results in an additional cancer risk of 1.3 in 1,000,000, a risk ATSDR considers very low (see Table 28B, Appendix B).

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Appendix J. National-Scale Air Toxics Assessment

1J. Summary

The following description of the National-Scale Air Toxics Assessment (NATA) was compiled from the NATA overview on the U.S. Environmental Protection Agency's (U.S. EPA's) Web site available at http://www.epa.gov/ttn/atw/natamain/index.html [USEPA 2013].

NATA is U.S. EPA's ongoing, comprehensive evaluation of air toxics in the United States. U.S. EPA developed the NATA as a state-of-the-science screening tool for State/Local/Tribal Agencies. This screening tool helps to prioritize pollutants, emission sources, and locations of interest for further study and to gain a better understanding of risks. NATA assessments do not incorporate refined information about emission sources. Rather, the assessments use general information about sources to develop risk estimates more likely to overestimate effects than to underestimate them. NATA data provides a snapshot of the outdoor air quality and the risks to human health that would result were air toxic emissions levels to remain unchanged.

The NATA assessments help guide efforts to cut toxic air pollution and to build on the already significant emissions reductions achieved in the United States since 1990. NATA informs national, state, and local efforts to collect air toxics information, characterize emissions, and help prioritize pollutants/geographic areas of interest for more refined data collection and analyses. The overall goal is to identify those air toxics of greatest potential concern in terms of population risk. In each state, ambient and exposure concentrations and risk-and-hazard estimates for air toxics are typically generated at the census tract level.

Computer models digest a single year of emissions data to yield concentration and risk estimates. These estimates reflect chronic exposures resulting from the inhalation of the air toxics emitted. But the estimates do not consider exposures that might occur indoors or as a result of exposures other than inhalation (i.e., dermal or ingestion).

Data interpretation is affected by NATA limitations, which must be kept in mind. The interpretation results should only be used to address questions for which the assessment methods are suited. Consequently, NATA assessments should not be used

- As a sole means for identifying localized hotspots[56]
- As a definitive means by which to pinpoint specific risk values within a census tract
- To characterize or compare risks at local levels, such as between neighborhoods
- As the sole basis for developing risk reduction plans or regulations
- To control specific sources or pollutants
- To quantify benefits of reduced air toxic emissions

For several carcinogenic chemicals detected in Refinery Row air, Table 1J shows the 2005 NATA estimated average concentrations for the United States, Texas, and Nueces County, as well as the Agency for Toxic Substances and Disease Registry (ATSDR) cancer risk evaluation guide (CREG)

[56] For analysis of air toxics in these smaller areas, other tools such as monitoring and local-scale assessments should be used to evaluate potential hot spots using more refined and localized data.

comparison value and the highest mean value of these chemicals in Refinery Row air. Four chemicals (arsenic, benzene, chloroform, and chromium) have CREG values about an order of magnitude[57] below the United States average, and thus in outdoor air these contaminants are expected regularly to exceed the CREG value. The CREG values of several other chemicals (1,3-butadiene, carbon tetrachloride, and naphthalene) are similar to or slightly less than the United States average levels.

Table 1J. Chemical Levels estimated in United States, Texas, Nueces County and Refinery Row Outdoor Air Compared with the ATSDR CREG (2 pages)

Chemical	*United States Average Level (ppb)*	*Texas Average Level (ppb)*	*Nueces County Average Level (ppb)*	*ATSDR CREG* Value (ppb)*	*Highest Refinery Row Outdoor Air Mean Level (ppb)*
Arsenic	0.000189	0.000147	8.81×10^{-5}	7.5×10^{-5}	0.00035
Benzene	0.332	0.293	0.293	0.04	2.21
1,3-butadiene	0.0316	0.0262	0.019	0.015	0.076
Cadmium	2.83×10^{-5}	1.50×10^{-5}	9.72×10^{-6}	0.00012	0.0013†
Carbon tetrachloride	0.0971	0.0971	0.0971	0.026	0.11
Chloroform	0.0195	0.018	0.016	0.0089	0.017
Chloroprene	0.000108	4.25×10^{-6}	2.20×10^{-6}	0.00091	0.007§
Chromium¶	0.000442	0.000254	0.000564	3.9×10^{-5}	0.00082
Cobalt	2.5×10^{-5}	6.2×10^{-6}	2.7×10^{-6}	4.6×10^{-5}	0.00028†
Lead	0.00028	0.0002	8.6×10^{-5}	0.0023‡	0.00029
Naphthalene	0.0135	0.0061	0.00382	0.014‡	0.058
1,1,2,2-Tetrachloroethane	0.00058	0.00055	0.00047	0. 0061‡	0.01†
1,1,2-Trichloroethane	0.000121	2.02×10^{-5}	2.38×10^{-5}	0.011	0.007§
Trichloroethylene	0.0149	0.00726	0.00409	0.045	0.055
Vinyl Chloride	0.00145	0.0016	0.000743	0.044	0.059†

Source: US Environmental Protection Agency. 2011. 2005 National-scale air toxics assessment. Made public 11 March 2011. Available at: http://www.epa.gov/ttn/atw/nata2005/.

[57] "Order of magnitude" refers to an estimate of size or magnitude expressed as a power of ten. An increase of one order of magnitude is the same as multiplying a quantity by 10, an increase of two orders of magnitude equals multiplication by 100, an increase of three orders of magnitude is equivalent of multiplying by 1000, and so on. Likewise, a decrease of one order of magnitude is the same as multiplying a quantity by 0.1 (or dividing by 10), a decrease of two orders of magnitude is the equivalent of multiplying by 0.01 (or dividing by 100), and so on.

* ATSDR develops CREGs using the U.S. Environmental Protection Agency's inhalation unit risk and a target risk level (10^{-6}). The target risk level of 10^{-6} represents a possible risk of one excess cancer case in a population of one million.

† A mean value could not be calculated because the detection rate for this chemical was ≤20%. The highest 95th percentile was used in absence of the mean.

‡ The value provided is a California Environmental Protection Agency carcinogenic screening level, not the CREG.

§ A mean value could not be calculated because the detection rate for this chemical was ≤20%. Additionally, because the chemical was detected in less than 5% of the samples, the 95th percentile represents a nondetect value. As a result, ATSDR used the method reporting limit divided by the square root of two.

¶ CREG provided is for hexavalent chromium and highest Refinery Row air mean level provided is from the Dona Park dataset.

ATSDR Agency for Toxic Substances and Disease Registry
CREG cancer risk evaluation guide
ppb parts per billion

2J. References

[USEPA] US Environmental Protection Agency. 2013. National air toxics assessments. Webpage last updated 22 February 2013. Available at: www.epa.gov/ttn/atw/natamain/index.html.

[USEPA] US Environmental Protection Agency. 2011. 2005 National-scale air toxics assessment. Made public 11 March 2011. Available at: http://www.epa.gov/ttn/atw/nata2005/.

Appendix K. Additional Assessment of Benzene Exposure

The Agency for Toxic Substances and Disease Registry (ATSDR) performed physiologically-based pharmacokinetic (PBPK) modeling to develop a more complete picture of benzene exposures at the Corpus Christi Refinery Row site in Texas. ATSDR applied PBPK modeling to data from the Huisache stationary air monitor (2005–2009), a 2010 exposure investigation (EI) in Refinery Row, the National Health and Nutrition Examination Survey (NHANES), and the critical toxicological study used in the derivation of the chronic minimal risk level (MRL). ATSDR used PBPK modeling to calculate

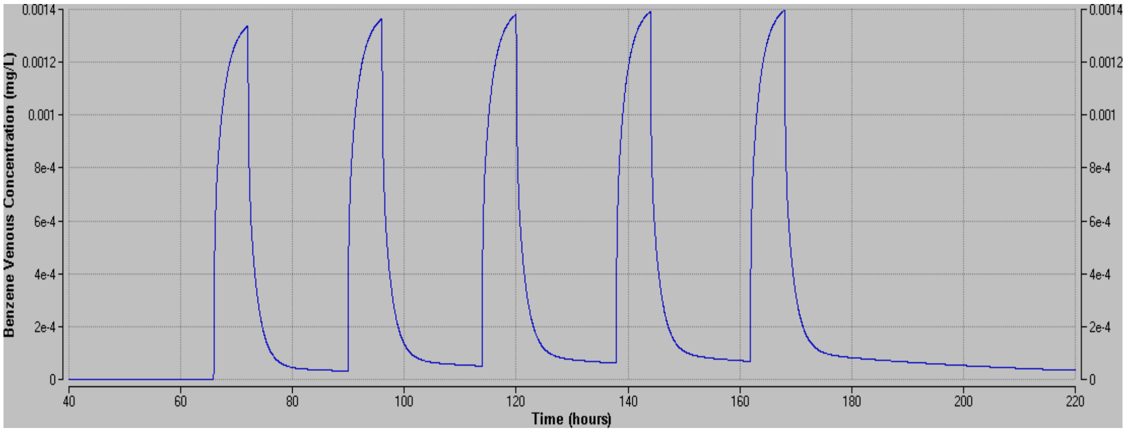
1. The blood benzene levels corresponding to documented occupational exposures in the critical study used for derivation of the chronic MRL.
2. The blood benzene level corresponding to continuous exposure at the chronic MRL.
3. The blood benzene levels corresponding to monthly benzene air concentrations detected at the Huisache stationary air monitor from 2005–2009.
4. The cumulative amount of benzene metabolized for the different exposure scenarios described in the previous three points.
5. The predicted blood benzene levels, called biomonitoring equivalents (BEs), that correspond to ambient air health-based noncancer comparison values (CVs).
6. The concentration of benzene in air that corresponds to blood benzene levels measured in the 2010 EI in Refinery Row.

1K. PBPK modeling of benzene air exposures

ATSDR used a PBPK model developed by Jeff Fisher in Berkeley Madonna from the original model developed by Yokley et al. (2006) [Ruiz et al. 2011; Mumtaz et al. 2012a, 2012b]. PBPK modeling of benzene exposure compared predicted internal doses from 1) occupational benzene exposures leading to minimal adverse noncancer health effects, 2) continuous exposure to benzene at the ATSDR chronic MRL, and 3) ambient air exposure levels of benzene reported at the Huisache stationary air monitor in Corpus Christi. Comparing exposure scenarios is of interest because the half-life for benzene is very short, and the internal dose varies with inhalation exposure concentration, frequency, and duration. The rate of benzene excretion is greatest during the first hour, and is followed by two or three slower phases [ATSDR 2007].

Figure 1K shows the predicted benzene blood concentration resulting from an occupational exposure, which is based on 8 hours exposure at work and 16 hours nonexposure off work each day, repeating for a 5-day work week. A 48-hour nonexposure weekend follows each work week. This pattern continues for 6 years of exposure. The occupational exposure scenario is based on data collected and reported by Lan et al. (2004). Lan and colleagues' occupational study is the basis for ATSDR's chronic inhalation MRL.

Figure 1K. Benzene Blood Concentrations Resulting from an Occupational Exposure*

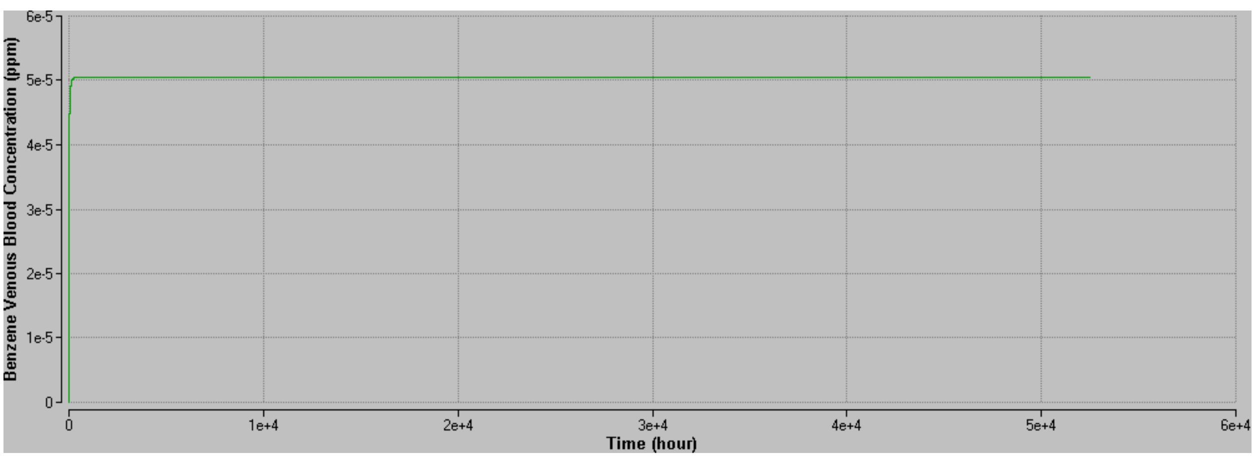


* Benzene blood concentrations from occupational air exposures of 0.1 parts per million[58] in adults are predicted by a PBPK model. The occupational exposure resulted in adverse health effects in the study and is the basis for ATSDR's chronic inhalation minimal risk level.

ATSDR Agency for Toxic Substances and Disease Registry
mg/L milligrams per liter
PBPK physiologically-based pharmacokinetic

Figure 2K shows the predicted benzene blood concentration resulting from an exposure to the chronic inhalation MRL benzene level of 3 parts per billion (ppb), which assumes continuous exposure and hence a steady-state straight line for a 6-year exposure.

Figure 2K. Benzene Blood Concentration Resulting from a Continuous Exposure Scenario*



* A PBPK model predicts benzene blood concentration in an adult male from a continuous air exposure at ATSDR's chronic inhalation minimal risk level (0.003 ppm).

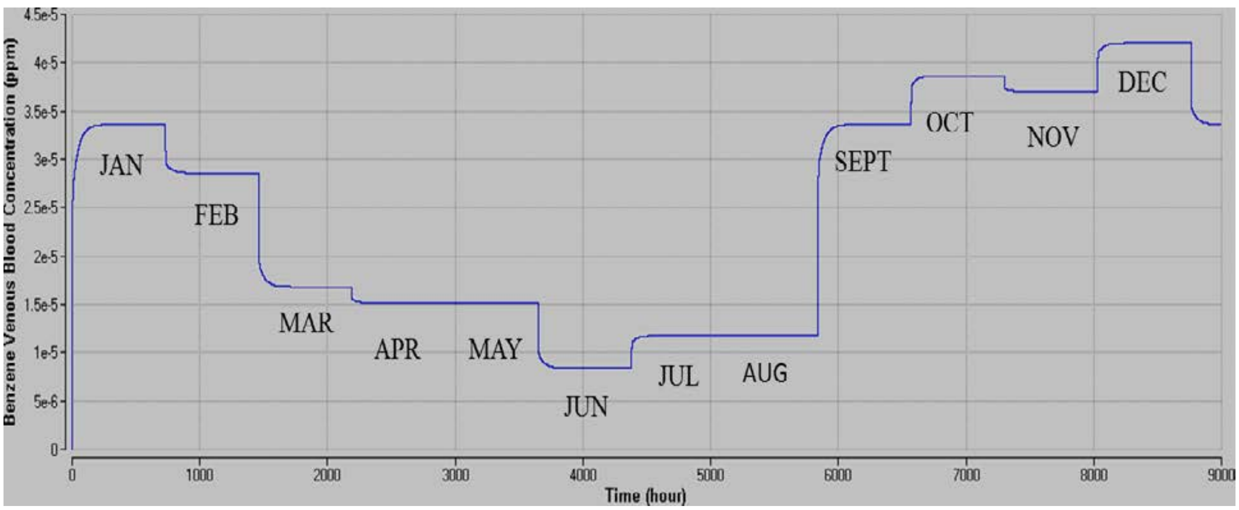
ATSDR Agency for Toxic Substances and Disease Registry
ppm parts per million

[58] Note, 1 part per million (ppm) = 1 milligram per liter (mg/L) = 1,000 nanograms per milliliter (ng/mL).

Figure 3K shows the predicted benzene blood concentrations resulting from Refinery Row exposures. Blood concentrations vary monthly with a specified benzene concentration and assume continuous exposure to this concentration for the month. This pattern repeats for the 6-year exposure. Refinery Row area exposures are based on a statistical trend analysis of ambient air benzene concentrations and on meteorological data collected at the Huisache stationary air monitor.

The Huisache monitor was selected because it reported the highest ambient air benzene concentrations. Of note, the information presented in this benzene appendix for the Huisache stationary air monitor is for data collected from 2005–2009. Huisache data for other years evaluated in this public health report (i.e., pre-2005 and 2010) were not available at the time ATSDR ran the PBPK model simulations. Although ATSDR used a smaller dataset for this appendix, these Huisache data are considered representative of current exposure.

Figure 3K. Benzene Blood Concentrations Resulting from a Residential Monthly Exposure Scenario*



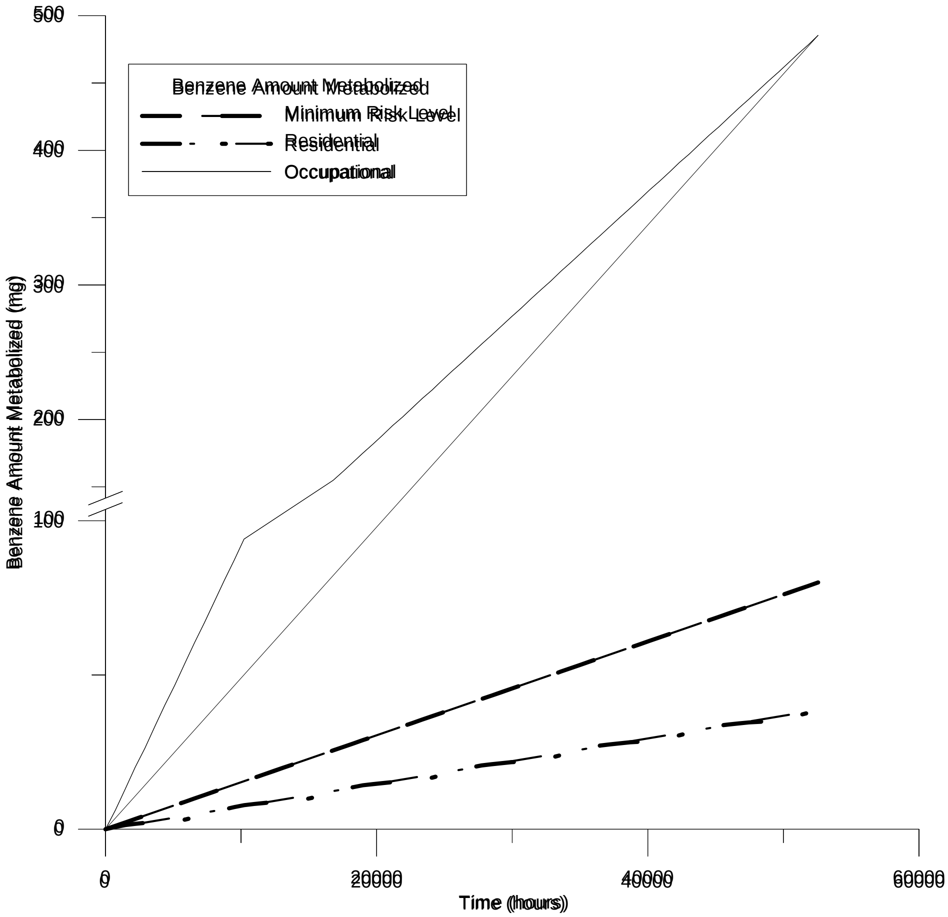
* Residential monthly air exposure identified by trend analysis of ambient air benzene data from the Huisache stationary air monitor, which represents the highest ambient air benzene concentrations during 2005–2009. The trend analysis for average benzene concentrations is identified by individual month. Average benzene exposure concentrations in ppm by month are as follows: Jan = 0.002, Feb = 0.0017, Mar = 0.001, Apr = 0.0009, May = 0.0009, Jun = 0.0005, Jul = 0.0007, Aug = 0.0007, Sep = 0.002, Oct = 0.0023, Nov = 0.0022, Dec = 0.0025.

ppm parts per million

Overall, Refinery Row exposures to ambient air benzene levels vary by season and month, and PBPK modeling allows ATSDR to account for this variation.

The most sensitive health endpoint for benzene toxicity is hematological effects mediated by benzene metabolites. Therefore, the dose metric selected for the internal dose comparison is the cumulative amount of benzene metabolized. While Figures 1K, 2K, and 3K show predicted benzene blood concentrations resulting from the individual exposure scenarios used in the PBPK modeling, Figure 4K depicts the predicted cumulative amount of benzene metabolized during each exposure scenario. PBPK modeling suggests that the occupational exposure resulted in 400-fold more benzene metabolized than benzene metabolized at the MRL level of exposure, and about 800-fold more than the Refinery Row residential exposure (see Figure 4K). The predicted benzene metabolized during continuous exposure at the MRL is 2-fold greater than during the Refinery Row residential exposure.

Figure 4K. Total Amount of Benzene Metabolized for Different Exposure Scenarios*



* PBPK modeling predicts the total amount of benzene metabolized for different exposure scenarios during a 6-year exposure duration. Note, the scale for the benzene amount metabolized changes after 100 milligrams. The exposure scenarios are

1. Minimal Risk Level = continuous air exposure at ATSDR's chronic inhalation minimal risk level of 0.003 ppm
2. Residential = monthly air exposure identified by trend analysis of ambient air benzene data from the Huisache stationary air monitor
3. Occupational = workday air exposure of 0.1 ppm identified during an occupational study

ATSDR Agency for Toxic Substances and Disease Registry
mg milligrams
ppm parts per million

These results are not meant to be predictive of harmful health effects; they are only meant to describe levels of predicted benzene metabolized according the different exposure scenarios. After accounting for monthly and seasonal variation in ambient air exposures, these results suggest that the internal dose of benzene metabolized from Refinery Row residential exposure is 1) less than the internal dose of benzene metabolized at the chronic inhalation MRL level of exposure, and 2) much less than the occupational level of exposure.

2K. Biomonitoring Equivalents

Biomonitoring equivalents (BEs) are defined as the concentration or range of concentrations of a chemical or its metabolite in a biological medium (blood, urine, or other medium) that is consistent with an existing health-based exposure guideline such as U.S. Environmental Protection Agency's (U.S. EPA) reference concentration (RfC), Texas Commission on Environmental Quality's (TCEQ) reference value (ReV), California EPA's reference exposure level (REL), or ATSDR's MRL.

Methodology first advanced by Hays et al. (2012) led to the development of BEs. ATSDR used a PBPK model developed by Jeff Fisher in Berkeley Madonna from the original model developed by Yokley et al. (2006) [Ruiz et al. 2011; Mumtaz et al. 2012a, 2012b]. ATSDR compared the resulting noncancer BEs to steady-state benzene blood levels estimated by PBPK modeling of Refinery Row ambient air benzene concentrations, based on benzene data from the Huisache stationary air monitor. BE derivation is in Table 1K.

