Health Consultation

Public Health Implications of Ambient Air Exposures as Measured in Rural and Urban Oil & Gas Development Areas – an Analysis of 2008 Air Sampling Data

GARFIELD COUNTY

GARFIELD COUNTY, COLORADO

Prepared by the
Colorado Department of Public Health and Environment

AUGUST 26, 2010

Prepared under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

A health consultation is a verbal or written response from ATSDR or ATSDR's Cooperative Agreement Partners to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR or ATSDR's Cooperative Agreement Partner which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Foreword

The Colorado Department of Public Health and Environment's (CDPHE) Environmental Epidemiology Section has prepared this health consultation in cooperation with the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is part of the US Department of Health and Human Services and is the principal federal public health agency responsible for the health issues related to hazardous waste. This health consultation was prepared in accordance with the methodologies and guidelines developed by ATSDR.

The purpose of this health consultation is to identify and prevent harmful health effects resulting from exposure to hazardous substances in the environment. Health consultations focus on health issues associated with specific exposures so that the state or local department of public health can respond quickly to requests from concerned citizens or agencies regarding health information on hazardous substances. The Colorado Cooperative Program for Environmental Health Assessments (CCPEHA) of the Environmental Epidemiology Section (EES) evaluates sampling data collected by our partners, determines whether exposures have occurred or could occur in the future, reports any potential harmful effects, and then recommends actions to protect public health. The findings in this report are relevant to conditions at the site during the time this health consultation was conducted and should not necessarily be relied upon if site conditions or land use changes in the future.

For additional information or questions regarding the contents of this health consultation or the Colorado Cooperative Program for Environmental Health Assessments, please contact:

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Summary and Statement of Issues

INTRODUCTION The Garfield County Public Health Department (GCPHD) requested assistance from the Colorado Cooperative Program for Environmental Health Assessments (CCPEHA) of the Environmental Epidemiology Section of CDPHE to evaluate the potential public health hazards with respect to ambient air pollution in the county. Exploration for natural gas and oil is rapidly increasing in Garfield County, the state of Colorado, and throughout the West. Given the rapid development of the oil and gas industry within Garfield County, and the proximity to residential housing, increased oil and gas development activity within Garfield County has generated concerns about potential impacts to public health.

Based on the results and recommendations of the previous health consultation (ATSDR, 2008), GCPHD enhanced air quality monitoring in 2008 by analyzing samples for 90 speciated non-methane organic compounds (SNMOCs) and carbonyls, increasing the frequency of sampling to a weekly or bi-weekly basis, and focusing on 4 of the original 14 monitoring sites. The 2008 ambient air quality monitoring study findings indicated that some of the primary organic chemicals associated with petroleum and natural gas emission sources were higher in rural Garfield County than in other urban areas (e.g., Grand Junction) outside the County where measurements were available (GCPHD, 2009).

Therefore, the GCPHD requested that CCPEHA evaluate the 2008 data, identify any potential public health implications resulting from inhalation of ambient air in Garfield County and recommend actions to reduce the exposure, if necessary. It is important to note that this health consultation serves as one piece of a multi-pronged approach designed by Garfield County to address air quality concerns via different health assessment methodologies. The resulting assessments, for example, include a screening-level risk assessment by the Colorado Department of Public Health and Environment (CDPHE) according to the United States Environmental Protection Agency (EPA) National Air Toxics Program *Risk Assessment Reference Library.*

ATSDR and CCPEHA's top priority is to ensure the Garfield County community has the best information possible to safeguard its health.

OVERVIEW

CCPEHA and ATSDR have reached one important conclusion regarding exposure to ambient air in the areas of Garfield County which are in close proximity to oil and natural gas development activities.

CONCLUSION 1

It cannot currently be determined if breathing ambient air in those areas of Garfield County which were monitored could harm people's health.

BASIS FOR DECISION

This conclusion was reached because the cancer risks and noncancer hazards for 65 out of 86 contaminants cannot be quantitatively estimated due to the unavailability of chronic inhalation toxicity values. Thus, overall, there is an inability to determine if breathing ambient air in the monitored areas of Garfield County could harm people's health. Nonetheless, the quantitative or qualitative evaluation based on the available toxicity information indicates the following:

- The quantitative evaluation of cancer risk, based on the available toxicity values for 6 carcinogenic contaminants, indicates that inhalation of ambient air in the monitored areas of Garfield County is associated with a low increased risk of developing cancer. The reason for this is that the estimated cumulative theoretical cancer risks from 6 carcinogenic COPCs in the urban and rural oil and gas development areas are slightly below the high-end of EPA's acceptable risk range.