Results suggest the highest steady-state benzene blood levels estimated by PBPK modeling of Huisache ambient air levels are less than all BEs developed from the identified, long-term noncancer comparison values. A hazard quotient (HQ) describes the extent of concordance by comparing the benzene blood levels estimated by PBPK modeling from benzene ambient air levels at Huisache with noncancer BEs estimated by PBPK modeling of the ambient air comparison values developed by each agency. All HQs are less than 1, suggesting Refinery Row long-term benzene air exposures are not likely a concern for harmful noncancer health effects.

Table 1K. Biomonitoring Equivalent Derivation* (2 pages)

Biomonitoring Equivalents for Chronic Noncancer Comparison Values				
BE Derivation Step	***US EPA chronic RfC***	***TCEQ ReV***	***California EPA REL***	***ATSDR chronic inhalation MRL***
Target organ	Decreased lymphocyte count	Decreased lymphocyte count	Hematological effects	Decreased B cell counts
Point of Departure	7.2 ppm, BMCL, 1 sd	7.2 ppm, BMCL, 1 sd	0.53 ppm, NOAEL	0.100 ppm, BMCL, 0.25 sd
LOAEL to NOAEL adjustment	3	1	1	1
Duration adjustment	5/7 days/week 10/20 m^3/day	5/7 days/week 10/20 m^3/day	5/7 days/week 10/20 m^3/day	6/7 day/week 8/24 hours/day
Subchronic to chronic adjustment	3	1	1	1
Adjusted POD for continuous exposure	0.3 ppm	2.6 ppm	0.2 ppm	0.03 ppm
Human equivalent BE_{POD}, Benzene in blood (ng/mL)	2.7	23	1.8	0.27
Intraspecies uncertainty factor	10	10	10	10
Incomplete database	3	3	1	1

Biomonitoring Equivalents for Chronic Noncancer Comparison Values				
BE Derivation Step	***US EPA chronic RfC***	***TCEQ ReV***	***California EPA REL***	***ATSDR chronic inhalation MRL***
BE, Benzene in blood (ng/mL)	0.09	0.77	0.18	0.027
Hazard Quotient†	0.013/0.09 = 0.14	0.013/0.77 = 0.017	0.013/0.18 = 0.07	0.013/0.027 = 0.48

Data Sources:

Agency for Toxic Substances and Disease Registry. 2007. Toxicological profile for benzene (updated). Atlanta: US Department of Health and Human Services. Available at: http://www.atsdr.cdc.gov/ToxProfiles/tp3.pdf.

California Environmental Protection Agency. 2000. Air toxics "hot spots" program risk assessment guidelines part III: technical support document for the determination of noncancer chronic reference exposure levels. Chronic toxicity summary, benzene: pp. A-6-16. Office of Environmental Health Hazard Assessment. Oakland, California. Available at: http://www.oehha.org/air/chronic_rels/pdf/22Summs.pdf.

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* Biomonitoring equivalents (BEs) were estimated by PBPK modeling.

† The hazard quotient was calculated by dividing the PBPK estimated blood level for Huisache (0.013 ng/mL) by the biomonitoring equivalent benzene in blood level for each comparison value.

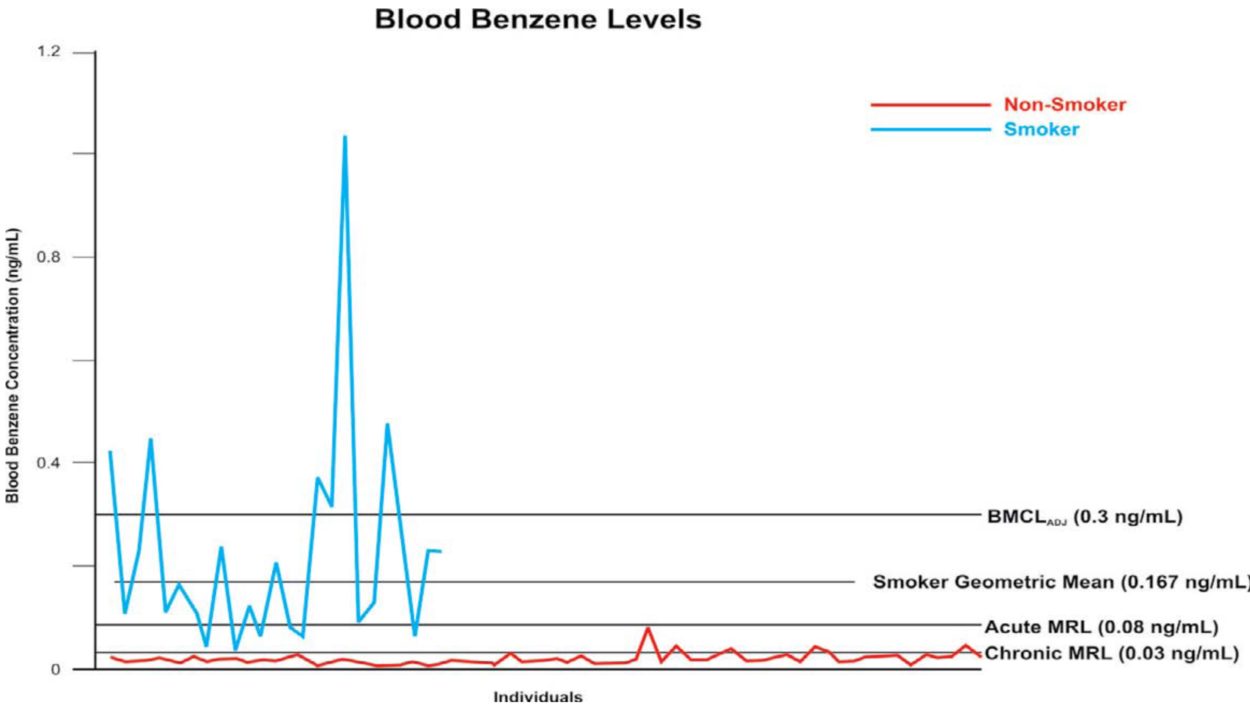
ATSDR	Agency for Toxic Substances and Disease Registry
BMCL	benchmark concentration, lower bound
BE	biomonitoring equivalent
LOAEL	lowest-observed-adverse-effect-level
m^3	cubic meter
MRL	minimal risk level
ng/mL	nanograms per milliliter
NOAEL	no-observed-adverse-effect-level
PBPK	physiologically-based pharmacokinetic
POD	point of departure
ppm	part per million
REL	reference exposure level
ReV	reference value
sd	standard deviation
TCEQ	Texas Commission on Environmental Quality
US EPA	U.S. Environmental Protection Agency

3K. Exposure Investigation

In 2010, ATSDR conducted an exposure investigation (EI) to measure concurrent benzene blood levels and personal benzene air exposure levels (as measured with passive diffusion badges) in two Refinery Row neighborhoods [ATSDR 2011]. An EI is a snapshot in time of current blood levels and ambient air levels. The EI report is available at http://www.atsdr.cdc.gov/sites/corpuschristi/reports.html. In this public health report appendix, ATSDR shows the PBPK modeling results in order to compare benzene blood levels measured in the Refinery Row community with corresponding estimates of personal benzene exposure levels.

Figure 5K shows health-based comparison values as BEs estimated by PBPK modeling in relation to measured benzene blood concentrations in smokers and nonsmokers during the EI. This figure suggests that Refinery Row area smokers had benzene blood levels greater than the BE that corresponds to ATSDR's chronic MRL. Most smokers were also above the BE that corresponds to the acute MRL. This figure also suggests that Refinery Row area nonsmokers had benzene blood levels below the BE that corresponds to the acute MRL. Most nonsmokers were also below the BE that corresponds to the chronic MRL.

Figure 5K. Health-based Comparison Values Shown in Relation to Measured Benzene Blood Levels in Smokers and Nonsmokers During the Exposure Investigation*

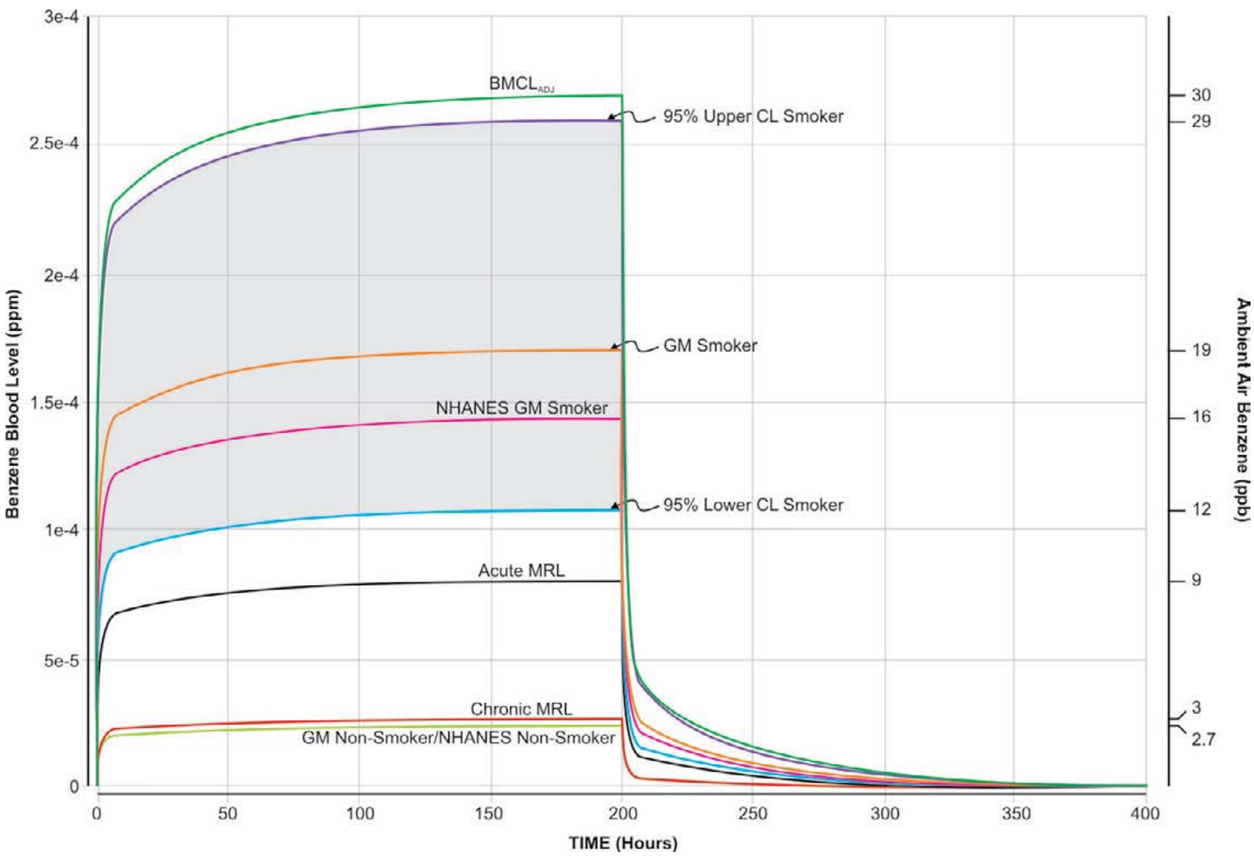


* Characterization and time of last benzene exposure is unknown. Health-based comparison values are shown as biomonitoring equivalents estimated by PBPK modeling.

$BMCL_{ADJ}$ benchmark concentration, lower bound, adjusted for continuous exposure
MRL minimal risk level
ng/mL nanograms per milliliter

In Figure 6K, ATSDR shows the results of PBPK reverse dosimetry modeling of benzene blood levels to obtain estimated, associated ambient air levels at several concentrations of interest. During the EI, the geometric mean benzene air concentration (as measured with passive diffusion badges) was 1.1 ppb, with a range of not detected (ND) to 11 ppb. Figure 6K suggests slightly higher estimated benzene ambient air levels of 2.7 ppb for nonsmokers than the geometric mean measured benzene personal air level (1.1 ppb) found for the EI participants. PBPK reverse dosimetry modeling of smoker's benzene blood levels suggests the estimated benzene ambient air levels for smokers (19 ppb) is higher than the range of measured EI personal benzene air levels. Mean residential benzene ambient air levels at the Huisache stationary air monitor were 1.5 ppb (2005–2009), a level slightly lower than the estimated benzene ambient air level of 2.7 ppb for nonsmokers. Overall, Figure 6K suggests that the smoking population is likely being exposed to higher concentrations of benzene than the population that is only being exposed to the benzene in ambient air.

Figure 6K. Benzene Blood Levels and Associated Ambient Air Levels Estimated by a PBPK Model



* PBPK reverse dosimetry modeling of benzene blood levels were used to obtain estimated, associated ambient air levels during 200 hours continuous simulated exposure at the concentrations of interest.

BMCL$_{ADJ}$ benchmark concentration, lower bound, adjusted for continuous exposure
CL confidence limit
GM geometric mean
MRL minimal risk level
NHANES National Health and Nutrition Examination Survey
PBPK physiologically-based pharmacokinetic
ppb parts per billion
ppm parts per million

4K. National Health and Nutrition Examination Survey

ATSDR's exposure investigation that measured benzene blood concentrations and measured personal air concentrations can be compared with the National Health and Nutrition Examination Survey (NHANES) [Syumanski et al. 2009]. NHANES is a program of studies designed to assess the health and nutritional status of adults and children in the United States. The NHANES protocol includes a home interview followed by a standardized physical examination in a mobile examination center. As part of the examination component, blood, urine, and other samples are collected and analyzed for various chemicals. The NHANES test population is selected to be representative of the civilian, noninstitutionalized population of the United States. These NHANES data do not identify potential health effects, but might help in identifying unusual exposures.

The geometric means (GMs) of benzene blood levels measured during the EI in the Refinery Row area were similar to the GMs of NHANES blood levels for both smokers and nonsmokers (see Table 2K and Figure 6K). For nonsmokers, the GMs of both the EI and NHANES benzene blood levels were below the 0.024-nanograms per milliliter (ng/mL) detection limit, which is also the reported value, although actual values were less. A detection limit (DL) is the lowest concentration that can be reliably distinguished from zero, but is not quantifiable with acceptable precision. Although at the DL the analyte is proven to be present, its reported concentration is an estimate [USEPA 1991]. The 0.024-ng/mL benzene blood level is below the biomonitoring equivalents estimated by PBPK modeling for both the ATSDR acute MRL (0.08 ng/mL) and chronic MRL (0.03 ng/mL). For smokers, both EI and NHANES GM benzene blood levels exceeded the BEs associated with ATSDR's acute and chronic MRLs. EI blood levels compared with health guidance values are in Table 2K and Figures 5K and 6K, and NHANES levels are compared with health guidance values in Table 2K and Figure 6K.

The GMs of EI measured nonsmoker, benzene blood levels are below health-based comparison values and similar to NHANES values, suggesting no unusual exposure compared with a general population sample of the United States. The PBPK estimated blood level for Huisache (0.013 ng/mL) is also below health-based comparison values. The GMs of EI-measured smoker blood levels are somewhat higher than NHANES smoker levels, and both values exceed acute and chronic comparison values (see Table 2K).

Table 2K. Benzene Comparisons* (2 pages)

<table>
<tr><th colspan="5">Benzene Comparisons</th></tr>
<tr><th>Parameter</th><th>NHANES</th><th>Exposure Investigation</th><th>Monitor (Huisache)</th><th>Comparison Value*</th></tr>
<tr><td>Air</td><td>1.0 ppb (measured)</td><td>1.1 ppb (measured)</td><td>1.5 ppb (measured)</td><td>3 ppb (chronic), 9 ppb (acute)</td></tr>
<tr><td>Blood† - Smoker</td><td>0.138 ng/mL (measured)</td><td>0.167 ng/mL (measured)</td><td>---</td><td rowspan="2">0.03 ng/mL (estimated chronic), 0.08 ng/mL (estimated acute)</td></tr>
<tr><td>Blood† - Nonsmoker</td><td><0.024 ng/mL (measured)</td><td><0.024 ng/mL (measured)</td><td>0.013 ng/mL (estimated)</td></tr>
</table>

* Comparison values for air are ATSDR's acute and chronic minimal risk levels. Comparison values for blood are biomonitoring equivalents estimated by PBPK modeling from ATSDR's minimal risk levels.

† Measured blood levels are geometric means.

ppb parts per billion
--- not applicable

ng/mL nanograms per milliliter
NHANES National Health and Nutrition Examination Survey

5K. Additional Assessment of Benzene—Conclusions

ATSDR performed PBPK modeling to compare benzene ambient air exposures 1) during an occupational study exposure leading to adverse health effects, 2) during the continuous exposure at ATSDR's MRL, and 3) during the monthly exposure variation in the Refinery Row area. These results suggest the cumulative amount of benzene metabolized during the described occupational exposure is 400-fold greater than continuous exposure at the MRL level; it is also 800-fold greater than the Refinery Row residential exposure. The benzene metabolized during continuous exposure at the MRL is 2 fold greater than during residential exposure. These results better describe the range of uncertainty between levels known to result in adverse health effects and levels believed protective of public health. Agencies usually determine a point of departure, calculate a level of continuous exposure, and select appropriate uncertainty factors to derive a comparison value believed to be protective. PBPK modeling can be an alternative way to normalize and improve exposure characteristics and reduce uncertainty.

ATSDR also compared PBPK-modeled BEs (based on ambient air comparison values) with PBPK-modeled benzene blood levels (based on ambient air benzene concentrations from the Huisache stationary air monitor). Results suggest that PBPK modeled estimates of the highest, steady-state benzene blood levels for Huisache are less than all BEs developed from the identified, long-term noncancer comparison values.

In addition, ATSDR used a PBPK model to compare personal benzene exposure levels with benzene blood levels collected during the 2010 EI. Results suggest that Refinery Row area smokers had benzene blood levels greater than ATSDR's chronic MRL, and most were above the acute MRL. Results also suggest that Refinery Row area residents who did not smoke had benzene blood levels below the acute MRL, and most were below the chronic MRL. Results further suggest that the smoking population is likely exposed to higher concentrations of benzene than the population that is only exposed to benzene in ambient air.

Benzene blood levels measured during the EI were compared with NHANES benzene blood level data. Results suggested that compared with a sampling of the United States general population, no apparent, unusual benzene exposure occurred in the Refinery Row area. Geometric means (GMs) of blood levels of Refinery Row area nonsmokers compared favorably with GMs of nonsmoker blood levels reported in NHANES, although GMs from Refinery Row area smokers were slightly higher than smoker's blood levels reported in NHANES.

6K. References

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Appendix L. Health Outcome Data Evaluation

Residents in neighborhoods near Corpus Christi's Refinery Row have health concerns about how Refinery Row facilities might affect their environment. Specifically, residents believe they have higher-than-normal occurrences of

- Asthma
- Birth defects
- Cancers
- Developmental disabilities
- Diabetes
- Nonasthma respiratory illness such as emphysema, chronic bronchitis, and shortness of breath
- Skin disorders

As part of the public health evaluation process, the Agency for Toxic Substances and Disease Registry (ATSDR) reviewed available, relevant health outcome data for indications of increased illness in the Corpus Christi Refinery Row (CCRR) area.

The Texas Department of State Health Services[59] routinely collects information on the health of populations within geographic areas throughout the state. For ATSDR's evaluation of residents' health in the Refinery Row area, several state health service programs provided data and provided technical assistance in the appropriate use of those data. This health outcome data evaluation examined data from the Texas Asthma Control Program (TACP), the Texas Birth Defects Registry, the Texas Cancer Registry, and the Texas Diabetes Program. These readily available data sources were of great assistance in the health outcome evaluation, but these sources did not include data for site-specific evaluation of nonasthma respiratory illness, developmental disabilities, or skin disorders.

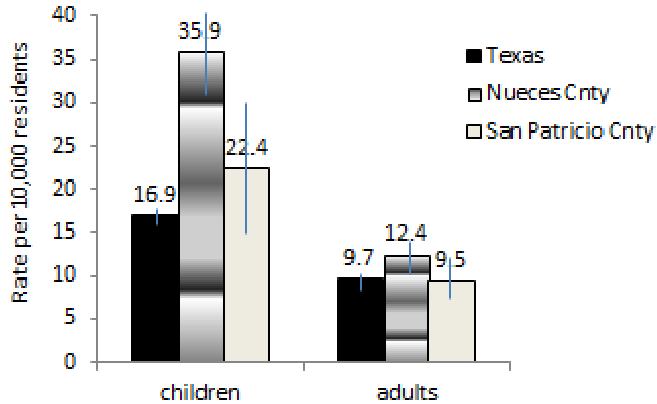
1L. Respiratory Outcomes—Asthma

Asthma affects more children than any other chronic disease and is one of the most frequent reasons for hospital admissions among children. TACP collects and analyzes hospital discharge data by demographic characteristics (e.g., age, sex, and race) and county to determine the rate of asthma-related hospitalizations. TACP 2009 hospitalizations were the most recent data available at the time of analysis.

Refinery Row is in Nueces County and near the border of San Patricio County. TACP data show in 2009, asthma hospitalization rates among children were higher in Nueces County (36 per 10,000 residents) compared to both San Patricio County (22 per 10,000 residents) and Texas statewide (17 per 10,000 residents). From 2005 through 2008, asthma hospitalizations among children were markedly higher in Nueces County (42 per 10,000 residents in 2008) and San Patricio County (43 per 10,000 residents in 2008) than in Texas statewide (15 per 10,000 residents in 2008). In 2009, asthma hospitalization rates among adults were similar for Nueces County, San Patricio County, and Texas statewide (see Figures 1L, 2L, and 3L).

[59] Referred to throughout this public health assessment as "Department of State Health Services" (DSHS).

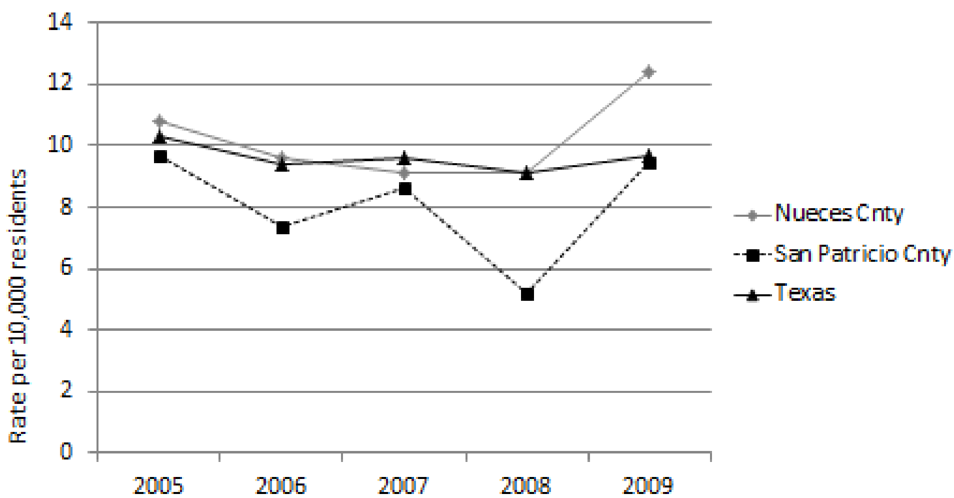
Figure 1L. Asthma Hospital Admission Rates*, 2009



* Age-adjusted to the 2000 US population

Data provided by the Texas Asthma Control Program, Texas Department of State Health Services.
Data Source: Texas Health Care Information Collection, Texas Hospital Inpatient Discharge Public Use Data File, (2009), Center for Health Statistics, Texas Department of State Health Services.