- The quantitative evaluation of long-term (chronic) noncancer hazards, based on the available toxicity values for 21contaminants, indicates that inhalation of ambient air in the monitored areas of Garfield County is associated with a low increased risk of developing long-term (chronic) noncancer health effects. The reason for this is that the noncancer dose estimates are below the health based guidelines.

- The quantitative evaluation of short-term (acute) noncancer hazards, based on the available toxicity value for benzene, indicates that inhalation of ambient air in the monitored areas of Garfield County is associated with a low increased risk of developing acute noncancer health effects; however, this conclusion is associated with the uncertainty because insufficient data are available to evaluate intermittent short-term peak exposures.

- The qualitative evaluation of 65 contaminants with no toxicity values indicates that exposure to these 65 contaminants individually is not likely to result in significant cancer and noncancer effects because the levels measured are much lower than those known to cause health effects. We cannot likewise assume that the cumulative health effects from these contaminants is minimal, though, because the contaminants are of similar classes and might interact synergistically to cause health effects. It should be noted that the current state of the science is unable to assess exposures to complex mixtures of air toxics, especially, synergistic and antagonistic interactions at low levels.

NEXT STEPS

Although we cannot quantify the health impact of contaminants with limited toxicological information, it is important to continue monitoring. This will allow further assessment of those contaminants for which health guidelines are available. It will also add to the knowledge base about the levels of less-well-studied contaminants and indicate areas for further investigation. We recommend that Garfield County should continue to do the following:

- Continue long-term air monitoring; increase the frequency of sampling; and develop a complete list of contaminants associated with oil and gas development.
- Conduct short-term (acute) air monitoring by collecting 1-hour air samples in order to evaluate health risks posed by intermittent peak exposures.
- Conduct source apportionment including sources other than the oil and gas operations, such as stationary industrial sources and mobile traffic sources.
- Continue management of the risk posed by potential exposures to air toxics as a result of increase in oil and gas development activities (e.g., additional monitoring, sample analysis, and action as appropriate).

FOR MORE INFORMATION

If you have concerns about your health, you should contact your health care provider. Please call Raj Goyal, Ph.D at 303-692-2634 or Shannon Rossiter, JD, MPH at 303-692-2617 for more information on the Garfield County health consultation.

Background

The Garfield County Public Health Department has been monitoring air quality since 2005 in response to residents' concerns regarding the health impacts of increased oil and gas development activities. An air quality monitoring study was conducted from June 2005-May 2007 (GCPHD/CDPHE, 2007). This study focused on 43 volatile organic compounds (VOCs), with sampling on a once per month or once per quarter basis, across 14 monitoring sites. At the request of the GCPHD, CCPEHA evaluated the public health implications based on the 2005-2007 air monitoring data (ATSDR, 2008).

Data from the 2005-2007 air monitoring study was used by Garfield County in a multi-pronged approach to address air quality concerns via different health assessment methodologies. The resulting assessments included a screening-level risk assessment by the Colorado Department of Public Health and Environment (CDPHE), a Health Risk Analysis of Oil and Gas Industry Public Health Concerns in Garfield County by the Saccomanno Research Institute, and an ATSDR health consultation by the CCPEHA.

The 2008 ATSDR health consultation, *Public Health Implications of Ambient Air Exposures to Volatile Organic Compounds as Measured in Rural, Urban, and Oil & Gas Development Areas*, concluded that the ambient air quality in Garfield County constituted an indeterminate public health hazard, based on the estimated theoretical cancer risks as well as noncancer hazards. Three major sources of uncertainty were factored into this conclusion: (1) the inability to realistically and continuously monitor ambient air at all places of interest and in the breathing zone of the exposed population, (2) the reality that some of the monitoring locations may detect emissions from sources other than the oil and gas development activities; and (3) the inability to adequately capture intermittent peak exposures, as indicated by grab sampling events. Additionally, it was noted that the estimated theoretical cancer risks and noncancer hazards for benzene at the Brock monitoring site, in the oil and gas development area, appeared to be significantly higher than those in the urban and rural areas, causing some potential concern. As part of the 2008 health consultation, CCPEHA made several recommendations, including continued air monitoring with a re-designed monitoring plan to facilitate a more thorough health risk evaluation for short-term and long-term exposures. It was recommended that Garfield County increase the frequency of sampling, include a complete list of contaminants associated with oil and gas development, and add monitoring sites that are similar to Brock (ATSDR 2008).