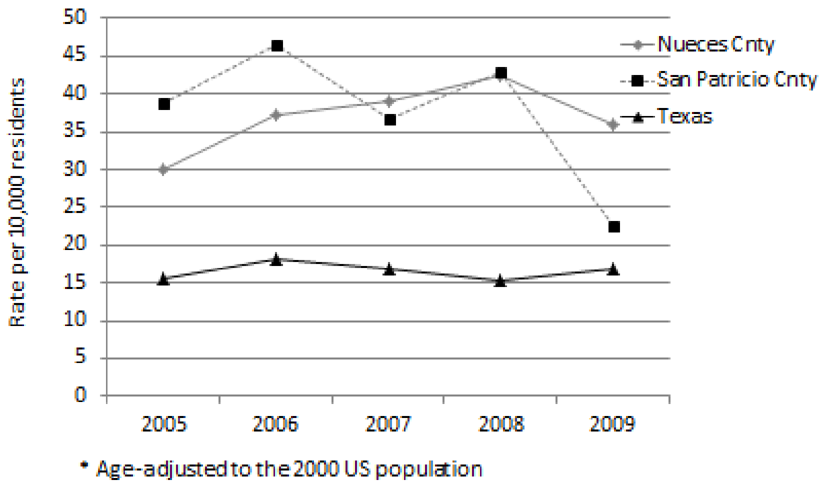
Figure 2L. Asthma Hospital Admission Rates* among Adults, 2005–2009



* Age-adjusted to the 2000 US population

Data provided by the Texas Asthma Control Program, Texas Department of State Health Services.
Data Source: Texas Health Care Information Collection, Texas Hospital Inpatient Discharge Public Use Data File, (2009), Center for Health Statistics, Texas Department of State Health Services.

Figure 3L. Asthma Hospital Admission Rates* among Children, 2005-2009



Data provided by the Texas Asthma Control Program, Texas Department of State Health Services.
Data Source: Texas Health Care Information Collection, Texas Hospital Inpatient Discharge Public Use Data File, (2009), Center for Health Statistics, Texas Department of State Health Services.

To decrease preventable asthma and reduce the severity of asthma symptoms, TACP focuses on both indoor and outdoor air quality. The U.S. Environmental Protection Agency (U.S. EPA) set National Ambient Air Quality Standards for six "criteria pollutants" considered harmful to public health. The criteria pollutants include ground-level ozone, particulate matter, lead, nitrogen dioxide, sulfur dioxide, and carbon monoxide. Some of these outdoor, criteria pollutants are known asthma triggers. As recently as March 2006, the Corpus Christi metropolitan area was close to noncompliance with federal standards for at least one such outdoor criteria pollutant. Indoor pollutants that are common asthma triggers include tobacco smoke, dust, roaches, mold, household chemical odors, and compounds released from gas stoves and space heaters. Successful asthma management requires that people identify outdoor and indoor asthma triggers in the environment so they can control, avoid, or eliminate them.

To address the social and economic burden of asthma in Texas, TACP, through funding from the Centers for Disease Control and Prevention, provides asthma-control data, educational materials, and other resources for health care professionals, community-based organizations, schools, and the public. Through its educational partners, TACP provides activities throughout the state (see http://www.dshs.state.tx.us/asthma/default.shtm).

In the Corpus Christi area, TACP engages in several activities and works with several partners. In 2011, TACP provided asthma-initiative funding to Driscoll Children's Health Plan (DCHP). This financial assistance helped fund a series of meetings that stimulated interest and participation in in Corpus Christi's previously dormant Coastal Bend Asthma Initiative (CBAI). The meetings resulted in establishment of a plan for coordinated presentations and community events throughout Asthma Awareness Month (May 2011). Since Asthma Awareness Month, interest in participating with CBAI has increased dramatically. Multiple and diverse stakeholders have made commitments to work with CBAI to promote asthma management in their areas. Participants include coordinators of state health plans in Nueces County, hospitals, universities, colleges, the Coastal Bend Regional Health Advisory Board, and the Texas A&M Health Science Center – Coastal Bend Health Education Center. The reactivated CBAI successfully engaged the Corpus Christi Independent School District, allowing Driscoll Children's Health Plan to develop and promote asthma education and information in two elementary schools, both identified as having higher than average incidence of asthma among their students. Principals, a school nurse, and a parent liaison at those elementary schools actively participated in CBAI/DCHP meetings. CBAI/DCHP also made presentations at school Parent Teacher Association meetings, as well as at a session for volunteers who substitute for absent school nurses. Promoting asthma educator certification is an additional CBAI/DCHP objective.

2L. Birth Defects

2L.1. Background—Texas Reports

Between 2001 and 2010, the Texas Department of State Health Services[60] (formerly the Texas Department of Health) produced seven reports on birth defects occurrence among deliveries to residents in Corpus Christi and surrounding areas. Section 4C in Appendix C contains a summary of each of these reports.

A 1996 DSHS analysis of Texas Birth Defects Registry data from 1996 through 2002 found that 15 birth defects in a list of ZIP codes comprising almost all of Nueces County were significantly elevated and recommended them for inclusion in a follow-up case-control study [DSHS 2006]. A 2008 follow-up case-control study measured the association between those suggested birth defects and maternal residential proximity to 23 refineries or chemical plants as well as other sites of concern to area residents. Although results indicated that mothers' residence near refineries and chemical manufacturing plants showed higher likelihoods of diaphragm anomalies and gastroschisis, the associations were not statistically significant [DSHS 2008].

Although not specific to Corpus Christi Refinery Row, a statewide analysis of neural tube defects among offspring in Texas and air pollution exposure is nonetheless relevant. That study found an association between environmental levels of benzene and spina bifida and was the first study to assess the relationship between ambient air levels of benzene, toluene, ethyl benzene, and xylene and the prevalence of neural tube defects among offspring [Lupo 2011].

2L.2. ATSDR Assessment of Birth Defects

2L.2.1. Methods

As part of this public health evaluation, ATSDR examined the occurrence of birth defects in the offspring of mothers living in the vicinity of Refinery Row. ATSDR then compared those birth defect occurrences with occurrences in Corpus Christi areas farther from Refinery Row. To assist ATSDR, DSHS did a preliminary study to identify which birth defects to include. DSHS compared the occurrence of a comprehensive range of defects in the Corpus Christi area with two other selected areas, and suggested ATSDR consider 63 birth defects for inclusion in the public health evaluation [DSHS 2010].

ATSDR concurred with the DSHS recommendations. The DSHS Birth Defects Epidemiology and Surveillance Branch provided data for deliveries in the tri-county Corpus Christi area according to the following criteria:

[60] Referred to throughout this public health assessment as "Department of State Health Services" (DSHS).

1. Delivered in 1999 (first year the Texas Birth Defects Registry was statewide) through 2007 (most recent year with finalized data in the Texas Birth Defects Registry)
2. Elevated birth defect category in the Corpus Christi area based on preliminary analysis
3. All cases with any birth defect monitored by the Texas Birth Defects Registry
4. Neural tube defects
5. Selected conotruncal heart defects

DSHS also provided data on the number of births in the same area and period. ATSDR calculated rates of birth defects in proximity areas defined as up to 2 miles, 2 to 5 miles, 5 to 10 miles, and more than 10 miles from Refinery Row (see Figure 56A, Appendix A). Also, ATSDR used crude and adjusted prevalence rate ratios to compare the occurrence of birth defects up to 2 miles away with birth defect occurrence more than 10 miles from Refinery Row within the tri-county (Nueces, San Patricio, and Kleberg) Corpus Christi area (see Figure 57A, Appendix A). ATSDR also compared underlying population characteristics, such as maternal age, race-ethnicity, and maternal education. These population characteristics were important because potentially they could influence the occurrence of birth defects, and if so, the statistical analyses needed to consider them.

2L.2.2. Data Analysis

DSHS provided data from the Birth Defects Registry and data on births from Texas birth certificates. Data included deliveries in the tri-county Corpus Christi area from 1999 through 2007. ATSDR's Geographic Research, Analysis, and Services Program determined geographic proximity areas surrounding Refinery Row. ATSDR sent those data to DSHS, where the DSHS Geographic Information System (GIS) staff combined the data with the geocoded residence locations of cases and births to determine the proximity area for each residence. DSHS then stripped off the residence locations and sent the proximity area assignments back to ATSDR.

Within each proximity area, ATSDR calculated birth prevalence per 10,000 births for the 63 birth defect groups selected on preliminary analysis, neural tube defects, conotruncal heart defects, and all cases with one or more defect. The formula is

$$Birth\ prevalence = \frac{Cases\ of\ birth\ defect\ X\ in\ area\ Y}{Births\ in\ area\ Y} \times 10{,}000$$

For each birth defect ATSDR calculated a prevalence ratio and 95% confidence interval to compare the occurrence of cases up to 2 miles away from Refinery Row with the occurrence of cases 10 miles or farther away. The formula is

$$Birth\ prevalence\ ratio = \frac{Prevalence\ of\ defect\ X\ up\ to\ 2\ miles\ away}{Prevalence\ of\ defect\ X\ 10\ or\ more\ miles\ away}$$

ATSDR calculated those ratios using Poisson regression, which also allowed calculation of the 95% confidence interval (95% CI) around the ratio. The CI considers random variation and gives a range in which the true, underlying ratio will occur 95% of the time. If birth prevalence were the same in the area up to 2 miles away from Refinery Row and in the comparison area of 10 or more miles away, the ratio would be 1.00. Any value above 1.00 indicates that the birth prevalence is higher in the up to 2-mile area. If the 95% CI exceeds 1.00, then this elevation is unlikely to have been due simply to random variation, although that remains a possible explanation 5% of the time. Poisson regression analysis also helped to calculate crude prevalence ratios and ratios adjusted for maternal age, educational attainment, and ethnicity.

Reasons other than proximity to Refinery Row might explain the higher birth defect prevalence, such as a higher proportion of Hispanic/Latino births; neural tube and several other defects are higher in Hispanics/Latinos [Canfielda et al. 2009]. Thus, ATSDR also analyzed the data for Hispanics/Latinos only and used Poisson regression to calculate crude prevalence rations and ratios adjusted for maternal educational attainment and age.

2L.2.3. Results

Table 34B, Appendix B, summarizes mother's age, educational attainment, and race/ethnicity by proximity area for cases in the DSHS Birth Defects Registry. ATSDR's analysis of birth defect cases in the tri-county Corpus Christi area found that compared with mothers residing 10 miles or more away, a significantly higher percentage of mothers residing within 2 miles of Refinery Row were of Hispanic origin—57% and 81% respectively. Also compared with mothers residing 10 miles or more away, a significantly higher percentage of mothers residing within 2 miles of Refinery Row did not graduate from high school—28% and 48% respectively. The number of birth defect cases based on maternal age, however, did not significantly differ between the comparison areas.

Table 35B, Appendix B, summarizes the number and prevalence of the selected birth defects within each proximity area. Table 36B, Appendix B, summarizes prevalence ratios with 95% CIs. Compared with mothers living more than 10 miles from Refinery Row, mothers living within 2 miles of Refinery Row were about 1.5 times more likely to have offspring with a ventricular septal defect. After adjusting for maternal educational attainment, age, and Hispanic/Latino origin, the association of living in the vicinity of Refinery Row with the occurrence of ventricular septal defects remained statistically significant (ratio = 1.4, 95% CI = 1.1–1.8). A prevalence ratio is not presented when the statistical model was not valid due to either no occurrence or rare occurrence for certain birth defects within a specified area.

Studies of birth defect surveillance data in the United States has shown Hispanic/Latino mothers have a higher prevalence of certain birth defects, (e.g. neural tube defects) perhaps due to a lower intake of folic acid [Williams et al. 2005; Hamner et al. 2011]. Because the vast majority of mothers residing in close proximity to Refinery Row are of Hispanic/Latino origin (81%), ATSDR also analyzed birth defect registry data for only Hispanic/Latino mothers. The results summarized in Table 37B and Table 38B, Appendix B, were similar in all cases. After adjustment for maternal education and age, Hispanic/Latino mothers living within 2 miles of Refinery Row had a statistically significant, increased occurrence of ventricular septal defects compared with mothers living 10 miles or more away. Hispanic/Latino mothers living within 2 miles of Refinery Row were 1.8 times more likely to have a child born with "other anomalies of the aorta" than Hispanic/Latino mothers living 10 or more away; and, after adjustment for maternal education and age, this association persisted.

2L.2.4. Limitations

ATSDR's birth defects analysis is limited. The analysis could only measure a mother's residential proximity to Refinery Row facilities—not a mother's actual exposure to toxicants. ATSDR could not therefore make any definitive conclusions about associations between Refinery Row facilities and birth defects.

Also, in this study ATSDR examined 63 birth defects. Using 95% confidence intervals, ATSDR would expect 5% of those birth defects—or 3 to 4 of the 63 birth defects—to show a statistically significant association with Refinery Row proximity. But ATSDR observed only 2 such cases, meaning the results could have arisen by chance alone.

In addition to these limitations, other limitations include

1. Neural tube defects (NTDs) were of interest: these disorders have shown an association with living in proximity to various industries that emit pollutants [Suarez 2007]. In this birth defects analysis, a large number of NTD cases were not included (27 of the 55) because registry data did not have the mother's place of residence—thus we could not map the case to a proximity area.
2. Unfortunately, most of the NTD cases were fetal deaths, and in such instances birth defects registry data tended to be incomplete.
3. For some birth defects, the number of cases living within the proximity areas was very small, which limited ATSDR's ability to detect statistical associations.

2L.2.5. Conclusions

ATSDR found that two of the 63 birth defects examined had prevalence rates slightly higher for mothers living within 2 miles of Refinery Row compared to rates in the tri-county area 10 or more miles away. Mothers living within 2 miles of Refinery Row were more likely to have a child born with ventricular septal defect or with "other anomalies of the aorta." However, the associations were not very strong (1.5 times more likely to have a child born with ventricular septal defect and 1.8 times more likely to have a child born "other anomalies of the aorta"). ATSDR cannot determine if these birth defect increases are due to air pollution from industries along Refinery Row. ATSDR expected to detect a few birth defect increases just by chance due to the large number of comparisons; and, maternal lifestyle and health factors that are linked to birth defects were not available for the study analysis. Furthermore, ATSDR's air evaluation did not identify any chemicals at levels of potential health concern for birth defects.

2L.2.6. Recommendations

Ventricular septal defects and certain anomalies of the aorta were elevated in the area closest to Refinery Row. Based on the number of birth defects examined, these increases could be due to chance, genetics, or risk factors such as obesity, diabetes, and poverty that were not available for the analysis. But ATSDR does support such ongoing public health efforts as

1. The Texas Birth Defects Registry continuing to monitor birth defects in the Corpus Christi area,
2. The Regional Health Awareness Board (RHAB) organizing meetings with the March of Dimes and others to develop community intervention strategies to prevent birth defects ,
3. RHAB partnering with the public school systems to provide information to young girls about the importance of good nutrition and health care, and
4. U.S. EPA conducting research on environmental exposures and birth defects.

Additional resources could provide needed health education programs about the importance of prenatal health care and the dangers to an unborn child of obesity and uncontrolled diabetes, which have been shown to increase the risk of certain birth defects.

3L. The Burden of Diabetes

Diabetes is a complex, serious health problem. In recent years, in Texas and throughout the United States, diabetes prevalence has steadily increased. Diabetes appears in two forms: Type 1 and Type 2. Type 1 diabetes accounts for fewer than 10 percent of all diabetes cases. It usually starts in childhood and is caused by genetic and environmental factors that impair the body's immune system. People who have Type 1 diabetes are dependent on insulin to regulate their blood glucose. Type 2 diabetes is much more common. It accounts for about 95 percent of all diabetes. The most common risk factors for Type 2 diabetes are obesity and physical inactivity. High blood pressure, high cholesterol, and smoking can also cause diabetes-related complications. In addition, African Americans, Hispanics, and American Indians are more likely to develop Type 2 diabetes. Recent scientific studies suggest that environmental contaminants and occupational exposures contribute to the nation's increase in both Type 1 and Type 2 diabetes [Longnecker and Daniels 2001].

Research has found that women with diabetes are more likely to have babies with birth defects. Specifically, children born to women with diabetes have a greater chance of heart problems, brain and spinal defects, oral clefts, kidney and gastrointestinal tract defects, and limb deficiencies [Correa et al. 2008]. Women of childbearing age who have diabetes should note that only 5% or fewer children born with one or more birth defects were born to diabetic mothers. Still, the research results should serve as a reminder for women to take better care of themselves, exercise, maintain a healthy weight and, when pregnant, get regular prenatal care.

Diabetes prevalence data for Texas comes mainly from the annual Behavioral Risk Factor Surveillance System survey (BRFSS). State-based telephone surveys conducted in cooperation with DSHS and the Centers for Disease Control and Prevention collect BRFSS data. Surveyors invite only respondents aged 18 years and older to answer the survey. The questions regarding diabetes do not separate type of diabetes, and ATSDR did not count as diabetic females who reported only having diabetes during pregnancy. Using data from the 2008 telephone survey, the age-adjusted estimate of adults with diagnosed diabetes was 10.0% for residents of Nueces County and 9.4% for residents of San Patricio County. The age-adjusted prevalence for the state of Texas statewide in 2008 was 10.1% [CDC 2012]. These data do not indicate an increased prevalence of diabetes in the Refinery Row area.

4L. Cancer Occurrences

At ATSDR's request, the Texas Department of State Health Services examined the occurrence of cancer within a 5-mile buffer zone surrounding Corpus Christi Refinery Row. Using Arc GIS, ATSDR's Geospatial Research, Analysis, and Services Program identified ZIP codes in the Corpus Christi area within an approximate 5-mile buffer surrounding Refinery Row (78401, 78402, 78404, 78405, 78406, 78407, 78408, 78409, 78410, 78411, 78416, 78417 and 78370). Because the cancer registry relied on ZIP codes for its area analysis, ATSDR used a 5-mile buffer zone as opposed to the 2-mile zone it used for the birth defect analysis.

And ZIP codes did reasonably delineate the 5-mile buffer zone. DSHS used Texas Cancer Registry (1999–2008) data for these ZIP codes and used statewide data to determine whether selected cancers were elevated within the buffer zone. DSHS examined cancer incidence because incidence data are a better indicator of cancer occurrence than is cancer mortality. A death certificate might give, for example, liver cancer as the underlying cause of death when the cause is actually metastasis from another cancer site. Thus mortality data might misclassify the cancer site of origin. With incidence data, DSHS gets a case report—with the exception of death-certificate only cases (< 3%)—that DSHS reviews to determine the cancer site of origin. The Texas Cancer Registry data are complete through 2008.

Following the National Cancer Institute guidelines, the DSHS compared the occurrence of selected cancers in the CCRR ZIP code area. To determine whether a statistically significant excess of cancers occurred in the geographic area of concern, DSHS compared the number of observed cases with what would be "expected" by applying statewide cancer rates to the 2000 Census population data for the area. The DSHS report contains details of the analysis, and Appendix 5C contains the results. The expected number of cases takes into account the race, sex, and ages of those diagnosed with cancer. To determine a statistically significant excess of cases, DSHS calculated standardized incidence ratios and corresponding 99% confidence intervals for both males and females.

From January 1, 1999 to December 31, 2008, there was no statistical difference in the incidence of 12 cancers

brain/CNS	breast
childhood brain cancer subtypes	childhood leukemia subtypes
corpus and uterus	esophagus
lung and bronchus	non-Hodgkin's lymphoma
prostate	select leukemia subtypes
total childhood cancers	total leukemia

in the CCRR area compared with Texas.

But for male colon and rectum, bladder, kidney, and liver cancer, the number of cases reported for the CCRR area was statistically greater than expected. Tables 1–3, Appendix M, contain analysis summaries. Because of the noted excess of some cancers in males, DSHS will continue to update this investigation as more data become available. It is important to note, however, that while this investigation determined whether the amount of selected Refinery Row cancers was more than expected, the investigation could not determine either the cause of the cancers or possible associations with any risk factors. The DSHS report contains general information on cancer risk factors and reaffirms that eating a healthy diet and refraining from tobacco are the best ways to prevent many kinds of cancer.

5L. References

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Appendix M. Summary Report of Texas Department of State Health Services Investigation of Specific Cancer Occurrences

August 1, 2011

Summary Report of
Texas Department of State Health Services Investigation of
Specific Cancers Occurrences
Within Zip Codes 78401, 78402, 78404, 78405, 78406, 78407, 78408, 78409, 78410, 78411, 78416, 78417, and 78370, Corpus Christi & Odem, Texas
Nueces County, Texas

Covering 1999–2008

Background

A request by the Agency for Toxic Substances & Disease Registry prompted the Texas Department of State Health Services (DSHS) to examine the occurrence of cancer in the zip codes within a five mile buffer zone surrounding Refinery Row, Corpus Christi, TX. To determine if selected cancers were elevated, DSHS evaluated complete, statewide incidence data (1999–2008) for cancers of the colon and rectum, lung and bronchus, breast, bladder, corpus and uterus, prostate, kidney and renal pelvis (area at the center of the kidney), liver and intrahepatic bile duct (within the liver), esophagus, brain/CNS, non-Hodgkin's lymphoma, total leukemia, select leukemia subtypes, total childhood cancers, childhood leukemia subtypes, and childhood brain cancer subtypes. Cluster analyses require complete statewide cancer data and currently the Texas Cancer Registry (TCR) is complete through 2008.

For this investigation DSHS used cancer incidence data which shows the number and types of cancer diagnosed each year. Cancer incidence data are the best indicator of cancer occurrence and cancer incidence data for Texas currently meet national standards for timeliness and data quality. This report presents information on methods used to conduct this investigation, the results, recommendations, and general information on cancer risk factors.

Investigation Methodology

According to the National Cancer Institute (NCI), a cancer cluster is a greater than expected number of cancers among people who live or work in the same area and who develop or die from the same cancer within a short time of each other. A cancer cluster investigation is designed with the specific intention of addressing the question, "Is there more cancer in the area or population of concern than we would expect?" While these types of investigations can be used to investigate whether the amount of cancer in a community is more than expected, they cannot determine either the cause of the cancers or possible associations with any risk factors.

DSHS follows guidelines recommended by the federal Centers for Disease Control and Prevention (CDC) for investigating cancer clusters.[1] If DSHS finds more cancer than expected or if rare or unlikely cancers are found in unusual age groups, various factors are considered to determine whether further study could identify a likely cause. Very few cancer cluster investigations in the United States proceed to this stage.

To determine whether a statistically significant excess of cancer existed in the geographic areas of concern, the number of observed cases was compared to what would be "expected" by applying state cancer rates to the 2000 Census population data for the area under investigation. Calculating the expected number(s) of cancer cases takes into consideration the race, sex, and ages of those who are diagnosed with cancer. This is important because all of these factors can impact cancer rates. When trying to determine if there is more or less cancer in a community compared to the rest of Texas, an investigation must ensure that differences in cancer rates are not simply due to differences in population demographics. Since a higher than expected number of cancer cases in a community can occur by chance alone, the role of chance also is considered in the statistical analysis.