Based on the results and recommendations of the previous health consultation report (ATSDR, 2008), Garfield County Public Health Department enhanced air quality monitoring in 2008. These enhancements included: sampling for 90 speciated non-methane organic compounds (SNMOCs) and carbonyls, increasing the frequency of sampling to a weekly or bi-weekly basis, and reducing the number of sites from the 14 that were sampled in 2005-2007 to 4 sites for the 2008 air monitoring. These 4 sites were selected to represent maximum oil and gas development activities in both urban and rural areas. The 2008 ambient air quality monitoring study findings indicated that some of the primary organic chemicals associated with petroleum and natural gas emission sources were higher in rural Garfield County than in other urban areas (e.g., Grand Junction) outside the County where measurements were available (GCPHD, 2009).

Purpose

Garfield County Public Health Department has requested that CCPEHA evaluate potential public health implications, based on the 2008 air monitoring data, resulting from inhalation of ambient air in Garfield County, recommend appropriate actions to reduce the exposure, help guide risk management decision-making, and inform future air monitoring studies.

Site Description and History

Garfield County is located in the heart of perhaps the most oil and gas rich region of the United States. Although the immense richness of energy reserves in this community has been understood for some time, changes in the value of natural gas, along with technology improvements and federal energy policy changes, has caused the extraction of these resources to become expedited. Colorado, like most western states, recognizes separate ownership of the surface estate and the underground mineral estate. As such, natural gas wells and associated facilities are frequently within a few hundred feet of local residences.

In general, air, soil, and water qualities can be affected by extraction of natural gas that is rich in methane (EPA, 2000). Benzene, toluene, ethyl benzene, and xylenes are naturally present in many hydrocarbon deposits, and may be present in drilling and hydraulic fracturing processing chemicals (Brown, 2007). Sometimes methane must be separated from fluids and other gases in processes that emit volatile organic compounds (VOCs) into the air. Chemicals containing VOCs may also be used when a well is drilled and also during a process known as hydraulic fracturing (“fracking”), in which chemical mixtures are injected into wells to break up rock formations and release gases. Compressors and other equipment also emit VOCs (Brown, 2007). In addition, VOCs are released during leaks from tubing, valves, tanks, or when wastes are brought to the surface and evaporated from open pits (EPA, 2000).

A more detailed description of the site and its history is available in the 2008 health consultation, *Public Health Implications of Ambient Air Exposures to Volatile Organic Compounds as Measured in Rural, Urban, and Oil & Gas Development Areas*, available at: http://www.cdphe.state.co.us/dc/ehs/GarfieldCounty.pdf.

Demographics

The demographic data listed herein is U.S. Census 2000 data for Garfield County. In 2000, the county had a population of 43,791 – 21,302 (49%) females and 22,489 (51%) males. The median age was 34 years. Twenty-seven percent of the population were under 18 years old and 9% were 65 years and older. In 2000, there were 16,230 households in the census tract. The average household size was 2.65 persons. Within the county, for people reporting one race, 92% were White alone; 0.5% were Black or African American; 0.7% were American Indian and Alaska Native; 0.4% percent were Asian. Two percent reported two or more races. Seventeen percent of the people in the county were Hispanic or Latino. Ten percent of the people living in the county were foreign born. Among people at least five years old, 16% speak a language other than English at home (US Census 2000).

The population of Garfield County is projected to be 72,562 by 2010, 109,763 by 2020, and 147,864 by 2030. This projected increase in population is largely attributable to job increases in Eagle and Pitkin Counties, the need to house large proportions of those workers in Garfield County, and it further considers energy development jobs growth with the predicted number of wells drilled increasing to nearly 20,000 wells by 2025 (WCGSP, 2005).

A significant and growing proportion of the Garfield County population consists of residents with limited capabilities in reading and speaking English. It is estimated that there were about 3,500 County residents in 2005 with limited English proficiency (LEP), compared with approximately 3,200 such residents identified at the time of the 2000 Census. These estimates are based on residents who self-identify themselves as LEP by reporting that they speak English less than “very well” (BBC, 2007).

Community Health Concerns

Historical Community Health Concerns

In the past few years, some Garfield County residents have expressed concerns regarding health effects that they believe may have environmental causes. Saccomanno Research Institute has recently released a report detailing perceptions of individuals about community health and priority health concerns (Coons and Walker, 2010). These historical community concerns range from mild complaints such as dizziness, nausea, respiratory problems, and eye and skin irritation to more severe concerns including cancer. Additionally, the community also had environmental concerns related to noise, odors, dust, and “toxic” chemicals in water and air. Additional information about historical community health concerns is also available in the 2008 health consultation, *Public Health Implications of Ambient Air Exposures to Volatile Organic Compounds as Measured in Rural, Urban, and Oil & Gas Development Areas*, available at: http://www.cdphe.state.co.us/dc/ehs/GarfieldCounty.pdf.

Discussion

Environmental Sampling and Data Used for Exposure Evaluation

Garfield County has continued ambient air monitoring, and implemented many of CCPEHA's recommendations from the 2008 health consultation. The air monitoring network was modified to encompass Speciated Nonmethane Organic Compounds (SNMOCs) and carbonyl compounds. These changes were designed to serve a wide range of purposes, including monitoring of criteria pollutant levels, ozone formation potential, toxics assessments, and source attribution.

The current monitoring network in Garfield County consists of four (4) stations. Overall, all four sites were located in close proximity (<1.5 mile) to oil and gas development activities in the Garfield County, with two sites (Parachute and Rifle) located in urban areas and two sites (Bell and Brock) in rural areas. Characteristics of the monitoring sites are described below and presented in Figure 1.

- Parachute: Parachute is a small urban center within very close proximity to oil and development activities. The town is located along Interstate 70 and is the transportation hub for heavily traveled roads which service the surrounding canyons.
- Rifle: Rifle is a rapidly growing urban center on the Interstate 70 corridor. Rifle is in close proximity to oil and gas development activities, and is also central to industrial support for the oil and gas industry.
- Brock: The Brock site is a rural location about four (4) miles south of Rifle, amid oil and development activities.
- Bell: The Bell-Melton site is a rural homestead approximately four miles south of the town of Silt, in close proximity to moderate oil and gas development activities.

In 2008, SNMOCs and carbonyl compounds were monitored at all four (4) sites in Garfield County. SNMOCs and carbonyl compounds are subsets of VOCs. VOCs are generally carbon- and hydrogen-based chemicals that exist in the gas phase or can evaporate from liquids. VOCs can react in the atmosphere to form ozone and fine particulate matter.

The speciated non-methane organic compounds were collected with whole-air Summa canisters over a 24-hour period and analyzed via gas chromatography, in accordance with EPA Method TO-12. Likewise, carbonyls were collected on DNPH-coated cartridges and analyzed by liquid chromatography in accordance with EPA Method TO-

11a. These methods can be accessed at http://www.epa.gov/ttn/amtic/airtox.html. The laboratory that was used for sample analyses performs analyses nationally for EPA's air toxics program. Thus, data from this study are expected to be of high quality. Sampling was conducted once every 6th day for the speciated non-methane organic compounds (approximately 60 samples per year) and once every 12th day for the carbonyls (approximately 30 samples per year). While this follows general EPA protocols, the quantity of data is less than ideal for a robust statistical analysis on a one-year basis and can lead to an increased uncertainty.

The results of the sampling analysis and summary statistics for the data used in this evaluation are presented in Appendix B.

Exposure Evaluation

Selection of Contaminants of Potential Concern (COPCs)

The maximum detected concentration of 21 contaminants was compared with conservative health based environmental guidelines or Comparison Values (CVs) to select COPCs at each of the 4 sites for further evaluation of potential health effects. Exposures to contaminants below the environmental guidelines are not expected to result in adverse or harmful health effects. Yet, exceeding the comparison value (CV) does not necessarily mean that the contaminant poses a public health hazard. The amount of contaminant, duration and route of exposure, exposure probability, and the health status and lifestyle of the exposed individual are important factors in determining the potential for adverse health effects.

When more than one CV is available for comparison for the same chemical, the lower of these values is used as a conservative measure. In accordance with the CDPHE and EPA Region 8 protocol for the selection of COPCs, if multiple contaminants exist on-site, the CV values are multiplied by 0.1 (EPA, 1994). For non-carcinogenic contaminants, multiplying the CV by 0.1 is thought to account for any additive adverse effects from multiple chemicals.