Attached tables (Tables 1–3) present the number of observed cases for males and females; number of "expected" cases; standardized incidence ratio (SIR); and corresponding 99% confidence interval. The SIR is simply the number of observed cases divided by the number of "expected" cases. When the SIR of a selected cancer is equal to 1.0, then the number of observed cases is equal to the expected number of cases, based on incidence rates in the state. When the SIR for a particular cancer is less than 1.0, there are fewer cases of that type of cancer in the area than would be expected. Conversely, an SIR greater than 1.0 indicates that there are more cases of a specific type of cancer in the area than would be expected.

Since an excess of cancer can occur by chance alone, statistics are used in the analysis to calculate the 99% confidence intervals to determine the likelihood that the resultant SIR (whether it is greater or lower than 1.0) is due to chance. A 99% confidence interval provides a range that we would expect the SIR to fall 99% of the time. If the confidence interval for a specific SIR includes 1.0, the result is not statistically significant and the observed number of cases is within the range not considered to be different than the expected number of cases. Confidence intervals are particularly important when trying to interpret small numbers of cases. Wide confidence intervals, which are common when dealing with small populations and small numbers of cases, reflect a greater uncertainty in the results. For instance, if only one or two cases are expected, three or four observed cases will result in a very large SIR. A more extreme example would be when due to the small size of the population the expected number of cases is less than 1.0; in this instance one observed case can result in a very high SIR. As long as the 99% confidence interval contains 1.0, the SIR is still within the expected range and therefore is not statistically significant.

Investigation Results

From January 1, 1999 to December 31, 2008, the number of cancers of the lung and bronchus, breast, corpus and uterus, prostate, esophagus, brain/CNS, non-Hodgkin's lymphoma, total leukemia, select leukemia subtypes, total childhood cancers, childhood leukemia subtypes, and childhood brain cancer subtypes were within the expected range in both males and females in the combined zip codes. The number of male colon and rectum, bladder, kidney, and liver cancer cases found reported for the combined zip codes was statistically greater than what was expected. Analysis summaries are presented in Tables 1–3.

Discussion

All cancer types in females fell within the expected ranges; however, the number of cancer cases of colon and rectum, bladder, kidney, and liver in males were statistically higher than what was expected. This type of investigation cannot determine why the number of cancer cases is higher than expected in these areas.

Like other studies, this cancer cluster investigation had limitations. The incidence data used in the cluster analysis did not include data for the most recent years. Also, cancer incidence data are based on residence at the time of diagnosis. It is possible that some residents who developed cancer no longer lived in the area at the time of diagnosis, so were not included in the analyses. However, it is also possible that people may have moved into the area and then developed cancer because of an exposure from a prior residential location or other factors. These cases are included in the investigation.

Recommendations

Because of the elevated SIRs, we will continue to update this investigation as new information or data become available.

Information on Cancer and Cancer Risk Factors:
Overall, the occurrence of cancer is common, with approximately two out of every five persons alive today predicted to develop some type of cancer in their lifetime.[2] In Texas, as in the United States, cancer is the leading cause of death for people under the age of 85.[3] Also, cancer is not one disease, but many different diseases. Different types of cancer are generally thought to have different causes. If a person develops cancer, it is probably not due to one factor but to a combination of factors such as heredity; diet, tobacco use, and other lifestyle factors; infectious agents; chemical exposures; and radiation exposures. Although cancer may impact individuals of all ages, it primarily is a disease of older persons with over one-half of cancer cases and two-thirds of cancer deaths occurring in persons 65 and older. Finally, it takes time for cancer to develop, between 10–40 years can go by between the exposure to a carcinogen and a diagnosis of cancer.[4]

The chances of a person developing cancer as a result of exposure to an environmental contaminant are slight. Most experts agree that exposure to pollution, occupational, and industrial hazards account for fewer than 10% of cancer cases.[5] The Harvard Center for Cancer Prevention estimates 5% of cancer deaths are due to occupational factors, 2% to environmental pollution and 2% to ionizing/ultraviolet radiation.[6] In contrast, the National Cancer Institute estimates that lifestyle factors such as tobacco use and diet cause 50 to 75 percent of cancer deaths.[7] Eating a healthy diet and refraining from tobacco are the best ways to prevent many kinds of cancer. It is estimated that one-third of all cancer deaths in this country could be prevented by eliminating the use of tobacco products. Additionally, about 25 to 30 percent of the cases of several major cancers are thought to be associated with obesity and physical inactivity.[8]

Known Risk Factors for Cancers Examined in This Investigation:
The following is a brief discussion summarized from the American Cancer Society and the National Cancer Institute about cancer risk factors for the specific cancers studied in this investigation.[9,10]

The occurrence of cancer may vary by race/ethnicity, gender, type of cancer, geographic location, population group, and a variety of other factors. Scientific studies have identified a number of factors for various cancers that may increase an individual's risk of developing a specific type of cancer. These factors are known as risk factors. Some risk factors individuals can do nothing about, but many are a matter of choice.

Breast Cancer

Simply being a woman is the main risk factor for developing breast cancer. Breast cancer can affect men, but this disease is about 100 times more common among women than men. White women are slightly more likely to develop breast cancer than are African-American women, but African Americans are more likely to die of this cancer because they are often diagnosed at an advanced stage when breast cancer is harder to treat and cure. Other risk factors for breast cancer include aging, presence of genetic markers such as the BRCA1 and BRCA2 genes, personal and family history of breast cancer, previous breast biopsies, previous breast irradiation, diethylstilbestrol therapy, oral contraceptive use, not having children, hormone replacement therapy, drinking alcohol, and obesity. Secondhand smoke may also be a risk factor. Currently, research does not show a link between breast cancer risk and environmental pollutants such as the pesticide DDE (chemically related to DDT) and PCBs (polychlorinated biphenyls).

Prostate Cancer

Prostate cancer is the most common type of malignant cancer (other than skin) diagnosed in men, affecting an estimated one in five American men. Risk factors for prostate cancer include aging, a high fat diet, physical inactivity, and a family history of prostate cancer. African American men are at higher risk of acquiring prostate cancer and dying from it. Prostate cancer is most common in North America and northwestern Europe. It is less common in Asia, Africa, Central America, and South America.

Colon and Rectum Cancer

Researchers have identified several risk factors that increase a person's chance of developing colorectal cancer: family and personal history of colorectal cancer, hereditary conditions such as familial adenomatous polyposis, personal history of intestinal polyps and chronic inflammatory bowel disease, aging, a diet mostly from animal sources, physical inactivity, obesity, smoking, and heavy use of alcohol. People with diabetes have a 30%-40% increased chance of developing colon cancer. Recent research has found a genetic mutation leading to colorectal cancer in Jews of Eastern European descent (Ashkenazi Jews).

Lung and Bronchus Cancer

The greatest single risk factor for lung cancer is smoking. The American Cancer Society estimates that 87% of lung cancer is due to smoking. Several studies have shown that the lung cells of women have a genetic predisposition to develop cancer when they are exposed to tobacco smoke. Other risk factors include secondhand smoke, asbestos exposure, radon exposure, other carcinogenic agents in the workplace such as arsenic or vinyl chloride, marijuana smoking, recurring inflammation of the lungs, people with silicosis and berylliosis, personal and family history of lung cancer, and arsenic in drinking water. In some cities, air pollution may slightly increase the risk of lung cancer. This risk is far less than that caused by smoking.

Bladder Cancer

The greatest risk factor for bladder cancer is smoking. Men get bladder cancer at a rate four times that of women. Smokers are more than twice as likely to get bladder cancer as nonsmokers. Whites are two times more likely to develop bladder cancer than are African Americans. Other risk factors for bladder cancer include occupational exposure to aromatic amines such as benzidine and beta-napthylamine, aging, chronic bladder inflammation, personal history of urothelial carcinomas, birth defects involving the bladder and umbilicus, infection with a certain parasite, high doses of certain chemotherapy drugs, and arsenic in your drinking water.

Kidney and Renal Pelvis Cancer

Kidney cancer risk factors include smoking, obesity, a sedentary lifestyle, occupational exposure to heavy metals or organic solvents, advanced kidney disease, family history, high blood pressure, certain medications, and aging. Men and African Americans have higher rates of kidney cancer.

Corpus and Uterus Cancer

Corpus and uterus cancer include cancer of the endometrium (lining of the uterus). Risk factors for endometrial cancer include menstrual periods before age 12, menopause after age 52, infertility or not having children, obesity, treatment with the drug Tamoxifen, estrogen replacement therapy, certain ovarian diseases, a diet high in animal fat, diabetes, aging, family history of endometrial cancer, and early pelvic radiation therapy. Women who have had breast or ovarian cancer may have increased risk of getting endometrial cancer.

Liver and Intrahepatic Bile Duct Cancer

In contrast to many other types of cancer, the number of people who develop liver cancer and die from it is increasing. Men and Asian Americans have higher rates of liver cancer. The risk factors for liver cancer include viral hepatitis, cirrhosis, long-term exposure to aflatoxin, exposure to vinyl chloride and thorium dioxide, diabetes, obesity, anabolic steroids, arsenic in drinking water, bile duct disease, ulcerative colitis, liver fluke infection, and aging. Chemicals that are associated with bile duct cancer include dioxin, nitrosamines, and polychlorinated biphenyls (PCBs).

Brain/CNS Cancer

The large majority of brain cancers are not associated with any risk factor. Most brain cancers simply happen for no apparent reason. A few risk factors associated with brain cancer are known and include radiation treatment, occupational exposure to vinyl chloride, immune system disorders, and family history of brain and spinal cord cancers.

Esophageal Cancer

Compared with women, men have a three-fold higher rate of esophageal cancer. African Americans are two times more likely to have esophageal cancer than whites. Other risk factors for esophageal cancer include aging, use of tobacco products, alcohol, obesity, gastric reflux, diets low in fruits and vegetables, lye ingestion, frequent drinking of very hot liquids, achalasia, tylosis, and esophageal webs.

Non-Hodgkin's Lymphoma

Risk factors for non-Hodgkin's lymphoma include: infection with Helicobacter pylori; human immunodeficiency virus (HIV); human T-cell leukemia/lymphoma virus (HTVL-1); Epstein-Barr virus;, or hepatitis C virus. Other possible risk factors include aging; certain genetic diseases; radiation exposure; immuno-suppressant drugs after organ transplantation; benzene exposure; the drug Dilantin; exposure to certain pesticides; a diet high in meats or fat, obesity, or certain chemotherapy drugs.

Childhood Lymphoid Leukemia

Possible risk factors for childhood lymphoid leukemia include: having a sibling with leukemia; being white or Hispanic; being exposed to x-rays before birth; being exposed to radiation; past treatment with chemotherapy or radiation therapy; or having certain genetic disorders, such as Down syndrome.

Childhood Acute Myeloid Leukemia

Possible risk factors for childhood acute myeloid leukemia include: having a sibling, especially a twin, with leukemia; Hispanic ethnicity; being exposed to cigarette smoke or alcohol before birth; having a history of myelodysplastic syndrome; past treatment with chemotherapy or radiation therapy; being exposed to ionizing radiation or chemicals such as benzene; or having certain genetic disorders, such as Down syndrome, Fanconi's anemia, or Noonan's syndrome.

Acute Lymphocytic Leukemia (ALL)

Possible ALL risk factors include: being male, being white; being older than 70; past treatment with chemotherapy or radiation therapy, radiation exposure; certain viral infections;, or having a certain genetic disorder, such as Down syndrome.

Chronic Lymphocytic Leukemia (CLL)

Possible CLL risk factors include: being middle-aged or older, male, or white; a family history of CLL or cancer of the lymph system; or having exposure to herbicides or insecticides including Agent Orange, an herbicide used during the Vietnam War.

Acute Myeloid Leukemia (AML)

Possible AML risk factors include the following: being male; smoking, especially after age 60; treatment with chemotherapy or radiation therapy in the past; treatment for childhood ALL in the past; being exposed to atomic bomb radiation or the chemical benzene; or having a history of a blood disorder such as myelodysplastic syndrome. Scientists estimate that as many as one out of five cases of AML is caused by smoking.

Chronic Myeloid Leukemia (CML)

Being exposed to high-dose radiation (such as surviving an atomic bomb blast or nuclear reactor accident) is the only known environmental risk factor for chronic myeloid leukemia.

Childhood Brain/CNS Cancer

The vast majority of brain cancers happen for no apparent reason and are not associated with anything which the child or parent did or didn't do, or anything that the child was exposed to in the environment. The only established risk factors for brain cancer are ionizing radiation and family history.

For additional information about cancer, visit the "Resources" link on the DSHS Web site at http://www.dshs.state.tx.us/tcr/.

Questions or comments regarding this investigation may be directed to Ms. Brenda Mokry, Epidemiology Studies & Initiatives Branch, at 512-776-3606 or Brenda.Mokry@dshs.state.tx.us.

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Table 1
Number of Observed and Expected Cancer Cases and Adjusted Standardized Incidence Ratios, Selected Childhood Cancers (Aged 0-19 Years), Refinery Row Zip Codes, Corpus Christi, TX 1999–2008

	Males 0-19			
Site	**Observed**	**Expected**	**SIR**	**99% CI**
Total Childhood Cancers	46	41.4	1.1	0.7 – 1.6
Lymphoid Leukemias	15	9.5	1.6	0.7 – 3.0
Acute Myeloid Leukemia	0	1.9	0.0	0.0 – 2.8
Chronic Myeloproliferative Diseases	2	0.9	2.4	0.1 – 10.9
Myelodysplastic Syndrome & Other Myeloproliferative Diseases	0	0.5	0.0	0.0 – 11.5
Unspecified and Other Specified Leukemias	0	0.6	0.0	0.0 – 9.3
Ependymomas and Choroid Plexus Tumor	1	0.7	1.4	0.0 – 10.2
Astrocytomas	5	3.2	1.6	0.3 – 4.5
Intracranial & Intraspinal Embryonal Tumors	0	1.5	0.0	0.0 – 3.5
Other Gliomas	1	1.2	0.9	0.0 – 6.3
Other Specified Intracranial & Intraspinal Neoplasms	0	0.1	0.0	0.0 – 48.7
Unspecified Intracranial & Intraspinal Neoplasms	1	0.1	9.2	0.1 – 68.3
	Females 0-19			
Site	**Observed**	**Expected**	**SIR**	**99% CI**
Total Childhood Cancers	30	34.3	0.9	0.5 – 1.4
Lymphoid Leukemias	5	7.8	0.6	0.1 – 1.8
Acute Myeloid Leukemia	2	1.5	1.3	0.1 – 6.0
Chronic Myeloproliferative Diseases	0	0.3	0.0	0.0 – 19.1
Myelodysplastic Syndrome & Other Myeloproliferative Diseases	0	0.3	0.0	0.0 – 19.1
Unspecified and Other Specified Leukemias	0	0.6	0.0	0.0 – 9.6
Ependymomas and Choroid Plexus Tumor	0	0.1	0.0	0.0 – 78.0
Astrocytomas	3	2.4	1.2	0.1 – 4.5
Intracranial & Intraspinal Embryonal Tumors	1	1.0	1.0	0.0 – 7.1
Other Gliomas	0	1.1	0.0	0.0 – 4.8
Other Specified Intracranial & Intraspinal Neoplasms	0	0.1	0.0	0.0 – 37.2
Unspecified Intracranial & Intraspinal Neoplasms	1	0.1	7.0	0.0 – 52.2

Note: The SIR (standardized incidence ratio) is defined as the number of observed cases divided by the number of expected cases. The latter is based on race-, sex-, and age-specific cancer incidence rates for Texas during the period 1999–2008. The SIR has been rounded to the first decimal place.

*Significantly higher than expected at the $p < 0.01$ level.
**Significantly lower than expected at the $p < 0.01$ level.

Table 2
Number of Observed and Expected Male Cancer Cases and Adjusted Standardized Incidence Ratios Selected Cancers (All Ages), Refinery Row Zip Codes, Corpus Christi, TX, 1999–2008

	Males			
Site	**Observed**	**Expected**	**SIR**	**99% CI**
Colon and Rectum	383	301.9	1.3*	1.1 – 1.5
Lung and Bronchus	473	405.4	1.2	1.0 – 1.3
Bladder	172	133.1	1.3*	1.1 – 1.6
Prostate	722	741.1	1.0	0.9 – 1.1
Breast	5	5.0	1.0	0.2 – 2.9
Kidney and Renal Pelvis	171	125.2	1.4*	1.1 – 1.7
Liver and Intrahepatic Bile Duct	116	83.6	1.4*	1.1 – 1.8
Esophagus	55	38.4	1.4	1.0 – 2.0
Brain/CNS	44	42.1	1.0	0.7 – 1.5
Non-Hodgkin's Lymphoma	111	116.4	1.0	0.7 – 1.2
Total Leukemia	95	87.0	1.1	0.8 – 1.4
Acute Lymphocytic Leukemia	20	15.1	1.3	0.7 – 2.3
Chronic Lymphocytic Leukemia	25	25.5	1.0	0.6 – 1.6
Acute Myeloid Leukemia	23	22.5	1.0	0.6 – 1.7
Chronic Myeloid Leukemia	14	11.6	1.2	0.5 – 2.3
Aleukemic, Subleukemic, & NOS	2	3.7	0.5	0.0 – 2.5

Note: The SIR (standardized incidence ratio) is defined as the number of observed cases divided by the number of expected cases. The latter is based on race-, sex-, and age-specific cancer incidence rates for Texas during the period 1999–2008. The SIR has been rounded to the first decimal place.

*Significantly higher than expected at the $p < 0.01$ level.
**Significantly lower than expected at the $p < 0.01$ level.

Table 3
Number of Observed and Expected Female Cancer Cases and Adjusted Standardized Incidence Ratios Selected Cancers (All Ages), Refinery Row Zip Codes, Corpus Christi, TX, 1999–2008

	Females			
Site	**Observed**	**Expected**	**SIR**	**99% CI**
Colon and Rectum	326	281.4	1.2	1.0 – 1.3
Lung and Bronchus	312	304.9	1.0	0.9 – 1.2
Breast	756	751.0	1.0	0.9 – 1.1
Corpus and Uterus	140	133.4	1.1	0.8 – 1.3
Bladder	53	47.4	1.1	0.8 – 1.6
Kidney and Renal Pelvis	82	92.2	0.9	0.7 – 1.2
Liver and Intrahepatic Bile Duct	46	42.2	1.1	0.7 – 1.6
Esophagus	18	11.9	1.5	0.8 – 2.7
Brain/CNS	34	38.1	0.9	0.6 – 1.4
Non-Hodgkin's Lymphoma	109	116.1	0.9	0.7 – 1.2
Total Leukemia	59	73.4	0.8	0.6 – 1.1
Acute Lymphocytic Leukemia	10	12.9	0.8	0.3 – 1.7
Chronic Lymphocytic Leukemia	14	20.5	0.7	0.3 – 1.3
Acute Myeloid Leukemia	17	20.2	0.8	0.4 – 1.5
Chronic Myeloid Leukemia	12	10.0	1.2	0.5 – 2.4
Aleukemic, Subleukemic, & NOS	3	3.8	0.8	0.1 – 2.9

Note: The SIR (standardized incidence ratio) is defined as the number of observed cases divided by the number of expected cases. The latter is based on race-, sex-, and age-specific cancer incidence rates for Texas during the period 1999–2008. The SIR has been rounded to the first decimal place.

*Significantly higher than expected at the $p < 0.01$ level.
**Significantly lower than expected at the $p < 0.01$ level.

Appendix N. Community Concerns Evaluation

During the public health evaluation process, concerns that Refinery Row area residents expressed to Agency for Toxic Substances and Disease Registry (ATSDR) staff divide into four main groups: 1) odor concerns, 2) health concerns, 3) environmental concerns, and 4) miscellaneous concerns. To the extent possible, ATSDR addresses these concerns in this appendix.

N1. Odor Concerns

Over the years, Refinery Row area residents repeatedly expressed concerns about recurring odors in the air. Industrial odor sources in the area include air pollutants released from the various refineries, a meat processing facility, sewage treatment facilities, and other industries. Cars, trucks, barges, and other transport vehicles using Highway I-37 and the Corpus Christi Ship Channel are also odor sources, as well as the nearby airport. Natural and agricultural odor sources occur throughout the Corpus Christi area.

N1.1. Odors and Health

Environmental odors can affect people's sense of well being and reduce their quality of life. Odors can also be a warning of potential risk and might cause symptoms in sensitive persons [Schiffman and Williams 2005]. Exactly how odors relate to health varies by chemical and by person. For many chemicals, people can smell odors at levels far lower than the levels known to cause symptoms or diseases. Conversely, some chemicals might have harmful effects at levels below their odor thresholds.[61] Further, some chemicals, such as carbon monoxide, do not exhibit any odor at all. So because the air is odoriferous does not mean chemicals are present at harmful levels; conversely, the absence of odors does not mean that the air is harmless to breathe.

Not everyone reacts to odors in the same way. Some people might adversely react to an environmental odor, while others might have no reaction at all. Many factors, including personal traits and habits, affect how someone responds to environmental odors. People with lung diseases, such as asthma and chronic obstructive pulmonary disease (COPD), migraines, and depression might be particularly sensitive to odor effects. For example, on February 18, 2010, one ATSDR staff member developed a headache while working in the Dona Park neighborhood. But this staff member suffers from chronic migraine headaches and is especially sensitive to environmental odors. On this particular day, the staff member noted a strong, rotten-egg-like odor.

When an airborne chemical is near its odor threshold, people can first *detect* the odor. As the chemical's airborne levels increase, people can *recognize* the specific odor type and might exhibit various health symptoms, such as headache, eye irritation, throat irritation, cough, wheezing, and nausea. As noted previously, a chemical's harmful levels are sometimes above and sometimes below odor thresholds. In some cases, health symptoms might actually be due to a nonodorous chemical in the air at harmful levels rather than an odorous chemical.

Several factors help explain a person's reaction to environmental odors. Health symptoms might happen when a person breathes an odorous chemical at levels that also cause irritation or other toxicological (harmful) effects. In this instance, the irritation rather than the odor likely causes the health symptoms. Basically, when an odorous chemical in the air stimulates odorant receptors mediated by the olfactory nerve in the nasal cavity, the odor sensations produced are described as floral, fruity, earthy, fishy, and

[61] Odor thresholds are defined as the level that the odor can first be detected by smell.

other such adjectives. When, however, the chemical also activates the trigeminal nerve endings in the upper and lower respiratory system, sensations such as irritation, burning, stinging, scratching, and itching can occur. Although both odor and irritant sensations occur simultaneously, irritation more likely causes the health symptoms, rather than odor [Schiffman and Williams 2005].

Health symptoms from odors might also occur at nonirritating levels above the odor threshold, especially when the odor is unpleasant. People are genetically coded in a way that pleasant and unpleasant odors activate different parts of the brain, and a biological imperative appears to alert people reflexively to avoid unpleasant odors. And if unpleasant odors are strong, shallow and irregular breathing can occur. Breathing unpleasant odors can also exacerbate illnesses because the odors impair mood and induce stress. Further, in the absence of flu virus or allergy, learned associations might play a role; for example, if an unpleasant odor has previously been associated with flu or allergic symptoms, the odor alone might subsequently recreate these symptoms [Schiffman and Williams 2005].

Olfactory fatigue is another important reaction to environmental odors. Continuous exposure to an odor results in the disappearance of the odor even though the chemical remains in the air. If the exposure is not too prolonged, the odor might return after the person breathes fresh air for a few minutes. On the other hand, workers chronically exposed to strong odors can experience olfactory fatigue that persists for weeks [Amoore and Hautala 1983].

ATSDR's Web site has general information on odors and health at: http://www.atsdr.cdc.gov/odors/.

N1.2. Odor Threshold Limits

Several pollutants common to Refinery Row facilities are known to cause objectionable odors. These include certain sulfur-containing compounds and hydrocarbons. ATSDR, however, has not developed odor-based comparison values to screen environmental data. Thus to determine which chemicals in the air exceeded odor thresholds, ATSDR reviewed the literature and developed a list of available odor threshold limit values with which to screen Refinery Row area air data.

In the early 1980s, Amoore and Hautala (1983) were among the first to review and compile odor threshold data. The purpose of their 214-chemical review was to develop "charts that may be used to estimate the relative detectability, warning potential and rousing capacity of the odorous vapors". They primarily directed their research to potential applications of the odor threshold data in chemical safety, and in air and water pollution control.

Then in 1989, the American Industrial Hygiene Association (AIHA) reviewed and critiqued available odor threshold data on 182 chemicals. AIHA evaluated the methodologies from the available, published odor threshold references against a set of objective criteria. The criteria included factors associated with 1) odor panelist selection and training techniques, 2) the apparatus used in preparing, presenting, and quantifying the odorant concentration, and 3) the presentation method. The purpose of the AIHA review was to present the best estimate of odor threshold for chemicals satisfying the evaluation criteria in its review. AIHA considered the geometric mean of its acceptable data as a reasonable estimate of the actual odor threshold [AIHA 1989]. In 1992, the U.S. Environmental Protection Agency (U.S. EPA) used the AIHA approach and criteria to focus on development of an odor threshold reference guide for hazardous air pollutants listed in the 1990 Clean Air Act Amendment [USEPA 1992].

In 2006, the Texas Commission on Environmental Quality (TCEQ) released guidance that generally set acute, odor-based effects screening level (${}^{acute}ESL_{odor}$) values for chemicals at the lowest acceptable odor threshold value that met the evaluation criteria set by AIHA (1989) and U.S. EPA (1992). But with improved methods for odor measurement, in May 2010, TCEQ released interim guidelines for setting $^{acute}ESL_{odor}$ values that contained revisions from its 2006 guidance, which it considered possibly outdated. TCEQ guidance states the introduction of improved instrument calibration, improved panel screening procedures and the adoption of n-butanol as a reference material, have enabled more objective odor measurements [TCEQ 2010]. Standardized odor measurement methods, such as those by the American Society of Testing and Materials, ensure objective, quantitative, dependable, and reproducible results.

TCEQ's interim guidance incorporates the three quality levels defined by the National Advisory Committee for Acute Exposure Guideline Levels for Hazardous Substances [van Doorn et al. 2002] and the Netherlands National Institute for Public Health and the Environment [Ruijten et al. 2009]. These levels are defined as

> ***Level 1:*** the threshold of a compound determined according to standardized methods. For the specific methods noted in the TCEQ guidance, visit http://www.tceq.state.tx.us/assets/public/implementation/tox/esl/guidelines/odor.pdf.
>
> ***Level 2:*** thresholds from other sources other than the standardized methods that include an internal reference to an n-butanol standard.
>
> ***Level 3:*** thresholds measured without an internal reference to an n-butanol standard that met the criteria for odor studies established by AIHA (1989) and U.S. EPA (1992).

TCEQ interim guidance considers Level 1 odor threshold data first in setting $^{acute}ESL_{odor}$ values [TCEQ 2010, 2013]. If no Level 1 values are available, Level 2 quality data are considered. If no Level 1 or 2 odor thresholds are available, then Level 3 quality data are considered.

For its screening analysis of odors, ATSDR compiled available odor thresholds from AIHA (1989), U.S. EPA (1992), and TCEQ (2013) for the chemicals monitored in the Refinery Row area. Table 39B, Appendix B, provides odor threshold data for those chemicals with published odor thresholds by at least one of these entities.

N1.3. Odor Screening Results

ATSDR screened the maximum detected chemical air concentrations from monitoring in Corpus Christi against available odor threshold values. This evaluation did not consider chemicals without established odor thresholds.

Auto GC. Oak Park and Solar Estates monitors detected most chemicals below their respective odor thresholds. Two chemicals exceeded odor thresholds, but on rare occasions. Isopropylbenzene exceeded its odor threshold at Oak Park in 1 of 44,040 samples (0.002%) and at Solar Estates in 1 of 40,859 samples (0.002%). Styrene exceeded its odor threshold at Oak Park in 1 of 44,393 samples (0.002%.) From 2003 to 2010 the Huisache auto-GC detected no exceedences of the benzene odor threshold.

TCEQ Canisters. At no time did volatile organic compounds (VOCs) exceed their respective odor thresholds at the TCEQ air monitoring stations.

Industry Canisters. Before 2005, butyraldehyde exceeded its odor threshold at Crossley Elementary School in 1 of 314 samples (0.3%) and at Tuloso Midway Middle School in 1 of 356 samples (0.3%.) But after December 2004, butyraldehyde and several other VOCs were no longer part of the VOC analysis.

From the time industry began measuring contaminants in ambient air, these monitoring stations have not detected any other odor threshold exceedences.

AQP Triggered Canisters. From 2005 to 2010, the monitors triggered between 1 and 82 times. During these events, no odor threshold exceedences were detected at the Dona Park, Oak Park, Off Up River Road, Port Grain Elevator, and Solar Estates air monitoring stations. A few chemicals were detected above their respective odor thresholds in one sample at JI Hailey (1-pentene, isopentane, isoprene, and p-xylene + m-xylene) and West End Inner Harbor (isoprene and p-xylene + m-xylene).

Mobile Monitoring. Between July 1993 and March 2008, ATSDR compiled mobile monitoring data from 24 sampling events in the Corpus Christi Refinery Row area. As shown in Table 40B, Appendix B, during the mobile monitoring events, 12 chemicals

benzene	methyl t-butyl ether
butyraldehyde	Methylcyclohexane
isopentane	Styrene
isopentane + c-2-butene	Toluene
isoprene	n-pentane
isopropylbenzene	m-xylene + p-xylene

were detected above their respective odor thresholds in 9 or fewer samples. In addition, Table 42B, Appendix B, shows that during mobile events, sulfur dioxide exceeds its odor threshold less than 10% of the time.

Hydrogen sulfide's odor threshold varies widely and depends on individual sensitivity. In the literature the range is from 0.5 to 300 ppb [ATSDR 2006]. ATSDR thus screened the hydrogen sulfide data with the lowest reported odor thresholds from two sources—that is, with 4.5 ppb [AIHA 1989] and 0.5 ppb [Ruth 1986]. During mobile monitoring events hydrogen sulfide frequently exceeded its odor thresholds (see Table 43B, Appendix B). Hydrogen sulfide was detected over the 4.5 ppb odor threshold in 46–100% of the samples, and detected over the 0.5 ppb odor threshold in 47–100% of the samples.

Sulfur Compounds. For continuous monitoring at seven of the eight stationary air monitors, sulfur dioxide did not exceed its odor threshold value of 300 ppb. At the Tuloso Midway Middle School, since continuous monitoring began in 1984, three samples exceeded the sulfur dioxide odor threshold level. These three exceedences occurred many years ago (i.e., before 1998.)

For continuous monitoring, Table 41B, Appendix B, provides hydrogen sulfide data that exceeded the two odor thresholds at the seven stationary monitors. Hydrogen sulfide odor threshold exceedences were not frequent (0.08% – 1.9%) when compared with the 4.5 ppb odor threshold, but were more frequent (16% – 31%) when compared with the 0.5 ppb odor threshold.

N1.4. Odor Discussion

The majority of chemicals detected in ambient air along Refinery Row are below their respective odor thresholds. A few chemicals were detected above their respective odor thresholds infrequently, i.e., less than 10% of the time. These chemicals are benzene, butyraldehyde, isopentane, isopentane + c-2-butene, isoprene, isopropylbenzene, methyl t-butyl ether, methylcyclohexane, styrene, sulfur dioxide, toluene, 1-pentene, n-pentane, and m-xylene + p-xylene.

As stated previously, not everyone reacts to odors the same way. And some people (e.g., people with asthma) might be particularly sensitive to odor effects. People living and working in the area may occasionally experience odor-related health symptoms when breathing levels of those chemicals that are infrequently detected above their respective odor thresholds. However, because these chemicals were not detected regularly above odor thresholds, ATSDR considers it unlikely that any of these chemicals are associated with the concerns expressed by area residents about recurring odors in their communities' air.

One chemical was detected more frequently above its lowest odor threshold—hydrogen sulfide.

Tables 39B and 41B, Appendix B, show hydrogen sulfide was detected frequently above its lowest odor threshold along Refinery Row 1) prior to 2005 and between 2005–2010 and 2) during stationary air monitoring and mobile monitoring events. These exceedences occurred at industrial and ship channel areas, as well as neighborhood areas.

Hydrogen sulfide is a flammable, colorless gas with a characteristic odor of rotten eggs. People usually can smell hydrogen sulfide at low concentrations in air. However, the level one smells this chemical depends on each person's sensitivity and the variability is large, ranging from 0.5 ppb to 300 ppb [ATSDR 2006]. Hydrogen sulfide occurs naturally (e.g., from volcanoes, sulfur springs, undersea vents, and swamps). Hydrogen sulfide is also associated with sewage treatment plants, swine containment and manure-handling operations, landfills, petroleum refineries, natural gas plants, petrochemical plants, coke oven plants, food processing plants, and tanneries [ATSDR 2006].

There are numerous studies associating hydrogen sulfide odors and health symptoms [ATSDR 2006, 2012]. Some of these studies include:

- Odor and hydrogen sulfide were associated with respiratory symptoms and eye irritation in community members living near industrial hog operations [Schinasi et al. 2011].
- During a study of swine production areas, community members who detected odors reported symptoms such as headaches, runny nose, cough, and vomiting [Godbout et al. 2009]. Air monitoring reported about the same average hydrogen sulfide concentrations in exposed communities (1.1 – 1.6 ppb) and non-exposed communities (1.1 – 1.5 ppb), although the median log of the odor intensity value in the exposed communities was twice the non-exposed communities.
- A study of residents in a community bordering a landfill reported a strong association of odor with average hourly hydrogen sulfide concentrations [Heaney et al. 2011]. Specifically, this study found that the odor was strongly associated with mucosal irritation, upper respiratory symptoms, alteration of daily activities, and negative mood states. For the study, hydrogen sulfide measurements were recorded over a period of 80 days and the average hydrogen sulfide concentration was 0.22 ppb (range of 0 – 2.3 ppb.)
- In a controlled exposure study of 74 healthy adults, increases in ratings of odor intensity, irritation and unpleasantness were observed with increasing hydrogen sulfide levels [Fiedler et al. 2008]. A decline in verbal-learning task performance was observed during all three hydrogen sulfide exposure conditions (50 ppb, 500 ppb, and 5,000 ppb.)
- In an evaluation of increased emissions over two days from a pulp mill, the occurrence of participants reporting difficulties in breathing, irritation of the eyes, headache and nausea was

large in the high-exposure period [Haahtela et al. 1992]. The highest 4-hour concentration of hydrogen sulfide was 96 ppb and the 24-hour averages for the two days were 25 and 31 ppb.

- Odor and hourly hydrogen sulfide measurements were evaluated in low-income communities near industrial hog operations in eastern North Carolina [Horton 2009]. Stress or annoyance was associated with increasing levels of hydrogen sulfide. Hydrogen sulfide was also associated with nervous or anxious feelings. The highest measured hydrogen sulfide values in the 16 communities ranged from 2 ppb to 90 ppb, and the average values ranged from less than 0.01 ppb to 1.5 ppb.

Overall, both the stationary monitors and the mobile monitoring events show hydrogen sulfide regularly above its lowest odor threshold. People who live and work along Refinery Row may experience odor-related health symptoms such as eye irritation, headaches, cough, difficulties in breathing, negative mood states, and stress or annoyance when hydrogen sulfide exceeds it odor threshold. ATSDR finds that the community concern about recurring odors along Refinery Row may be associated with hydrogen sulfide in the ambient air both prior to 2005 and from 2005–2010. ATSDR considers it a prudent public health measure to reduce or eliminate releases of hydrogen sulfide into Refinery Row air wherever possible.

ATSDR also notes TCEQ is mandated to regulate odor as part of the Texas Clean Air Act so as not to interfere with the normal use and enjoyment of property. According to the TCEQ guidelines, persistent or recurrent exposure to strong odors may cause indirect health effects such as headaches and nausea. Refinery Row community members seeking information on how to make an environmental complaint to TCEQ regarding odor nuisances should visit TCEQ's website at: http://www.tceq.state.tx.us/compliance/complaints/odor_complaint.html.

N2. Health Concerns

Over the years, Refinery Row area residents have expressed a variety of health concerns

birth defects	abdominal spasms
cancer	skin rashes
brain tumors (in particular, pituitary tumors)	Diabetes
respiratory illnesses (in particular, asthma)	Alzheimer's disease
attention deficit/hyperactivity disorder	Miscarriages
eye irritation	Stress
burning throat	

to ATSDR staff. Birth defects, cancer and asthma are discussed in Section 9 of the main text. The remaining concerns are discussed here.

N2.1. Brain Tumors (in particular, pituitary tumors)

A brain tumor is a mass or growth of abnormal cells in the brain. Brain tumors can begin in the brain (primary brain tumors), or cancer can begin in other parts of the body and spread to the brain (secondary brain tumors) [Mayo Clinic 2010a].

The pituitary gland is a small, bean-shaped gland situated at the base of the brain, somewhat behind the nose and between the ears. Despite its small size, the gland influences nearly every part of the human body. The hormones it produces help regulate growth, blood pressure and reproduction [Mayo Clinic 2010b].

The vast majority of pituitary tumors are benign growths (adenomas). Adenomas remain confined to the pituitary gland or surrounding tissues and don't spread to other parts of the body.

The cause of uncontrolled cell growth in the pituitary gland, creating a tumor, remains unknown. A small percentage of pituitary tumor cases run in families, but most have no apparent hereditary factor. Although pituitary tumors can occur at any age, they are most likely to occur in older adults [Mayo Clinic 2010b].

Based on a review of the Refinery Row air data, ATSDR did not find any associations between the levels of potential carcinogens in outdoor air and brain tumors. As stated previously, ATSDR requested DSHS examine the occurrence of cancer within a five mile buffer zone surrounding Refinery Row. From January 1, 1999 to December 31, 2008, the number of cancers of the brain/central nervous system was within the expected range in both males and females in the Refinery Row area (see Section 4L of Appendix L).

N2.2. Attention Deficit/Hyperactivity Disorder

Attention-deficit/hyperactivity disorder (ADHD) is a chronic condition that affects millions of children and often persists into adulthood. ADHD includes problems such as difficulty sustaining attention, hyperactivity, and impulsive behavior. Children with ADHD also may struggle with low self-esteem, troubled relationships, and poor performance in school [Mayo Clinic 2011].

The causes and risk factors for ADHD are unknown, but current research shows that genetics plays an important role. In addition to genetics, scientists are studying other possible causes and risk factors including brain injury, environmental exposures (e.g., lead), alcohol and tobacco use during pregnancy, premature delivery, and low birth weight [CDC 2010].

Refinery Row community members expressed concern regarding ADHD and its occurrence in their community. In the United States, a national telephone survey of parents indicated 5.4 million children have been diagnosed with ADHD, which is nearly one in ten school age children with an ADHD diagnosis [CDC 2011b]. Unfortunately, information within geographic areas (such as counties) throughout the state is not available from this survey. Because readily available data sources are not available to permit a site-specific evaluation of ADHD for the Refinery Row community, ATSDR cannot address the question of whether rates are elevated compared to other counties in Texas or the United States.

N2.3. Eye Irritation

Eye irritation includes symptoms such as eye dryness, excess tearing, itching, pain, scratchiness, soreness, and redness. It is a common problem experienced by people of all ages. Eye irritation can occur for several reasons, including eye allergies, dry eye syndrome, viral infections, bacterial infections, and chemical exposure.

In Section 7 of the main text and Appendix I, ATSDR noted five chemicals (1-butanol, chlorine gas, chloroprene, 1,2-dichloropropane, and toluene) that have been associated with eye irritation in epidemiologic (human) or experimental (animal) studies, or both. However, the maximum levels of these five chemicals detected in Refinery Row air are an order of magnitude or more below levels documented to cause eye irritation.

As stated in Section N1.4 of this appendix, eye irritation is one of the health symptoms typically associated with odorous chemicals. In its odor review, ATSDR found that community concern about recurring odors along Refinery Row may be associated with hydrogen sulfide, which has been and is detected regularly above its lowest odor threshold. Symptoms like eye irritation are expected to resolve after exposure ends.

N2.4. Burning Throat

If the esophagus for any reason becomes inflamed, a burning throat sensation will result. Air pollution can also lead to a burning sensation in the rear of the throat and nose, due to the existence of chemicals in the air. In Section 7 of the main text and Appendix I, ATSDR noted three chemicals (benzene, chlorine gas, and 1,2-dichloropropane) that have been associated with throat irritation in the epidemiologic or experimental studies, or both. However, the levels of these three chemicals detected in Refinery Row air are an order of magnitude or more below levels documented to cause throat irritation.

N2.5. Abdominal Spasms

Abdominal spasms are involuntary contractions of the muscles of the abdomen. During a spasm, the muscle will feel stiff. These spasms can occur as a result of muscle strain during heavy use or overuse, fatigue, and dehydration. Abdominal muscle strain is a common injury among athletes. However, abdominal spasms may also be caused by acute disorders of the organs located within the abdomen. In Section 7 of the main text and Appendix I, ATSDR did not note any Refinery Row chemicals to be associated with abdominal spasms in the epidemiologic or experimental studies.

N2.6. Skin Rashes

A skin rash is an area of irritated or swollen skin that can be red and itchy, bumpy, scaly, crusty or blistered. The cause can often be determined from its visible characteristics and other symptoms. Common causes of skin rashes include other diseases, irritating substances, allergies, and a person's genetic makeup. Contact dermatitis, meaning inflammation of the skin, is caused by things that touch a person's skin such as certain chemicals and poison ivy [NIH 2012a]. In Section 7 of the main text and Appendix I, ATSDR noted five chemicals (arsenic, 1-butanol, chloroprene, 1,2-dichloropropane, and 1,1,2-trichloroethane) that have been associated with skin irritation in the epidemiologic or experimental studies, or both. However, the levels of these five chemicals detected in Refinery Row air are an order of magnitude or more below levels documented to cause skin irritation.

N2.7. Diabetes

Diabetes is a disease in which blood glucose levels are above normal. Most of the food people eat is turned into glucose, or sugar. A hormone called insulin helps glucose get into cells to give them energy. When a person has diabetes, the body either does not make enough insulin or cannot use its own insulin as well as it should [CDC 2011c].

Type 1 diabetes may account for about 5% of all diagnosed cases of diabetes. The exact mechanism for developing type 1 diabetes is unknown. The appearance of type 1 diabetes is suspected to follow exposure to an environmental trigger, such as an unidentified virus, in some genetically predisposed people. Risk factors are not well defined, but autoimmune, genetic, and environmental factors are involved in developing this type of diabetes [CDC 2011c].

Type 2 diabetes may account for about 90% to 95% of all diagnosed cases of diabetes. Like type 1 diabetes, the exact mechanism for developing type 2 diabetes is unknown. Risk factors for type 2 diabetes include older age, obesity, family history of diabetes, impaired glucose tolerance, physical inactivity, and race/ethnicity. African Americans, Hispanic/Latino Americans, American Indians, and some Asian Americans and Pacific Islanders are at particularly high risk for type 2 diabetes [CDC 2011c].

In Section 6I of Appendix I, ATSDR noted a study that documented a likely association of diabetes with particulate chlorine exposure [Reis et al. 2009]. In this study, the particulate chlorine was determined to be dominated by organochlorine pesticides. Conversely, Karnae and John (2011) found that much of the chlorine from the TCEQ Dona Park monitor was fresh and aged sea salt. And mean levels of particulate chlorine in Refinery Row air are more than an order of magnitude lower than the particulate chlorine level that has been associated with diabetes in the Reis et al. (2009) study.

In Section 3L of Appendix L, ATSDR reviewed diabetes prevalence data for Texas from the annual Behavioral Risk Factor Surveillance System survey (BRFSS). ATSDR noted that surveyors invite only respondents aged 18 years and older to answer the telephone survey and that the questions regarding diabetes do not separate the type of diabetes. Also, ATSDR did not count diabetic females who reported only having diabetes during pregnancy. Using data from the 2008 telephone survey, ATSDR found that these data do not indicate an increased prevalence of diabetes in the Refinery Row area.

ATSDR understands diabetes remains a major community concern. ATSDR supports the diabetes work by local organizations such as the Coastal Bend Diabetes Initiative (CBDI). The CBDI is a partnership of the medical profession, community leaders, and local industry that was created to provide a coordinated effort against diabetes-related illnesses. The CBDI mission is to reduce diabetes in the Corpus Christi area through a collaborative community effort to promote public awareness, education and prevention of diabetes [CBDI 2014]. For additional information, see http://coastalbenddiabetesinitiative.com/.

N2.8. Alzheimer's Disease

Alzheimer's disease is the most common form of dementia among older adults. Alzheimer's disease involves parts of the brain that control thought, memory, and language, and can seriously affect a person's ability to carry out daily activities [CDC 2011d].

Scientists do not yet fully understand what causes Alzheimer's disease. There probably is not one single cause, but several factors that affect each person differently. Age is the most important known risk factor for Alzheimer's disease. The number of people with the disease doubles every 5 years beyond age 65. Family history is another risk factor. Researchers believe that genetics may play a role in developing Alzheimer's disease [CDC 2011d].

ATSDR is not aware of any association between the chemicals detected in Refinery Row air and Alzheimer's disease.

N2.9. Miscarriages

A miscarriage is the loss of pregnancy from natural causes before the 20th week of pregnancy. Most miscarriages occur very early in the pregnancy, often before a woman even knows she is pregnant [NIH 2012b].