As shown in Table 1, acetaldehyde, formaldehyde, 1,3-butadiene, benzene, crotonaldehyde, and ethylbenzene were retained for analysis of cancer risks and non-cancer hazards at each of the four sites. In addition, toluene was retained for analysis of non-cancer hazards at the Bell and Parachute sites. 1,2,4-Trimethylbenzene and 1,3,5-trimethylbenzene were retained for analysis of non-cancer hazards at the Bell, Parachute, and Rifle sites.

In addition to the above-mentioned 9 contaminants, 65 contaminants had limited toxicological information and no available CVs or accepted inhalation toxicity values. Of these 65 contaminants, 59 are comprised of alkanes and alkenes, and 6 are aldehydes. Alkanes and alkenes are the primary components of natural gas, petroleum and/or gasoline vapor. The maximum concentrations, the Exposure Point Concentrations

(EPCs), and the detection frequencies for these contaminants is presented in Tables 4-7, and evaluated qualitatively below.

The Conceptual Site Model

The conceptual site model describes the primary contaminants of potential concern, contaminated sources, and the potential exposure pathways by which different types of populations (e.g. residents and outdoor workers) might come into contact with contaminated media. Exposure pathways are classified as either complete, potential, or eliminated. Only complete exposure pathways can be fully evaluated and characterized to determine the public health implications. A complete exposure pathway consists of five elements: a source, a contaminated environmental medium and transport mechanism, a point of exposure, a route of exposure, and a receptor population.

The overall conceptual site model for all complete and potential pathways in Garfield County is presented below.

Pathway Name	Exposure Pathway Elements						
	Source	Contaminated Medium	Point of Exposure	Potentially Exposed Population	Route of Exposure	Time Frame	Pathway Complete?
Outdoor Air	VOC emissions related to Oil and Gas extraction	Ambient Outdoor Air	Ambient Air	Residents	Inhalation	Present and Future	Yes

Public Health Implications

Quantitative Evaluation of Potential Cancer and Noncancer Health Effects for Contaminants with Known Toxicity Values

The purpose of this evaluation is to determine whether exposures to COPCs that exceed the CVs for the outdoor air exposure pathway might be associated with adverse health effects. This requires a calculation of site-specific exposure doses for an estimated duration of exposure on-site and comparison with an appropriate toxicity value (or health guideline).

The Exposure Point Concentration (EPC) is a high-end, yet reasonable concentration of a contaminant that people could be exposed to based on the available environmental data. For normally distributed data, EPA's statistical software package, ProUCL

Version 4.0 calculates EPCs using the 95% Upper Confidence Limit on the mean of the data for each COPC. If the data is not normally distributed, ProUCL recommends an alternative value to use in lieu of the 95% UCL depending on the type of data distribution. Because not all of the data evaluated were normally distributed, the ProUCL software recommended statistical method was used to calculate the EPC.

Exposure doses are estimates of the concentration of contaminants that people may come into contact with or be exposed to under specified exposure conditions. These exposure doses are estimated using: (1) the estimated exposure point concentration as well as the intake rate; and (2) the length of time and frequency of exposure to site contaminants. Assumptions made for the residents of Garfield County included exposure duration of 24 hours per day for 350 days per year for 30 years. In today's mobile society, it is unlikely that people will spend this much time at one location and therefore the calculated risk estimates are considered conservative. Additional information on the estimation of dose and risk is provided in Appendix C and on the toxicity of COPCs is provided in Appendix D.

Theoretical Cancer Risk Estimates

The theoretical cancer risks for acetaldehyde, formaldehyde, 1,3-butadiene, benzene, crotonaldehyde, and ethylbenzene are either below or at the mid-point of the EPA's acceptable risk range of 1 in a million to 100 in a million (Table 2). The estimated theoretical cancer risks for acetaldehyde range from 1.1E-06 at the Brock site to 2.14E-06 at the Rifle site. Estimated theoretical cancer risks for formaldehyde range from 8.1E-06 at the Bell site to 1.52E-05 at the Rifle site. Estimated theoretical cancer risks for 1,3-butadiene range from 8.41E-07 at the Bell and Brock sites to 2.35E-06 at the Rifle site. The estimated theoretical cancer risks for benzene range from 4.19E-06 at the Brock site to 1.2E-05 at the Parachute site. Estimated theoretical cancer risks for crotonaldehyde range from 3.33E-05 at the Parachute site to 7.67E-05 at the Brock site. Estimated theoretical cancer risks for ethylbenzene range from 2.69E-07 at the Brock site to 1.0E-06 at the Parachute site. In total, this indicates that inhalation of acetaldehyde, formaldehyde, 1,3-butadiene, benzene, crotonaldehyde, or ethylbenzene is associated with a low increased risk of developing cancer.