Various factors increase the risk of miscarriage [Mayo Clinic 2010c]:

- Age. Women older than age 35 have a higher risk of miscarriage than do younger women.
- Previous miscarriages. The risk of miscarriage is higher in women with a history of more than one previous miscarriage.
- Chronic conditions. Women with certain chronic conditions, such as diabetes or thyroid disease, have a higher risk of miscarriage.
- Uterine or cervical problems. Certain uterine abnormalities or a weak or unusually short cervix may increase the risk of miscarriage.
- Smoking and alcohol. Women who smoke or drink alcohol during pregnancy have a greater risk of miscarriage than do nonsmokers and women who avoid alcohol during pregnancy.
- Invasive prenatal tests. Some prenatal genetic tests, such as chorionic villus sampling and amniocentesis, carry a slight risk of miscarriage.

In Section 7 of the main text and Appendix I, ATSDR did not note any Refinery Row chemicals to be associated with miscarriages in the epidemiologic or experimental studies.

N2.10. Stress

Stress can come from any situation or thought that makes you feel frustrated, angry, nervous, or anxious. People react to stress differently: what is stressful for one person may be pleasurable or have little effect on others. People who feel stress may have pain in the abdomen, headaches, and muscle tightness or pain. People who are very stressed may notice a faster heart rate, skipped heartbeats, rapid breathing, sweating, trembling, and dizziness [NIH 2011].

In Section N.1 of this appendix, ATSDR notes breathing unpleasant odors can impair mood and induce stress. People who live and work along Refinery Row may experience odor-related health symptoms such negative mood states and stress when hydrogen sulfide exceeds it odor threshold.

N3. Environmental Concerns

Over the years, Refinery Row area residents have expressed a variety of environmental concerns to ATSDR staff.

N3.1. Air pollution from the refineries

Both industrial facilities and motor vehicles can be significant contributors to air pollution in metropolitan areas. It is important to note that attributing airborne exposures to individual sources is an extremely difficult task. In this public health evaluation, ATSDR uses the conditional probability function (CPF) to show chemical trends in the Refinery Row area. The CPF, which is used to show the probability that the chemical concentration is within a given interval when the winds are from a given direction and speed, is a useful tool for gaining an idea of potential sources.

In Section 6.4 of the main text and Appendix G, ATSDR provided the results of its CPF plots for stationary air monitors that divided the benzene, hydrogen sulfide, particulate matter, and sulfur dioxide concentrations into various concentration ranges. The plots show that potential Refinery Row-related sources exist when these compounds are in the top concentration ranges. Because of the uncertainty in determining the extent to which each individual source contributes to general air pollution, however, ATSDR's evaluation only shows potential sources; the evaluation does not provide quantitative estimates of each source's impact on levels of air pollution.

N3.2. Air pollution from the highway

As noted in the previous response, both industrial facilities and motor vehicles can be significant contributors to air pollution in metropolitan areas. Interstate 37 (I-37) is a 143-mile highway that connects Corpus Christi and San Antonio, Texas. In Corpus Christi, I-37 lies along the southern boundary of Refinery Row.

Mobile sources can be a significant source of chemicals such as benzene. ATSDR cannot be certain of exactly how much the highway contributes to general air pollution in the Refinery Row area. Overall though, the CPF plots do not show I-37 as a major source of benzene concentrations in the top ranges (see Figures 20A–22A, Appendix A).

ATSDR notes that community members interested in local air pollution initiatives in Corpus Christi can contact the Pollution Prevention Partnership (see http://outreach.tamucc.edu/p3/index.html). The Pollution Prevention Partnership was started in 1995 to address air quality issues in Corpus Christi. The partnership delivers a broad range of environmental assistance programs and services including environmental education, pollution prevention, and environmental compliance assistance to citizens, schools, businesses, industry, and government [TAMU 2012].

N3.3. Hydrogen Fluoride Releases

Community members in Corpus Christi have expressed concerns to ATSDR about accidental releases of hydrogen fluoride from area refineries. Although ATSDR cannot directly address community concerns about accidental hydrogen fluoride releases because the agency does not have data on hydrogen fluoride levels in Refinery Row air, permitting authority, or enforcement authority, the agency provides the following general information regarding hydrogen fluoride.

Hydrogen fluoride (HF) is a colorless, fuming liquid or gas. When it is dissolved in water, it is called hydrofluoric acid. Airborne hydrogen fluoride concentrations of 3,000 ppb can produce irritation of the eyes and throat. Hydrogen fluoride has a strong irritating odor that is discernible at concentrations of about 40 ppb. Odor generally provides adequate warning of hazardous concentrations in air [ATSDR 2011a; CDC 2006].

Refineries use hydrogen fluoride in a manufacturing process called "alkylation" to produce high-octane fuel. In the early 1990s, as part of the Clean Air Act as amended, U.S. EPA was asked to study the hazards associated with the production and uses of hydrogen fluoride and to make recommendations about reducing these hazards based on the findings [USEPA 1993]. In November 1993, the Occupational Safety and Health Administration (OSHA) released a bulletin to alert field personnel to the potential safety and health risks posed by hydrogen fluoride used in alkylation units and to present the control measures implemented by industry to reduce workers' exposure, and pertinent OSHA requirements [OSHA 1993]. Facilities using hydrogen fluoride have employed several techniques in attempt to mitigate the effects and minimize the hazards of hydrogen fluoride releases. These control measures have included water systems to knock down hydrogen fluoride vapors and put out fires, scrubber systems in the vents that help to absorb hydrogen fluoride vapors, emergency isolation valves, and emergency systems that can remove hydrogen fluoride from failing equipment [USEPA 1993].

In Corpus Christi, industry works with the Local Emergency Planning Committee to communicate to the public about incidents and emergencies. See Miscellaneous Concerns, Section N4.7, for further information about the emergency alert systems in Corpus Christi.

N3.4. Groundwater contamination in Hillcrest

To address community concerns expressed during a December 2009 neighborhood meeting, TCEQ conducted the Hillcrest Community Environmental Investigation (HCEI). The objective of the HCEI was to determine whether there are environmental impacts from VOCs to soil, groundwater, or ambient air in the Hillcrest community and adjacent areas [TCEQ 2011a].

The Hillcrest community gets its drinking water from the City of Corpus Christi–O.N. Stevens Water Treatment Plant [TCEQ 2012a]. This drinking water is monitored by the city and is suitable for drinking and household use. As such, Hillcrest community members do not drink the groundwater under their community. However, if volatile chemicals exist in the groundwater, these chemicals could potentially move from the groundwater, through the soil, and into the air.

CITGO East and Flint Hills East lie adjacent to Hillcrest's western and northern borders. Both refineries monitor groundwater to delineate the boundary between contaminated and clean groundwater. Also, both refineries have recovery wells in place to recover phase separated hydrocarbons, which is oil floating on groundwater, and dissolved phase hydrocarbons, which is chemicals within the groundwater [TCEQ 2011b].

As part of the HCEI, TCEQ conducted two groundwater sampling events in Hillcrest during two different seasons to account for potential seasonal variation. TCEQ and U.S. EPA collected and analyzed split groundwater samples during the events. TCEQ used its groundwater-to-air protective concentration levels (PCLs) to evaluate the possibility that a potential pathway of exposure from groundwater-to-air could be of health concern. TCEQ reported that the measured levels of all VOCs, polycyclic aromatic hydrocarbons (PAHs), and total petroleum hydrocarbons (TPH) from both TCEQ and U.S. EPA groundwater samples were below their respective groundwater-to-air PCLs. TCEQ stated that exposures to the reported levels of VOCs, PAHs, and TPH in the groundwater are not expected to result in adverse health effects, even in potentially sensitive populations such as children [TCEQ 2012b].

In response to comments on the HCEI that contaminated groundwater from the refineries has migrated into the Hillcrest neighborhood, TCEQ responded that although areas of groundwater contamination were observed beyond the boundaries of responsible party facilities, these areas were not residential areas [TCEQ 2011c]. TCEQ reported that the responsible parties have been directed to expand their assessment and/or remediation efforts in response to these new data [TCEQ 2011c].

N3.5. Soil contamination in Dona Park

TCEQ conducted the Dona Park Neighborhood Assessment (DPNA) to address community concerns about soil exposures. The DPNA was a thorough look at environmental cleanups conducted in Dona Park and Manchester Place. These neighborhoods are south of the former ASARCO/Encycle facility. ASARCO employed an air discharge smokestack as part of its zinc smelter operations. Emissions from the smokestack were a potential source of zinc, cadmium, and lead contamination in these neighborhoods [TCEQ 2011d].

As part of the DPNA, all properties where access was granted were assessed for the chemicals of concern. Of the nearly 500 yards that were tested, five exhibited concentrations above TCEQ's PCLs and required cleanup, which was completed in July and August 2011 [TCEQ 2011d].

Also, TCEQ asked DSHS to evaluate the potential public health implications of contaminants found in soil samples collected in the Dona Park neighborhood. DSHS concluded that [DSHS 2013]

- Children who regularly ingest residential soil could experience small increases in blood lead levels.
- Cadmium levels found in soil samples are not expected to result in adverse health effects in adults or children.
- It is possible for cadmium to be present in fruits or vegetables grown in the soil; however, this pathway is not expected to present a significant health risk for children or adults.

DSHS plans to continue to work with environmental agencies and local health authorities to provide exposure prevention education.

N4. Miscellaneous Concerns

Over the years, Refinery Row area residents have expressed a variety of miscellaneous concerns to ATSDR staff.

N4.1. Pets' Health (in particular, dogs with tumors, legs collapsing, seizures, and blindness)

Pets can be fun. They can add a feeling of companionship and safety to a person's life. ATSDR notes, though, its mission is to prevent harm to *human* health by identifying communities where people might be exposed to hazardous substances in the environment. Nonetheless, like with people, pets' health can be impacted by their environment. In Section 7 of the main text and Appendix I, ATSDR did not note any Refinery Row chemicals to be associated with legs collapsing, seizures, and blindness in the epidemiologic or experimental studies. Long-term exposure to several chemicals is associated with a low risk of cancer in people (malignant tumors). ATSDR suggests community members concerned about their pet's health speak with their veterinarian.

N4.2. Locations of the stationary air monitors

ATSDR acknowledges there are a limited number of stationary air monitors that can be sited and maintained within any geographic area. Although the amounts of chemicals that are taken in by each person day-to-day is not known, stationary air monitors provide useful information on the airborne chemical levels in a particular area.

The stationary air monitoring set up in Corpus Christi is one of the most comprehensive systems ATSDR has ever encountered. Air monitoring data are collected by three different air monitoring networks that use different equipment and analytical methods. Stationary air monitors are located throughout the Refinery Row area (see Figure 8A, Appendix A). The monitors are located where people could potentially be exposed, including schools, parks and neighborhoods, as well as in close proximity to refinery operations and the ship channel. In addition to the stationary air monitors, 24 mobile monitoring events occurred in the Corpus Christi Refinery Row area. These monitoring events captured air chemical levels at a variety of locations, including facility fence-lines and neighborhoods. These short-term mobile events provided additional insight into the levels of chemicals found throughout the Refinery Row area.

ATSDR notes though, a stationary air monitor is not located in every neighborhood, park and school in the Refinery Row area. However, ATSDR believes the locations of the current monitors provide good coverage. As part of its cross-network comparisons (see Section 6.2 and Appendix G), ATSDR compared the benzene measurements at one location with measurements at other locations. In general, the most significant and strongest data correlations existed between sites that were geographically closest to each other. Overall though, ATSDR found significant correlations between all locations, each of which showed similar benzene measurements on concurrent days despite the use of different devices and analytical methods.

Therefore, ATSDR finds the locations of the stationary air monitors, combined with the locations of the mobile monitoring events, are sufficient to support the agency's public health evaluation of the Refinery Row air shed.

N4.3. Stationary air monitors might not capture all of the releases the community experiences

Because ambient air is a continuous medium (air is not contained), assessing air quality is complex and requires different strategies. The first challenge is to get air data in both *space* and *time* that are useful for public health evaluations.

- "Space" refers to having air measurements in locations where people are being exposed. As stated previously, for the Refinery Row site, stationary air monitors are located by schools, parks and neighborhoods, as well as in close proximity to refinery operations and the ship channel. The three networks set up along Refinery Row provide good coverage for most chemicals across the area of interest. See previous response regarding locations of the monitors.
- "Time" refers to having air monitoring data that allow for the evaluation of past and current exposures, as well as for the evaluation of short-term and long-term exposures.
    - For this public health report, ATSDR evaluated available air monitoring data from the 1980s through 2010. This allowed for an evaluation of both past and current exposures to ambient air in the Refinery Row area.
    - Two general types of stationary air monitoring—continuous and semi-continuous—have occurred in the Refinery Row area. For example, measurements of hydrogen sulfide, sulfur dioxide, and many VOCs are collected continuously, day after day, year after year. Semi-

continuous monitoring of VOCs and metals also occurs every 2 to 6 days depending on the monitor. These air data can provide hourly (continuous monitoring), daily (continuous and semi-continuous monitoring), and yearly (continuous and semi-continuous monitoring) averages allowing for the evaluation of both short-term and long-term exposures.

As stated previously, the stationary air monitoring set up in Corpus Christi is one of the most comprehensive systems ATSDR has ever encountered. The stationary air monitors capture air data for both *space* and *time* that are useful for public health evaluation. However, ATSDR does agree that the stationary monitoring data may not capture all of the releases the community experiences because they are not available for all pollutants, over all time frames, and across all locations of interest. But the available monitoring data can be used to make inferences about air pollution levels during time frames when—and at locations where—no monitoring occurred. For example, ATSDR's cross-network comparisons of benzene measurements found significant correlations between Auto GC locations (measurements collected 24 hours every day) and canister monitoring locations (measurements collected every 2–6 days). ATSDR's chemical trends analyses for benzene showed proximity to Refinery Row clearly affected the relationships of some locations and wind direction at other locations. Because the measurements for the Auto GC and canister locations were correlated and trends identified, ATSDR can infer 1) that benzene levels at canister locations on days with no monitoring would have the same correlation to levels measured at the Auto GC locations and 2) that other locations within the Refinery Row area where no monitoring occurred (at all) would also show similar correlations and trends based on location. The levels would be expected to follow the same trends (slightly higher or lower concentrations) depending on proximity to the Auto GC locations and by wind direction.

In addition, ATSDR integrates the stationary air monitoring data with other environmental and health information about the area. For the Refinery Row area, this includes mobile monitoring reports, model data, meteorological data, health outcome data, and exposure investigation data. The goal of this report is to expand and enhance what is currently known about air toxics in the Refinery Row area. The report conclusions provide an overall picture of the Refinery Row area using all available information about the area.

N4.4. Lack of data on metals

Monitoring data are not available for all pollutants across all locations of interest. Compared to the number of VOC monitoring sites, ATSDR agrees there are fewer air monitors measuring metals in the Refinery Row area.

Currently, there is one monitor (Dona Park) that monitors metals. This monitor is centrally located in the Refinery Row area (see Figure 8A, Appendix A). ATSDR evaluated the metals data from this monitor in Section 7 of the main text and Appendix I.

Although there is only one currently operating monitor measuring metals concentrations, in the early 1980s, metals data were collected at four monitoring sites and lead data at a fifth site. Spatially, these monitors are located west of Refinery Row, as well as north, south, and southeast. Although ATSDR did not evaluate these 1980s metals data for public health significance, ATSDR did provide information to put the metals levels in perspective (Section 7 of the main text and Appendix I).

N4.5. Impact of pollution on property values

While concerns about loss of property values are legitimate, it is not within the authority of ATSDR to address this issue.

N4.6. Permitting of Las Brisas Facility

Las Brisas Energy Center had planned to construct and operate a 1,320 megawatt electric generating facility and upgrade the existing bulk terminal at the Port of Corpus Christi, Texas [LBEC 2009]. In January 2011, TCEQ issued an air permit for the facility, which allows the construction phase to begin [LBEC 2011]. Community members expressed concern about potential air pollution from the proposed facility. However, in January 2013, plans to construct Las Brisas were cancelled [PennWell Corporation 2013].

N4.7. Confusion about sirens that go off at the different refineries

On many occasions, community members have expressed concern to ATSDR staff regarding their confusion about the sirens that go off at the different refineries. Each facility has its own siren system. So while an alternating high/low pitch siren at one facility means there is a vapor release, a rapidly cycling high pitch siren means vapor release at a different facility.

However, the sirens at the facilities are not meant to advise the community. The sirens at the facilities are meant only to provide on-site personnel (i.e., on-site workers) with information about site-specific procedures that the workers should be following for safely drills, releases, etc. In the event of an emergency that could impact the community, Corpus Christi's Local Emergency Planning Committee (LEPC) provides public outreach. Through the LEPC, several emergency notification systems have been put in place for the community [LEPC 2014]:

- ReverseAlert system—Corpus Christi and Nueces County's ReverseAlert system notifies community members by phone, text, or email about imminent danger. Reverse alerts are automatically sent to residents in areas affected and include information about storms, fires, flash floods, industrial accidents, roadway closures, evacuations, crime bulletins, and other incidents that threaten public safety. Sign up at reversealert.org.
- 826-INFO (4636)—This is a phone number community members can call to find out more information during a significant emergency.
- KLUX 89.5 FM—During a major community emergency, 89.5 FM will begin broadcasting emergency information about the situation.

To assist the community, this topic was part of ATSDR's June 2011 workshop series entitled "It's All about Your Health." During one of the workshops, staff from LEPC played tapes of the siren systems to demonstrate the various wails, pulses, high pitches and low pitches. LEPC also spoke with community members and industry representatives about the siren confusion and safety procedures.

In Corpus Christi, the function of LEPC is to provide for joint emergency planning, training, and public outreach. In response to the concern about confusing sirens, LEPC is currently looking into the possibility of a community-wide siren system along Refinery Row. This community siren would sound different than all the facility alarms, be placed at the facilities' boundaries, and would activate with the specific purpose to alert the community of emergencies. Community members seeking more information about LEPC activities should visit http://www.cclepc.org/.

N4.8. Data quality and study design for environmental investigations

ATSDR considers data quality and study design an integral part of its environmental investigations. To the extent possible, the agency includes the concerned community in the study design process. For example, ATSDR designed its exposure investigation (EI) with input from the community including:

- In January 2010, ATSDR held a meeting in Corpus Christi to present a concept for the EI and to solicit input from meeting participants.
- In early February 2010, ATSDR held numerous conference calls with several community leaders to help us identify and recruit EI participants. On February 18 and 19, 2010, teams consisting of community members and ATSDR staff recruited additional participants for the EI during door-to-door canvassing in the Hillcrest and Dona Park neighborhoods. To better accommodate residents, we arranged home visits with the participants to collect samples. At the request of the community, we also included children in the test population.
- On March 22-25, 2010, ATSDR staff collected air, blood, and urine samples with the assistance of phlebotomists from local hospitals. A total of 90 residents from the Hillcrest and Dona Park communities participated in the EI.
- In May 2010, ATSDR sent letters to all participants with an explanation of their individual test results. Contact information was also provided so the participants or their physicians could call us to further discuss the results.
- On June 17, 2010, EI participants, as well as other interested residents, were able to meet with ATSDR staff (a toxicologist and medical doctors) in person to discuss their test results at the Oveal Williams Senior Center in Corpus Christi.
- In January 2011, ATSDR staff held a public meeting that included a discussion of the results of the EI report.

Throughout EI process, ATSDR staff were available to answer community questions and concerns about data quality and study design.

Unlike the EI, for this public health report ATSDR relied on air data collected by a variety of other entities and did not collect its own data. Thus, ATSDR was not able to provide input into the designs of the air monitoring programs. However, ATSDR reviewed available information on the data quality objectives of the three stationary air monitoring networks and determined the data were suitable for public health evaluation purposes. ATSDR also performed "cross-network comparisons" to provide further insight into data quality: despite the fact that each network used different measurement devices, the expected results showed reasonably comparable concurrent measurements in the same locations (see Section 6.2 of the main text and Appendix G).

For the mobile monitoring events, ATSDR compiled these data from TCEQ toxicology reports; the agency did not review the original laboratory reports or the data quality procedures. Overall, ATSDR assumed the TCEQ toxicology reports contained valid data. However, when a mobile report indicated some data did not meet the data quality objectives for the project and the data were qualified, ATSDR provided this information in this document.

N4.9. Distrust of government agencies

Trust doesn't come automatically—it is earned. ATSDR commits to work in partnership with the community, scientists, and other organizations in Corpus Christi. ATSDR believes that the more opportunities the agency creates to get to know the community, to listen respectfully to their concerns, and to help them understand how the agency's activities will respond to their concerns, the more the community will trust ATSDR's work at the site. Therefore, for the Corpus Christi Refinery Row site, ATSDR staff sought community collaboration by

- Actively encouraging participation of community members in the Exposure Investigation,
- Meeting one-on-one with concerned residents,
- Hosting public meetings and public availability sessions,
- Organizing health education and promotion events,
- Presenting agency activities at local board meetings, and
- Participating in local health-care events.

ATSDR also understands the key to successfully addressing complex environmental exposure issues is building broad, working partnerships among interested parties. Therefore, ATSDR has been working in close cooperation with other government agencies, including U.S. EPA, TCEQ, and DSHS. ATSDR supports the many initiatives these government agencies have undertaken in Corpus Christi to address community concerns about a variety of issues, from birth defects to soil contamination.

ATSDR values community input. Therefore, everyone in the community will have the chance to review this public health evaluation report and comment on the results. ATSDR will do its best to address all comments and make sure they are in the final report.

N4.10. Communication between community members and ATSDR

Open and honest communication with the community is very important to ATSDR.

ATSDR relies on a variety of mechanisms to keep the community engaged and updated regarding site activities including

- Over 5,000 addresses on a Corpus Christi Refinery Row mailing list,
- A site-specific website (available at http://www.atsdr.cdc.gov/sites/corpuschristi/),
- An email listserv (for those community members who provided the agency with their email address), and
- Visits to the site to hold one-on-one meetings with community members and host public meetings.

Also available to community members is a general toll-free hotline (at 1-800-CDC-INFO) that puts community members in touch with the appropriate ATSDR staff member to address their site-specific questions.

For the Refinery Row site, ATSDR also looked for additional mechanisms to engage and update the community regarding site activities. For example, ATSDR participated in events hosted by other stakeholders and government agencies including:

- In April 2010, ATSDR participated in a Corpus Christi Air Quality Project advisory board meeting. During the meeting, ATSDR provided updates on its EI and public health evaluations activities as well as answered questions about those activities.
- In March 2011, ATSDR participated a Regional Health Awareness Board (RHAB) Public Forum. The purpose of the forum was to discuss health concerns raised by the community and the roles that ATSDR and TCEQ were playing in addressing those concerns.
- In July 2011, ATSDR participated in the 46th Annual Health Fair in Corpus Christi sponsored by the Nueces County Medical Society. At the fair, ATSDR discussed environmental health and the agency's public health activities with community members.
- In November 2011, ATSDR participated in U.S. EPA's Environmental Summit in Corpus Christi. The summit objectives were to (1) identify key environmental issues, including those related to fence-line communities, (2) bring together agencies, city, industry and other stakeholders to find ways to address those key issues, and (3) identify and work together on environmental initiatives of common interest that will benefit Corpus Christi.
- In July 2012, ATSDR participated 47th Annual Health Fair in Corpus Christi sponsored by the Nueces County Medical Society.

Overall, ATSDR strives to effectively communicate with the public and to foster opportunities for meaningful interaction.

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Appendix O. Facility Profiles

This Agency for Toxic Substances and Disease Registry (ATSDR) report appendix includes brief profiles for selected Refinery Row facilities and provides further information and perspective regarding these facilities. As described in Section 3.2 of the main text, through searches of the U.S. Environmental Protection Agency's (U.S. EPA's) Toxics Release Inventory (TRI) database, the Texas Commission on Environmental Quality's (TCEQ's) Mobile Monitoring Team (MMT) reports, and concerns expressed to the agency, ATSDR identified 26 facilities and documents them in this section. Figure 8A, Appendix A, shows the location of those 26 facilities.

Note that the purpose of this appendix is to provide general background information on each facility—not to document each facility's entire history. ATSDR notes that this appendix does not summarize the self-reported estimated annual air emissions that some of the facilities submitted to the TRI database because TRI data are reviewed in Appendix H. For each facility of interest, this appendix briefly reviews the following facility-specific information:

Background. This section indicates the address, type of facility, years of operation, and general facility process information. Where information is available, each facility in this section also identifies previous facility owners, names of holding companies, and other commonly-used names. Much of the information in this section comes from ATSDR's review of TCEQ's files and online information sources.

Short-Term Estimated Air Emissions. This section summarizes the frequency and severity of certain short-term air releases that TRI's annual emission data do not characterize. Data on these emissions were obtained from TCEQ's "Air Emission Event Reports" database (http://www11.tceq.state.tx.us/oce/eer/index.cfm) [TCEQ 2011b]. TCEQ regulations require industrial facilities to disclose information associated with certain unplanned emission events and with scheduled activities that lead to excess emissions (e.g., process maintenance, shutdown, and startup activities). Whether reporting is required depends on several factors, such as the nature of the release and the amounts of chemicals emitted.

This appendix presents facility-specific information on Air Emission Event Reports submitted to TCEQ between 2003 and 2011. ATSDR used this information for insights into the frequency and severity of short-term emission events. All information provided by the facilities (including the chemical emission rates) is self-reported and is typically estimated. The estimates' accuracy is not known.

State and Federal Compliance. This section uses two objective measures to characterize regulatory compliance. The first metric is the facilities' annual compliance ratings reported by TCEQ. These ratings characterize compliance with multiple environmental regulations (e.g., Texas Solid Waste Disposal Act, Texas Clean Air Act, and Texas Radiation Control Act). A compliance rating of zero is assigned to facilities with perfect compliance histories, and higher numbers indicate increasing noncompliance. TCEQ has published the following guidelines for interpreting these ratings [TCEQ 2011a]:

Compliance Rating	*Classification*	*Interpretation*
0–0.1	High	Complies with environmental regulations extremely well
0.1–45.00	Average	Generally complies with environmental regulations
3.01	Average by default	No information is available on which to base a rating
45.01 or greater	Poor	Fails to comply with a significant portion of the relevant environmental regulations

Every September, TCEQ issues its facility-specific compliance ratings based on the previous 5 years of compliance information. This section presents the facility-specific compliance ratings that TCEQ published on September 1, 2011, which is when ATSDR prepared this appendix. Community members interested in the current compliance status for any of the facilities are encouraged to contact TCEQ's Regional office in Corpus Christi.

The second objective compliance metric uses information downloaded from U.S. EPA's Enforcement and Compliance History Online (ECHO) database [USEPA 2011a]. This section notes whether the facility is currently designated a "High Priority Violator" under the federal Clean Air Act. Facilities with this designation have the most serious form of violation in this database and indicate a more severe level of concern for the environment. Further information on any given violation (e.g., the specific allegations, the status of legal objections) can be obtained from U.S. EPA Region 6 offices. All U.S. EPA compliance data in this section are based on ECHO queries conducted in November 2011 and reflect facility-specific conditions dating back to November 2008.

Overall, ATSDR used the compliance information to provide a sense for which Refinery Row facilities most consistently met, or failed to meet, applicable environmental regulations and to identify the facilities that had violations alleging noncompliance. But noncompliance does not necessarily equate to increased emissions. Some facilities, for example, might be in noncompliance for administrative reasons. The point is that compliance alone does not necessarily mean a facility is not contributing to unhealthy levels of air pollution.

Miscellaneous. This section presents additional information on the Refinery Row facilities that does not fit into the categories listed above. Examples include brief summaries of dispersion modeling studies, additional insights on facility-wide emissions, and specific requirements outlined in EPA's Petroleum Refinery Initiative [USEPA 2009b]. All information presented in this section comes from ATSDR's review of TCEQ's files and online information sources.

10. Air Liquide Corpus Christi SMR Plant

Background. The Air Liquide Corpus Christi SMR Plant ("Air Liquide") is located at 5880 Up River Road. Air Liquide is a steam methane reformer (SMR) facility. Such plants use catalytic processes to manufacture hydrogen and steam from natural gas. Air Liquide opened in 1998 with a design capacity of 50 million standard cubic feet per day of hydrogen and 185,000 pounds (lbs) per hour of steam [PR Newswire 1998]. Air Liquide Large Industries US L.P. owns and operates the facility, which TCEQ now refers to as Hydrogen Plant Industrial Gas.

Short-Term Estimated Air Emissions. Between January 2003 and November 2011, Air Liquide experienced 21 events that required submission of Air Emission Event Reports to TCEQ [TCEQ 2011b]. These releases did not involve any of the chemicals of concern considered in this health evaluation.

State and Federal Compliance. TCEQ currently does not have a compliance rating for Air Liquide [TCEQ 2011a]. According to information downloaded from U.S. EPA's ECHO database, no violations or compliance issues have been noted at Air Liquide over the past 5 years [USEPA 2011a].

Miscellaneous. No formal complaints against the facility are on file with TCEQ [TCEQ 2011d].

2O. Anderson Oil Erigan-Quiroz Lease

Background. Anderson Oil Erigan-Quiroz Lease ("Erigan-Quiroz") is north of Interstate Highway 37 between North Clarkwood Road and Tuloso Road. Erigan-Quiroz operations include a gas well, a petroleum storage tank, and ancillary equipment. The entity has one permit associated with it through TCEQ, for a nonregistered petroleum storage tank. According to well log records held by the Railroad Commission of Texas [RRC 2012], the Dinero Oil Corporation previously operated the well.

Short-Term Estimated Air Emissions. TCEQ lists Erigan-Quiroz as a regulated entity, and Erigan-Quiroz has a permit for its petroleum storage tank [TCEQ 2011b]. TCEQ's Air Emission Event Reports database has no record of emission events involving Erigan-Quiroz.

State and Federal Compliance. Compliance information regarding Erigan-Quiroz was not available from TCEQ's Web site or from U.S. EPA's ECHO database [TCEQ 2011a; USEPA 2011a].

Miscellaneous. Outside of well logs maintained by the Railroad Commission of Texas, no information was identified regarding the Erigan-Quiroz lease [RRC 2012]. There are no formal complaints on file with TCEQ for the facility [TCEQ 2011d].

3OP. Anderson Oil FJ Smith Lease

Background. The FJ Smith Lease ("FJ Smith") is located just south of Interstate Highway 37 between North Clarkwood Road and Tuloso road. FJ Smith is associated with several oil and gas wells operated by various entities. According to the Railroad Commission of Texas, many of these wells are now plugged [RRC 2012]. Anderson Oil operates one well identified in the lease, and was listed as operating it as recently as 2008 [RRC 2012]. But TCEQ's and U.S. EPA's publicly accessible environmental databases contain only limited information on this site.

Short-Term Estimated Air Emissions. TCEQ does not list FJ Smith as a regulated entity; over the period of record, therefore, FJ Smith was not required to submit air emissions information to TCEQ [TCEQ 2011b].

State and Federal Compliance. Compliance information regarding the lease and associated wells was not available from TCEQ's Web site or from U.S. EPA's ECHO database [TCEQ 2011a; USEPA 2011b].

Miscellaneous. Outside of well logs maintained by the Railroad Commission of Texas, no information was identified regarding Anderson Oil and the FJ Smith Lease [RRC 2012]. There are no formal complaints on file with TCEQ for the facility [TCEQ 2011d].

40. Broadway Wastewater Treatment Plant

Background. The Broadway Wastewater Treatment Plant ("Broadway WWTP") is located at 1402 West Broadway Street. Broadway WWTP serves the downtown and North Beach areas of Corpus Christi, with a coverage area of more than 15,000 acres. First operational in 1938, the facility is designed to treat 10 million gallons of wastewater per day (MGD). The facility underwent significant changes in 1940, 1950, 1954, and 1980. Broadway WWTP currently treats less than 5 MGD of domestic wastewater [City of Corpus Christi 2012].

Short-Term Estimated Air Emissions. TCEQ regulates Broadway WWTP as two separate entities located at the same address. "Broadway Sewage Treatment" has one active air permit and "Broadway Plant" has active storm water, wastewater, and wastewater licensing permits. Over the period of record, TCEQ received no air emissions events associated with Broadway WWTP [TCEQ 2011b].

State and Federal Compliance. On September 1, 2011, TCEQ gave the City of Corpus Christi a compliance rating of 0.21 (considered "average") for its Broadway Plant site [TCEQ 2011a]. But that compliance rating only referenced the site's storm water and wastewater permits, not the air permit. According to U.S. EPA's ECHO database, over a 3-year period ending September 2011, Broadway WWTP had been out of compliance with Clean Water Act requirements for 11 of 12 quarters [USEPA 2011a], but the facility is currently not considered to be in "significant noncompliance" or a "high-priority violator." As stated in ECHO, some reasons for noncompliance include failing to collect required samples within the required reporting period and submitting required discharge monitoring reports after the deadlines [USEPA 2011a].

Miscellaneous. According to TCEQ's Central Registry, three complaints were filed with the agency regarding Broadway WWTP through 2011 [TCEQ 2011d]. Community members interested in additional information are encouraged to contact TCEQ's Regional office in Corpus Christi.

50. BTB Refining

Background. BTB Refining is located at 6600 Up River Road. BTB's refinery facility in Corpus Christi—also known as Trigeant—was formerly known as Neste Trifinery Petroleum Services. The facility has a rated capacity of 30,000 barrels per day and produces various fuel and asphalt products for the housing, transportation, and construction industries. It distributes its products through tank trucks, rail cars, barges, and ships [BTB Refining 2011].

Short-Term Estimated Air Emissions. Between January 2003 and November 2011, BTB Refining experienced one event that required Air Emission Event Reports to be submitted to TCEQ [TCEQ 2011b]. No chemicals of concern were emitted during that event.

State and Federal Compliance. On September 1, 2011, TCEQ gave the facility a compliance rating of 3.01 (considered "average by default") [TCEQ 2011a]. According to information downloaded from EPA's ECHO database, BTB Refining was not in violation of the Clean Air Act for the last 3-year time frame [USEPA 2011a].

Miscellaneous. No formal complaints are on file with TCEQ for BTB Refining [TCEQ 2011d].

60. CITGO Deep Sea Terminal

Background. CITGO Deep Sea Terminal is located at 4809 Up River Road. This facility is a subsidiary of CITGO Petroleum Corporation. The facility is in the "Petroleum Bulk Station and Terminal" industry.

Facilities in this industry generally have extensive bulk chemical storage capacity and engage in wholesale distribution of crude petroleum and petroleum products.

Short-Term Estimated Air Emissions. Between January 2003 and November 2011, CITGO Deep Sea Terminal submitted no Air Emission Event Reports to TCEQ [TCEQ 2011b].

State and Federal Compliance. On September 1, 2011, TCEQ gave CITGO Deep Sea Terminal a compliance rating of 0.02 (considered “high”) [TCEQ 2011a]. According to information downloaded from U.S. EPA’s ECHO database, CITGO Deep Sea Terminal was in high priority violation of the Clean Air Act as of November 2011 and over a 3-year period has been alleged noncompliance with the Clean Air Act for 12 quarters [USEPA 2011a]. The reasons for alleged noncompliance often change with time.

Miscellaneous. TCEQ has no formal complaints on file for the facility [TCEQ 2011d].

7O. CITGO East

Background. CITGO East is located at 1801 Nueces Bay Boulevard. CITGO East is a subsidiary of CITGO Petroleum Corporation. In Corpus Christi, CITGO East and West have a combined capacity to process 163,000 barrels of crude oil per day [EIA 2011] and to produce 4.2 million gallons of gasoline per day [CITGO Petroleum Corporation 2011]. The facilities refine heavy, sour crude oils into finished petroleum products, including liquid petroleum gas, gasoline, and diesel fuel [CITGO Petroleum Corporation 2011].

Short-Term Estimated Air Emissions. Between January 2003 and November 2011, CITGO East experienced 241 events that required submission of Air Emission Event Reports to TCEQ. These events released an estimated 1,225,000 lbs of reportable chemicals to the air. According to the data CITGO East submitted to TCEQ, benzene accounted for less than 2% of estimated emissions from these events (20,600 lbs) and 1,3-butadiene accounted for less than 0.01% of emissions (30 lbs) [TCEQ 2011b].

State and Federal Compliance. On September 1, 2011, TCEQ gave CITGO East a compliance rating of 43.00 (considered “average”) [TCEQ 2011a]. According to information downloaded from EPA’s ECHO database, CITGO East was in high priority violation of the Clean Air Act as of November 2011, and has been in alleged noncompliance with the Clean Air Act for 12 quarters over a 3-year time frame [USEPA 2011a].

Miscellaneous. As part of a 2004 consent decree under U.S. EPA’s Petroleum Refinery Initiative, CITGO East was required to reduce emissions of nitrogen oxide and sulfur dioxide [USEPA 2009b]. Further, the consent decree required CITGO East (and other CITGO refineries) to pay monetary penalties, invest in supplemental environmental projects, and implement emissions control technologies. Since 2004, CITGO East has achieved several emissions controls milestones related to fluid catalytic cracking units, sulfur recovery units, and heaters and boilers, although some milestones still remain [USEPA 2011c].

In 2008, TCEQ received five formal complaints for the CITGO East facility, all of which have been closed [TCEQ 2011d].

8O. CITGO West

Background. CITGO West is located at 7350 Interstate Highway 37. CITGO West is a subsidiary of CITGO Petroleum Corporation. CITGO East and West have a combined processing capacity of 163,000 barrels of crude oil per day [EIA 2011] and a production capacity of 4.2 million gallons of gasoline per day [CITGO Petroleum Corporation 2011]. The facilities refine heavy, sour crude oils into finished petroleum products, including liquid petroleum gas, gasoline, and diesel fuel [CITGO Petroleum Corporation 2011].

Short-Term Estimated Air Emissions. Between January 2003 and November 2011, CITGO West experienced 82 events that required Air Emission Event Reports to be submitted to TCEQ. These events released an estimated 197,000 lbs of reportable chemicals to the air. According to the data CITGO West submitted to TCEQ, benzene and isopentane combined for less than 0.5% of the estimated event emissions [TCEQ 2011b].

State and Federal Compliance. On September 1, 2011, TCEQ gave CITGO West a compliance rating of 0.20 (considered “average”) [TCEQ 2011a]. According to information downloaded from EPA’s ECHO database, CITGO West was in high priority violation of the Clean Air Act as of November 2011, and has been in alleged noncompliance with the Clean Air Act for 12 quarters over a 3-year time frame [USEPA 2011a].

Miscellaneous. As part of a 2004 consent decree under USEPA’s Petroleum Refinery Initiative, CITGO West has been required to reduce emissions of nitrogen oxide and sulfur dioxide [USEPA 2009b]. Further, the consent decree requires CITGO West (and other CITGO refineries) to pay monetary penalties, invest in supplemental environmental projects, and implement emissions control technologies. Since 2004, CITGO West has achieved several emissions controls milestones related to fluid catalytic cracking units, sulfur recovery units, and heaters and boilers, although some milestones still remain [USEPA 2011c].

TCEQ has no formal complaints on file with for the facility [TCEQ 2011d].

9O. Elementis Chromium

Background. Elementis Chromium is located at 3800 Buddy Lawrence Drive. Elementis Chromium is owned by Elementis PLC, a corporation based in the United Kingdom. Elementis Chromium went through several reorganizations since 2002. In U.S. EPA’s TRI database, it is listed as American Chrome & Chemicals LP.

The Elementis Chromium facility had two primary chemical products: chromic oxide and chromium hydrate. Elementis manufactured these chemicals in high-temperature kilns from sodium dichromate, ammonium sulfate, boric acid, and other feeds. Products had been used for various purposes, such as components of pigments and of metallurgical-grade chromic oxide [TCEQ 2009].

Short-Term Estimated Air Emissions. Between January 2003 and November 2011, Elementis Chromium did not experience any events that required Air Emission Event Reports to be submitted to TCEQ [TCEQ 2011b].

State and Federal Compliance. On September 1, 2011, TCEQ gave Elementis Chromium a compliance rating of 0 (considered “high”) [TCEQ 2011a]. According to information downloaded from EPA’s ECHO database, Elementis Chromium was not in violation of the Clean Air Act for the last 3-year time frame [USEPA 2011a].

Miscellaneous. TCEQ has no formal complaints on file for the facility [TCEQ 2011d].

10O. Encycle

Background. Encycle Texas Inc. (Encycle) is located at 5500 Up River Road. The former Encycle facility was a subsidiary of American Smelting and Refining Company (ASARCO) LLC. In its earliest years (1941 to 1985), the Encycle Corpus Christi facility produced high-grade zinc. In more recent years (1988 to 2002), the site was a commercial waste management operation that mostly treated inorganic hazardous and nonhazardous materials for recycling, reclamation, and volume reduction. Encycle ceased operations in 2003 and began facility closure activities continuing until 2005, when Encycle filed bankruptcy and vacated the property [TCEQ 2011c].

The federal bankruptcy court appointed a trustee to oversee and remediate the site. TCEQ obtained financial assurance funds to oversee corrective measures at the former Encycle facility [TCEQ 2011c]. Find additional information regarding current demolition, remediation and sampling activities at http://www.tceq.texas.gov/remediation/sites/encycle_facility/encycle.

Short-Term Estimated Air Emissions. Encycle experienced no events that required submission of Air Emission Event Reports to TCEQ [TCEQ 2011a].

State and Federal Compliance. Compliance information was not available from TCEQ's database or U.S. EPA's ECHO database [TCEQ 2011a; USEPA 2011a].

Miscellaneous. As part of a consent decree related to violations of federal waste management regulations, the federal Clean Water Act, and the Texas Solid Waste Disposal Act, Encycle and parent-company ASARCO previously agreed to pay civil penalties for past violations ($5.5 million) and to perform supplemental environmental projects, including development of a permanent 30 acre conservation area for public use in Corpus Christi [USEPA 2009c, TCEQ 2011c]. However, the slated supplemental environmental projects were not completed at the time the parent company filed for bankruptcy. A trustee was appointed by the federal bankruptcy court to oversee the Encycle estate and was allotted approximately $9.9 million to remediate the site [TCEQ 2011c].

TCEQ received seven formal complaints for this facility [TCEQ 2011d].

11O. Enterprise Products – Shoup Plant

Background. Enterprise Products Partners L.P.'s Shoup Plant ("Shoup") is located at 802 McKinzie Road. Shoup is a gas processing and fractionation facility. Gas processing involves separating natural gas liquids (NGLs) from the natural gas stream; fractionation involves further separating mixed NGLs into pure products, like ethane or propane. Enterprise Products Partners LP fully owns Shoup's gas-processing component while it co-owns the fractionation component with Duncan Energy Partners. Recent accounts indicate that the facility increased its fractionation capacity in 2010, and that the facility has a total natural gas processing capacity of 0.29 billion cubic feet per day [Enterprise Products Partners LP 2012].

According to TCEQ, over the past 15 years owners of the facility have included PG&E Hydrocarbons L.P., Valero Hydrocarbons L.P., Valero Hartman Company, El Paso Field Services L.P., and Enterprise Hydrocarbons. Currently, TCEQ records list on all facility permits "Enterprise Hydrocarbons" as the owner and operator.

Short-Term Estimated Air Emissions. Over the period of record covered in TCEQ's online databases (January 2003 to November 2011), Shoup experienced three events that required submission of Air Emission Event Reports to TCEQ [TCEQ 2011b]. These releases involved carbon monoxide, nitrogen oxides, and "natural gas volatile organic compounds (VOCs)," but did not include the chemicals of concern identified in this report.

State and Federal Compliance. On September 1, 2011, TCEQ gave Enterprise Hydrocarbons a compliance rating of 8.18 (considered "average") for the Shoup facility [TCEQ 2011a]. According to information downloaded from U.S. EPA's ECHO database, Shoup has been in alleged noncompliance with the Clean Air Act for 7 quarters over a 3-year time frame [USEPA 2011a].

Miscellaneous. TCEQ has no formal complaints on file for Shoup [TCEQ 2011d].

12O. Equistar

Background: Equistar is located at 1501 McKinzie Road. Equistar is a subsidiary of Lyondell Basell (formerly Lyondell Chemical Co. and Basell International Holdings). Oxy Petrochemical was the previous owner.

Equistar manufactures industrial organic chemicals including ethylene, propylene, benzene, 1,3-butadiene, and fuel products. At the Corpus Christi facility, Equistar's main production is in the Olefins Unit and the Butadiene Unit. The primary pollutants emitted by the facility include various volatile organic compounds and criteria pollutants.

Equistar receives feedstocks of petroleum liquids and liquefied petroleum gases via pipeline. The feedstocks contain complex hydrocarbons with relatively high molecular weights. Using steam and high temperatures, the pyrolysis furnaces break or "crack" the complex hydrocarbons into smaller molecules, resulting in a mixture of lower molecular weight hydrocarbons that are separated to meet product demands [TCEQ 2009].

Short-Term Estimated Air Emissions. Between January 2003 and November 2011, Equistar experienced 91 events that required submission of Air Emission Event Reports to TCEQ [TCEQ 2011b]. These events released an estimated 704,000 lbs of reportable chemicals to the air. According to the data Equistar submitted to TCEQ, benzene accounted for approximately 1% of estimated emissions from these events (7,400 lbs) and 1,3-butadiene accounted for fewer than 2% of emissions (12,000 lbs).

State and Federal Compliance. On September 1, 2011, TCEQ gave Equistar a compliance rating of 5.86 (considered "average") [TCEQ 2011a]. According to information downloaded from U.S. EPA's ECHO database, as of November 2011 Equistar was in high-priority violation of the Clean Air Act and over a 3-year period has been in alleged noncompliance with the Clean Air Act for 12 consecutive quarters [USEPA 2011a].

Miscellaneous. In July 2007 Equistar entered into a consent decree with U.S. EPA [USEPA 2009a]. The consent decree applies to seven Equistar facilities nationwide, including the Corpus Christi facility. The consent decree required Equistar to install equipment to reduce flare emissions, install continuous emission monitors on the majority of flares, and report and investigate flare incidents.

According to TCEQ's Central Registry, since 2003 Equistar received nine registered complaints. TCEQ has closed all of them [TCEQ 2011d].

13O. Flint Hills East

Background. Flint Hills East is located at 1607 Nueces Bay Boulevard. Flint Hills East, also known as Southwestern Refining Company and also sometimes referred to as the Koch Petroleum Group, is a subsidiary of Koch Industries, Inc.