The cumulative theoretical estimated cancer risk for acetaldehyde, formaldehyde, 1,3-butadiene, benzene, crotonaldehyde, and ethylbenzene combined is within EPA's acceptable risk range at the Bell, Brock, Parachute, and Rifle sites (Table 2). The cumulative theoretical cancer risk is 6.45E-05 at the Bell site, 9.15E-05 at the Brock site, 6.30E-05 at the Parachute site, and 8.5E-05 at the Rifle site. Table 2 shows a comparison of cancer risks across all monitoring sites. The cumulative cancer risk estimates are similar across all four monitoring sites. Crotonaldehyde, a possible human carcinogen, is one of the major contributors to the total cancer risk at each monitoring site. Formaldehyde, a probable human carcinogen, is the second major contributor to the total risk at each monitoring site. Benzene, a known human carcinogen, is the third major contributor to the total cancer risk at each monitoring site.

The cumulative cancer risk estimates for all 6 COPCs across the four monitoring locations are either above the mid-point or slightly below the high-end of EPA's acceptable cancer risk range of one to one-hundred in a million. These cumulative theoretical risk estimates suggest that inhaling acetaldehyde, formaldehyde, 1,3-butadiene, benzene, crotonaldehyde, or ethylbenzene in combination is associated with a low increased risk of developing cancer.

This conclusion must be viewed with caution. First, this risk estimate is conservatively calculated based on the exposure assumption of 24 hrs/day for 350 days/year over 30 years. Second, the inability to realistically and continuously monitor ambient air at all places of interest and in the breathing zone of the exposed population may result in over- or under-estimation of cancer risk. Third, uncertainties in the EPA carcinogenic toxicity value are notable as discussed in more detail in Appendix D. Fourth, these monitoring locations may detect emissions from sources other than the oil and gas development activities. However, it is important to note that the findings of the 2008 air quality monitoring report prepared by ARS Inc. for Garfield County (GCPHD, 2009) suggested that some of the primary chemicals related to petroleum and natural gas emission sources are higher in Garfield County than in areas outside the County. Specifically,

- Concentrations of light alkanes (ethane, propane, butane, and pentane) were 2 to 5 times higher across the four sites in Garfield County than sites outside of Garfield County (GCPHD, 2009). These alkanes are the primary components of natural gas.
- Concentrations of benzene, toluene, ethylbenzene, and/or m/p-xylenes (BTEX) across the four sites in Garfield County were higher than most averages reported across the United States. Some or all of the BTEX compounds were higher than the nearby, more urban, Grand Junction site. These compounds are the primary components of petroleum.
- Concentrations of styrene and n-hexane, especially, at the Bell site were higher than other Garfield sites, and higher than most regional sites.

<u>Noncancer Hazard Estimates: Chronic and Acute</u>

Significant chronic noncancer health effects are not likely from ambient air exposures to acetaldehyde, formaldehyde, 1,3-butadiene, benzene, crotonaldehyde, ethylbenzene, toluene, 1,2,4-trimethylbenzene, or 1,3,5-trimethylbenzene because the maximum values for these compounds are below the ATSDR and/or EPA health guidelines (Table 3). The majority of these chemicals are known to affect the respiratory, immune, and/or nervous systems (Table D1). None of the individual chemicals that are assessed at any monitoring site are found to have a HQ exceeding a value of one for chronic or acute exposure durations. All noncancer HQs are similar across the urban and rural oil & gas development areas. The cumulative hazard estimates across both sites in the urban area are also slightly below one (0.7 to 0.8). The major contributing chemicals to these cumulative hazards are acetaldehyde, formaldehyde, benzene, 1,2,4-trimethylbenzene, and 1,3,5-trimethylbenzene. These chemicals are associated with effects on the respiratory, immune, and nervous systems. The cumulative hazard estimate of slightly below one indicates a low increased potential for respiratory, neurologic, and immunologic effects based on continuous exposure at the two urban locations.

The acute HQs for benzene, based on the maximum detected concentration and ATSDR's acute MRL of 30µg/m³, are found to be 0.1 (Brock), 0.5 (Bell), 0.4 (Parachute), and 0.1 (Rifle), indicating that health effects from acute exposures are not likely to be significant . It should be noted that the acute hazards are estimated based on the maximum detected value for benzene, but this data was only collected on every 6^{th} day and may not have adequately captured short-term high exposures (e.g., intermittent peak exposures).

Qualitative Evaluation of Potential Health Risks of 65 Contaminants Without Toxicity Values

As already mentioned above, toxicological information is limited and/or sufficiently reviewed inhalation toxicity values are not available for 65 additional contaminants, making quantitative estimates of cancer risks and noncancer hazards impossible. Of these 65 contaminants, 59 are comprised of alkanes and alkenes, and 6 are aldehydes.

The ambient air concentration attributable to nine compounds (ethane, propane, n-butane, iso-butane, n-pentane, iso-pentane, n-decane, n-dodecane, and n-undecane) accounts for approximately 85% of the combined exposure point concentrations for all 59 alkanes and alkenes. The highest EPCs for these 9 contaminants (at the Parachute site) range between 13 and 117 µg/m³ (Tables 4 to 7).

At low concentrations, the toxicity of alkanes and alkenes has historically been considered to be minimal (Sandmeyer, 1981). For example, the occupational exposure limits (NIOSH-RELs) for n-butane, iso-butane, n-propane, and n-pentane range between 350,000 and 1,900,000µg/m³ - thousands of times higher than measured in the ambient air in Garfield County. It should, however, be noted that the occupational exposure limits are not intended to be used as acceptable levels for residential exposures that are evaluated in this assessment.

At concentrations much higher than the levels measured here, health effects that are associated with alkanes and alkenes include acting as anesthetics and subsequently asphyxiants, showing narcotic or other central nervous system depression effects, and dermal and pulmonary irritation. Unlike the alkanes, the alkenes do not exhibit neurotoxic properties (Sandmeyer, 1981). Some aliphatic hydrocarbons (propane, butane and isobutane) may be weak cardiac sensitizers in humans following inhalation exposures to high concentrations (e.g., greater than 1,800,000 µg/m³ for propane).

Six contaminants are classified as aldehydes, which generally act as irritants of the eyes, skin, and respiratory tract. It is important to note that some aldehydes have also been shown to be mutagenic and/or carcinogenic. The variation in toxicity among the individual aldehydes is large. Investigations are needed to further characterize the health effects of the common aldehydes.

Overall, based on the qualitative evaluation of health risks, it appears that exposure to these 65 contaminants individually is not likely to result in significant cancer and noncancer effects because the levels measured are much lower than those known to cause health effects. We cannot likewise assume that the cumulative health effects from these contaminants is minimal, though, because the contaminants are of similar classes and might interact synergistically to cause health effects. It should be noted that the current state of the science is unable to assess exposures to complex mixtures of air toxics, especially, synergistic and antagonistic interactions at low levels.

Uncertainty

This is not intended to be an in-depth discussion of all uncertainties. Rather, the focus is to highlight the major assumptions and limitations that are specific to this evaluation. In general, the uncertainties inherent in any risk assessment are likely to over- or underestimate exposures and health hazards. The magnitude of this uncertainty is generally unknown. Some of the major uncertainties of this evaluation include:

- the inability to realistically and continuously monitor ambient air at all places of interest and in the breathing zone of the exposed population;

- the limited toxicological data and unavailability of accepted inhalation toxicity values for 65 contaminants out of 86 detected contaminants; thus, overall risks may be underestimated;

- the cancer risk estimates for crotonaldehyde are considered to be uncertain because only one animal carcinogenicity study is available that was limited by only one sex of one species. There is insufficient evidence that inhalation is a route that results in crotonaldehyde- induced liver lesions or neoplastia.

- the current state of the science is unable to assess exposures to complex mixtures of air toxics, especially, synergistic and antagonistic interactions at low levels. However, the interactions among the components of petroleum are important to be considered since petroleum may contain several hundred hydrocarbons. The hydrocarbons present in the petroleum mixture principally include alkanes, alkenes, and aromatic BTEX compounds. Therefore, the number of possible interactions in a complex mixture of petroleum is very large.

- there are additional chemicals used in oil and gas development activities (e.g., metals, halogenated hydrocarbons, and polycyclic aromatic hydrocarbons) that may need to be monitored and analyzed to fully understand the potential risks associated with these activities in the region. Omitting these chemicals from evaluation may underestimate the potential risks posed by oil and gas activities.