Flint Hills East is a petroleum refining facility that produces various grades of gasoline, diesel, jet fuel, and other associated products from petroleum crude. The two Flint Hills refineries in Corpus Christi have a combined capacity to process 290,100 barrels of crude oil per day [EIA 2011].

Raw feedstock materials arrive at the facility via pipeline and marine vessels and are then stored in large tanks for eventual use in the various production units. The process units include initial crude fractionation, reforming, acid (hydrofluoric) alkylation, fluidized catalytic cracking, gas recovery, coking, hydro-cracking and treating, sulfur recovery, and power generation. The primary emitted pollutants are volatile organic compounds and criteria pollutants [TCEQ 2009].

Short-Term Estimated Air Emissions. Between January 2003 and November 2011, Flint Hills East experienced 92 events that required submission of Air Emission Event Reports to TCEQ [TCEQ 2011b]. These events released an estimated 358,000 lbs of reportable chemicals to the air. According to the data Flint Hills East submitted to TCEQ, benzene accounted for fewer than 0.25% of estimated emissions from these events (500 lbs), 1,3-butadiene accounted for fewer than 0.01% of emissions (40 lbs), and isopentane accounted for 1.6% (5,600 lbs).

Note that Flint Hills voluntarily began a pilot project to post publicly available emissions reports and updates from its two Corpus Christi refineries on its Web site at http://www.fhr.com/ehs/corpuspilot.aspx. The pilot project consolidates the air emissions reports filed with TCEQ along with any updates or retractions. In addition, Flint Hills will post on this Web site the follow-up letters sent to the Local Emergency Planning Committee that describe the actions the company took following an emissions event.

State and Federal Compliance. On September 1, 2011, TCEQ gave Flint Hills East a compliance rating of 2.73 (considered "average") [TCEQ 2011a]. According to information downloaded from U.S. EPA's ECHO database, as of November 2011 Flint Hills East was in high priority violation of the Clean Air Act and has been in alleged noncompliance with the Clean Air Act for 12 consecutive quarters over a 3-year period [USEPA 2011a].

Miscellaneous. As part of a 2000 consent decree under EPA's Petroleum Refinery Initiative, Flint Hills East has been required to reduce air emissions of nitrogen oxide and sulfur dioxide, pay monetary penalties, conduct supplemental environmental projects, and install pollution control equipment [USEPA 2009b]. The consent decree required substantial reductions in sulfur and nitrogen oxide emissions from the facility's Fluidized Catalytic Cracking Unit to be completed by 2008; since the consent decree was implemented, major changes include installing a new flare gas recovery system and installation of "ultra-low nitrogen oxide burners" on all heaters and boilers [USEPA 2011e].

TCEQ has no formal complaints on file for this facility [TCEQ 2011d].

14O. Flint Hills West

Background. Flint Hills West is located at 2825 Suntide Road. Flint Hills West is a subsidiary of Koch Industries, Inc., also sometimes referred to as the Koch Petroleum Group. Flint Hills West is a petroleum refining facility producing various grades of gasoline, diesel, jet fuel, and other petroleum products. The two Flint Hills refineries in Corpus Christi have a combined capacity to process 290,100 barrels of crude oil per day [EIA 2011].

Similar to Flint Hills East, raw feedstock materials arrive at the facility via pipeline and marine vessels and are then stored in large tanks for eventual use in the various production units. The process units include initial crude fractionation, reforming, acid (hydrofluoric) alkylation, fluidized catalytic cracking, gas recovery, coking, hydro-cracking and treating, sulfur recovery, and power generation. The primary pollutants emitted consist of volatile organic compounds and criteria pollutants [TCEQ 2009].

Short-Term Estimated Air Emissions. Between January 2003 and November 2011, Flint Hills West experienced 202 events that required submission of Air Emission Event Reports to TCEQ [TCEQ 2011b]. These events released an estimated 1,850,000 lbs of reportable chemicals to the air. According to the data Flint Hills West submitted to TCEQ, benzene accounted for fewer than 1% of estimated emissions from these events (14,000 lbs), 1,3-butadiene accounted for fewer than 0.01% of emissions (60 lbs), and isopentane accounted for fewer than 0.5% (5,400 lbs).

State and Federal Compliance. On September 1, 2011, TCEQ gave Flint Hills West a compliance rating of 8.26 (considered "average") [TCEQ 2011a]. According to information downloaded from U.S. EPA's ECHO database, as of November 2011 Flint Hills West was in high-priority violation of the Clean Air Act, and has been in alleged noncompliance with the Clean Air Act for 12 consecutive quarters over a 3-year period [USEPA 2011a].

Miscellaneous. As part of a 2000 consent decree under U.S. EPA's Petroleum Refinery Initiative, Flint Hills West was required to reduce air emissions of nitrogen oxide and sulfur dioxide, pay monetary penalties, conduct supplemental environmental projects, and install pollution control equipment [USEPA 2009b]. The consent decree required completion by 2010 of substantial reductions in sulfur and nitrogen oxide emissions from the facility's Fluidized Catalytic Cracking Unit. Since the consent decree, major changes include installing a new flare gas recovery system and installation of "ultra-low nitrogen oxide burners" on all heaters and boilers [USEPA 2011e].

TCEQ received three formal complaints for the Flint Hills West facility, all of which have been closed [TCEQ 2011d].

15O. Greenbriar Energy Inc. Well 1

Background. Greenbriar Energy Inc. ("Greenbriar") Well 1 and other ancillary equipment (e.g., tanks) are located along Nueces Bay in State Tract 746A. In December 1998, Well 1 of Greenbriar was drilled to a depth of 4,300 feet. In January 2000, the well was plugged. According to well logs on file with the Railroad Commission of Texas, Greenbriar Energy Inc. operated the well and Mid Coast Gas Services acted as the sole gatherer and purchaser [RRC 2012]. The site included ancillary equipment typically present at well pads, such as storage tanks and various interconnecting equipment.

Short-Term Estimated Air Emissions. TCEQ's Air Emission Event Reports database has no record of emission events occurring at Greenbriar Well 1 [TCEQ 2011b].

State and Federal Compliance. Compliance information regarding Greenbriar was not available from TCEQ's Web site or from U.S. EPA's ECHO database [TCEQ 2011a; USEPA 2011a].

Miscellaneous. Outside of well logs maintained by the Railroad Commission of Texas, ATSDR found no regarding Greenbriar's Well 1 [RRC 2012]. TCEQ has no formal complaints on file for the well [TCEQ 2011d].

16O. GulfMark Energy, Inc.

Background. GulfMark Energy, Inc. ("GulfMark") is located at 2500 Suntide Road. GulfMark is a permitted oil and gas waste hauler that operates at locations throughout the Gulf Coast, including Corpus Christi. According to the company's public biography, GulfMark purchases crude oil from petroleum-producing entities and stores and transports that crude oil to refining operations [GulfMark Energy Inc. 2012]. No data are available through TCEQ, ECHO, or TRI regarding the specific Corpus Christi facility. GulfMark is a subsidiary of Adams Resources and Energy, Inc.

Short-Term Estimated Air Emissions. TCEQ has not listed GulfMark in Corpus Christi as a regulated entity, most likely due to the nature its operations. Therefore, TCEQ required no air emissions information during the reporting period [TCEQ 2011b].

State and Federal Compliance. Compliance information regarding GulfMark in Corpus Christi is not available from TCEQ's Web site or from U.S. EPA's ECHO database [TCEQ 2011a; USEPA 2011a].

Miscellaneous. Outside of general information available from the company's Web site, ATSDR found no detailed environmental information regarding GulfMark in Corpus Christi. TCEQ has no formal complaints on file for this GulfMark facility [TCEQ 2011d].

17O. Javelina Gas Co

Background. Javelina Gas Co ("Javelina") is located at 5314 Interstate Highway 37. Javelina is a gas processing and fractionation facility that treats, processes, and fractionates off-gas from several Corpus Christi-area crude oil refineries. As of 2011, the facility had the capacity to process cryogenically (i.e., recover NGLs through very low temperature treatments) 140 million cubic feet of gas per day and to fractionate (i.e., separate) 29,000 barrels per day of NGLs [MarkWest Energy Partners LP 2011].

Markwest Energy Partners, LP owns and operates Javelina Gas Co. In 2005 Markwest purchased Javelina from El Paso Corporation, Kerr-McGee Corp., and Valero Energy Corp. Constructed in 1989, the facility has had many names, most common of which include derivatives of Markwest Javelina or Javelina Gas Processing Facility.

Short-Term Estimated Air Emissions. From the start of accessible emissions events reporting (January 31, 2003) through November 2011, Javelina experienced 72 events that required Air Emission Event Report submission to TCEQ [TCEQ 2011b]. The events involved release of various pollutants. Of the chemicals of concern considered in this health evaluation, emission event reports listed sulfur dioxide and hydrogen sulfide.

State and Federal Compliance. On September 1, 2011, TCEQ gave Javelina ("Javelina Fluid Products") a compliance rating of 0.91 (considered "average") [TCEQ 2011a]. EPA's ECHO database does not contain Clean Air Act compliance information for Javelina [USEPA 2011a].

Miscellaneous. TCEQ has 11 formal complaints on file for Javelin, all of which are closed [TCEQ 2011d].

18O. Koch Pipeline Viola Station

Background. Koch Pipeline's Viola Station is located across the street from the Flint Hills Refinery Office at 2825 Suntide Road. According to TCEQ, Koch Pipeline Viola Station's primary business is "truck delivery of crude oil." Owner Koch Pipeline is a wholly owned subsidiary of Koch Industries, Inc. TCEQ lists Dorado Oil Company as the operator of this site [TCEQ 2012].

Koch Pipeline owns and operates thousands of miles of pipeline to transport crude and refined products across the country. In the company's system, domestic crude oil is transported to Corpus Christi and refined products are carried from Corpus Christi refineries to other markets, including those in San Antonio, Austin, Bastrop, Waco, and the Dallas–Fort Worth metropolitan area [Koch Pipeline Company LP 2012]. Several facilities in the Refinery Row area are Koch Industries subsidiaries, including previously mentioned Flint Hills East and Flint Hills West. This profile focuses on Koch's pipeline Suntide Road address, nearest to these refineries.

Short-Term Estimated Air Emissions. From the start of accessible emissions events reporting (January 31, 2003 through November 2011), TCEQ received no air emission events regarding Koch Pipeline [TCEQ 2011b].

State and Federal Compliance. TCEQ did not provide a compliance rating for the specified Koch Pipeline facility [TCEQ 2011a]. According to information downloaded from U.S. EPA's ECHO database, the Koch Pipeline Viola facility is a Clean Air Act minor source [USEPA 2011a]. As a result, Koch Pipeline is not required to report compliance data to this database.

Miscellaneous. TCEQ has no formal complaints on file with for Koch Pipeline [TCEQ 2011d].

19O. Magellan Terminals Holding LP

Background. Magellan Terminals Holding LP, also known as Corpus Christi Terminals, is located at 1802 Poth Lane. Magellan Terminals is a marine terminal operated by Magellan Midstream Partners LP. The petroleum bulk storage business includes 41 storage tanks with a nominal shell capacity of 3,022,500 barrels. The facility receives and transfers materials via barge and truck; the facility is also connected via pipeline to several area refineries [Magellan Midstream Partners LP 2012].

According to TCEQ, the site has had many different owners and operators over recent decades, beginning with Williams Terminals Holdings and Magellan Terminals Holdings in 1999, and eventually the Hess Corporation and Magellan Midstream Partners [TCEQ 2012].

Short-Term Estimated Air Emissions. Over the period of record Magellan Terminals did report five air emission events to TCEQ, all of which occurred after August 2011 and three of which remain listed as "open" incidents [TCEQ 2011b]. All the releases described in the event reports involved various pollutants, but benzene was the only chemical of interest for this public health evaluation. Across all events, the total estimated quantity of benzene released was approximately 437 lbs. These releases occurred during scheduled storage tank refilling.

State and Federal Compliance. No compliance information was available through TCEQ for Magellan Terminals [TCEQ 2011a]. According to information downloaded from U.S. EPA's ECHO database, this site is a Clean Air Act "major source." Magellan Terminals last official Clean Air Act inspection was July 2006. TCEQ has since conducted additional inspections. According to ECHO data pulled in November 2011, Magellan Terminals is currently in compliance with Clean Air Act requirements and has remained so for at least the past 3 calendar years [USEPA 2011a].

Miscellaneous. Outside of general information available from the company's Web site, ATSDR identified no detailed environmental information regarding the Magellan Terminals site. TCEQ has no formal complaints on file with for this facility [TCEQ 2011d].

20O. Magnum Producing LP

Background. Magnum Producing, L.P. ("Magnum") well of interest is located on the north side of the Port of Corpus Christi, north of the Tule Lake Channel and west of Bulk Terminal Docks 1 and 2. Magnum has been approved by the Railroad Commission of Texas as a crude oil and natural gas well operator, and has been working in South Texas since the mid-1980s [Allied Resources, Inc. 2012]. Magnum currently operates approximately 150 wells, one of which—located northwest of the Port of Corpus Christi's bulk terminal docks—is the focus of this review.

Short-Term Estimated Air Emissions. TCEQ includes the Magnum site in its listing of regulated entities [TCEQ 2011b]. However, the information provided in that listing mostly pertains to facility location and ownership. No short-term air emissions information was included in the agency's emission event database for the entire period of record.

State and Federal Compliance. Compliance information regarding the Magnum site in Corpus Christi is not available from TCEQ's website and EPA's ECHO database [TCEQ 2011a; USEPA 2011a].

Miscellaneous. There are no formal complaints on file with TCEQ for the facility [TCEQ 2011d].

21O. Martin Operating LP

Background. Martin Operating LP is located at 502 East Navigation Boulevard. Martin Operating LP is commonly referred to as Corpus Barge Terminal or Martin Barge. TRI describes Martin Operating as a petroleum bulk station and terminal. This profile refers to the facility by its common name—Corpus Barge Terminal—not by its owner's name.

Short-Term Estimated Air Emissions. Between January 2003 and November 2011, Corpus Barge Terminal experienced no events that required Air Emission Event Reports to be submitted to TCEQ [TCEQ 2011b].

State and Federal Compliance. On September 1, 2011, TCEQ gave this facility a compliance rating of 0 (considered "high") [TCEQ 2011a]. EPA's ECHO database does not list any compliance history for Corpus Barge Terminal under the Clean Air Act [USEPA 2011a].

Miscellaneous. TCEQ has no formal complaints on file with for Corpus Barge Terminal [TCEQ 2011d].

22O. NuStar Energy LP

Background. NuStar Energy LP's Corpus Christi Terminal facility is located between Texaco Road, Navigation Boulevard, and Market Street. NuStar's business involves oil and gas transport, storage, and refining across the United States and internationally. According to U.S. EPA's Facility Registry System, NuStar Energy's Corpus Christi Terminal handles marine cargo handling, operates petroleum bulk stations and terminals, and transports crude oil by pipeline. The terminal currently has 10 storage tanks with a combined capacity of 345,000 barrels. NuStar's products and materials include distillates, gasoline, xylene, and toluene. NuStar receives materials via marine and pipeline and transports products via marine. The terminal has an onsite marine vapor combustor [USEPA 2012].

According to TCEQ, owners and operators that have been associated with at least some of the activities at the NuStar terminals include Diamond Shamrock, Sigmor Pipeline Company, Valero Energy Corporation, and NuStar Logistics.

Short-Term Estimated Air Emissions. TCEQ's Central Registry lists NuStar's Corpus Christi Terminal facility as multiple regulated entities [TCEQ 2011b]. Various environmental permits have been issued to the different entities. Across these entries and during the reporting period, only two emission events were reported for this facility. During the two reported events—both from September 2004—only one of the chemicals of concern released is of interest for this public health evaluation: the facility reported total estimated emissions of 0.56 lbs of benzene.

State and Federal Compliance. On September 1, 2011, for each listed owner and operator associated with NuStar's Corpus Christi Terminal, TCEQ gave a compliance rating of 0 (considered "high") [TCEQ 2011a]. According to information downloaded from U.S. EPA's ECHO database, terminal operations have not resulted in any Clean Air Act violations [USEPA 2011a].

Miscellaneous. TCEQ has two complaints on file with for the facility, both of which are closed [TCEQ 2011d].

23O. Texas Petroleum Investment Company – Tule Lake Field

Background. The Tule Lake Production Facility is located approximately 1.5 miles away from Navigation Boulevard between Nueces Bay and Tule Lake Channel. TCEQ lists the Texas Petroleum Investment Company's Tule Lake Field, also referred to as the Tule Lake Production Facility ("Tule Lake"), as an oil and gas production facility. Tule Lake had its air new source permit first approved in May 2007; a revised version was approved in October 2010 [TCEQ 2012].

Short-Term Estimated Air Emissions. For the entire reporting period, TCEQ's emission event database has no Tule Lake short-term emissions data [TCEQ 2011b].

State and Federal Compliance. TCEQ gave the Tule Lake Production Facility a compliance rating of 3.01 on September 1, 2009, which was classified as "average by default" [TCEQ 2011a]. No information on the facility was available from U.S. EPA's ECHO database [USEPA 2011a].

Miscellaneous. There are no formal complaints on file with TCEQ for the facility [TCEQ 2011d].

24O. Valero Asphalt Company Inc.

Background. The Valero Asphalt Company Inc. ("Valero Asphalt"), which TCEQ and U.S. EPA's ECHO database often refer to as the Corpus Christi Asphalt Terminal, is located at 6746 Up River Road. Valero Asphalt is a wholesale asphalt facility. The site was also previously known as Texas Fuel and Asphalt Company. The site has had multiple owners and operators, including Eagle Asphalt Products, Valero Marketing and Supply Company, and Ergon Asphalt and Emulsions. According to TCEQ, the first listed owner was Eagle Asphalt Products in 1991. TCEQ regulates the site as two entities [TCEQ 2012].

Short-Term Estimated Air Emissions. Although Valero Asphalt is included in TCEQ's air Emissions Inventory, during the reporting period TCEQ received no reports of any short-term emission events involving Valero Asphalt [TCEQ 2011b].

State and Federal Compliance. On September 1, 2011, TCEQ gave the owners and operators of Valero Asphalt a compliance rating of 0 (considered "high") [TCEQ 2011a]. According to U.S. EPA's ECHO database, because Valero Asphalt was not monitored under the Clean Air Act, no federal air compliance ratings are available [USEPA 2011a].

Miscellaneous. There are no formal complaints on file with TCEQ for the facility [TCEQ 2011d].

25O. Valero East

Background. Valero East is located at 1300 Cantwell Lane. Valero East is a subsidiary of Valero Energy Corporation. Valero East refines petroleum feedstocks and intermediates including crude oils, natural gasoline, gas oil, and residual fuel oil. Valero East's products include petroleum products, which in turn include gasoline and distillates. Pipeline and marine vessels deliver the feedstocks to the refinery, and pipeline, marine vessels, and trucks deliver the products to the customers. Key units at the refinery include a heavy oil cracker, a hydrodesulfurization unit, a hydrocracker, a reformer complex, and a methyl tertiary butyl ether plant. Valero East and West have a combined production capacity of 142,000 barrels of crude oil per day [EIA 2011].

Short-Term Estimated Air Emissions. Between January 2003 and November 2011, Valero East experienced 274 events that required submission of Air Emission Event Reports to TCEQ [TCEQ 2011b]. These events released an estimated 1,894,000 lbs of reportable chemicals to the air. According to the data Valero East submitted to TCEQ, benzene accounted for fewer than 0.25% of estimated emissions (3,800 lbs), 1,3-butadiene (9 lbs), chloroform (7 lbs), and isopentane accounted for fewer than 0.5% (6,700 lbs).

State and Federal Compliance. On September 1, 2011, TCEQ gave Valero East a compliance rating of 10.88 (considered "average") [TCEQ 2011a]. According to information downloaded from U.S.EPA's ECHO database, as of December 2011 Valero East was in high priority violation of the Clean Air Act and over a 3-year period has been in alleged Clean Air Act noncompliance for 12 consecutive quarters [USEPA 2011a].

Miscellaneous. As part of a 2005 consent decree under EPA's Petroleum Refinery Initiative, Valero East has been required to reduce air emissions of nitrogen oxide and sulfur dioxide [USEPA 2011d]. Further, the consent decree requires the company to pay monetary penalties, invest in environmentally beneficial projects, and implement emissions control technologies. The consent decree required substantial reductions in sulfur dioxide emissions from the facility's Fluidized Catalytic Cracking Unit to be completed by 2010; this was accomplished primarily through installation of wet gas scrubbers [USEPA 2011e].

TCEQ has 10 complaints on file for Valero East, all of which have been closed or referred [TCEQ 2011d].

26O. Valero West

Background. Valero West is located at 5900 Up River Road. Valero West is a subsidiary of Valero Energy Corporation. The facility refines petroleum feedstocks and intermediates including crude oils, natural gasoline, gas oil, and residual fuel oil to produce petroleum products including gasoline and distillates. The feedstocks are received at the refinery via pipeline and marine vessels. Products are shipped out via pipeline, marine vessels, and trucks. Key units at the refinery include a heavy oil cracker, a hydrodesulfurization unit, a hydrocracker, a reformer complex, and a methyl tertiary butyl ether plant. Valero East and West have a combined capacity to process 142,000 barrels of crude oil per day [EIA 2011].

Short-Term Estimated Air Emissions. Between January 2003 and November 2011, Valero West experienced 398 events that required Air Emission Event Reports to be submitted to TCEQ [TCEQ 2011b]. These events released an estimated 4,810,000 lbs of reportable chemicals to the air. According to the data Valero West submitted to TCEQ, benzene accounted for less than 0.25% of estimated emissions from these events (6,000 lbs), 1,3-butadiene accounted for less than 0.10% of emissions (1,300 lbs), and isopentane accounted for less than 1% (35,600 lbs).

State and Federal Compliance. On September 1, 2011, TCEQ gave Valero West a compliance rating of 9.5 (considered "average") [TCEQ 2011a]. According to information downloaded from EPA's ECHO database, Valero West was in high priority violation of the Clean Air Act as of November 2011, and has been in alleged noncompliance with the Clean Air Act for all 12 quarters over a 3-year time frame [USEPA 2011a].

Miscellaneous. In 2008, Valero West entered into a consent decree regarding Clean Water Act violations stemming from a spill of 3,400 barrels of oil into the Corpus Christi Shipping Channel. Further, as part of a 2005 consent decree under U.S. EPA's Petroleum Refinery Initiative, Valero West was required to reduce air emissions of nitrogen oxide and sulfur dioxide [USEPA 2011d]. Further, the consent decree required the company to pay monetary penalties, invest in environmentally beneficial projects, and implement emissions control technologies. And the consent decree required completion by 2005 of substantial reductions in sulfur dioxide emissions from the facility's Fluidized Catalytic Cracking Unit. Valero West met the 2005 deadline primarily by installation of wet gas scrubbers [USEPA 2011e].

TCEQ has 11 complaints on file with for the facility, all of which are closed [TCEQ 2011d].

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