- the reality that some of the monitoring locations may detect emissions from sources other than the oil and gas development activities. There are other multiple local outdoor emission sources that can impact air quality in the Garfield County. Among these are mobile and other stationary sources (e.g., traffic along the I-70 corridor, seasonal forest fires, and mining of coal and uranium). The contribution from different outdoor sources is not evaluated in this assessment. Although the 2008 air quality monitoring report indicated that some of the primary chemicals related to petroleum and natural gas emission sources are higher in Garfield County than in areas outside the County, neglecting to account for other sources will overestimate the contribution of risk posed by oil and gas development activities.

Child Health Considerations

In communities faced with air, water, or food contamination, the many physical differences between children and adults demand special emphasis. Children could be at greater risk than are adults from certain kinds of exposure to hazardous substances. Children play outdoors and sometimes engage in hand-to-mouth behaviors that increase their exposure potential. Children are shorter than are adults; this means they breathe dust, soil, and vapors close to the ground. A child’s lower body weight and higher intake rate results in a greater dose of hazardous substance per unit of body weight. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children can sustain permanent damage. Finally, children are dependent on adults for access to housing, for access to medical care, and for risk identification. Thus adults need as much information as possible to make informed decisions regarding their children’s health.

Conclusions

CCPEHA and ATSDR have reached one conclusion regarding exposure to ambient air in Garfield County:

- *It cannot currently be determined if breathing ambient air in the monitored areas of Garfield County could harm people’s health.* This conclusion was reached because the cancer risks and noncancer hazards for 65 out of 86 contaminants cannot be quantitatively estimated due to limited toxicological information and/or the unavailability of accepted inhalation toxicity values. Thus, overall, there is an inability to determine if breathing ambient air in the four monitored areas in close proximity to the natural gas and oil development activities in Garfield County could harm people's health. Nonetheless, the quantitative or qualitative evaluation based on the available toxicity information indicates the following:

- The quantitative evaluation of cancer risk, based on the available toxicity values for 6 carcinogenic contaminants, indicates that inhalation of ambient air in the monitored areas of Garfield County is associated with a low increased risk of developing cancer. The reason for this is that the estimated cumulative theoretical cancer risks from 6 carcinogenic COPCs in the urban and rural oil and gas development areas are slightly below the high-end of EPA's acceptable risk range.

- The quantitative evaluation of long-term (chronic) noncancer hazards, based on the available toxicity values for 21contaminants, indicates that inhalation of ambient air in the monitored areas of Garfield County is associated with a low increased risk of developing long-term (chronic) noncancer health effects. The reason for this is that the noncancer dose estimates are below the health based guidelines.

- The quantitative evaluation of short-term (acute) noncancer hazards, based on the available toxicity value for benzene, indicates that inhalation of ambient air in the monitored areas of Garfield County is associated with a low increased risk of developing acute noncancer health effects; however, this conclusion is uncertain because insufficient data are available to evaluate intermittent short-term peak exposures.

- The qualitative evaluation of 65 contaminants with no toxicity values indicates that exposure to these 65 contaminants individually is not likely to result in significant cancer and noncancer effects because the levels measured are much lower than those known to cause health effects. We cannot likewise assume that the cumulative health effects from these contaminants is minimal, though, because the contaminants are of similar classes and might interact synergistically to cause health effects. It should be noted that the current state of the science is unable to assess exposures to complex mixtures of air toxics, especially, synergistic and antagonistic interactions at low levels.

Recommendations

Although we cannot quantify the health impact of contaminants with limited toxicological information, it is important to continue monitoring. This will allow further assessment of those contaminants for which health guidelines are available. It will also add to the knowledge base about the levels of less-well-studied contaminants and indicate areas for further investigation. Based upon the data and information reviewed, CCPEHA has made the following recommendations:

- Continue long-term air monitoring; increase the frequency of sampling; and develop a complete list of contaminants associated with oil and gas development.
- Conduct short-term (acute) air monitoring by collecting 1-hour air samples in order to evaluate health risks posed by intermittent peak exposures.
- Conduct source apportionment including sources other than the oil and gas operations, such as stationary industrial sources and mobile traffic sources.
- Continue management of the risk posed by potential exposures to air toxics as a result of increase in oil and gas development activities (e.g., additional monitoring, sample analysis, and action as appropriate).

Public Health Action Plan

The public health action plan describes the actions designed to mitigate or prevent adverse human health effects that might result from exposure to hazardous substances associated with site related contamination. The CCPEHA at CDPHE and Garfield County Public Health commit to do the following public health actions to reduce exposure to site related contamination:

- By request, CCPEHA will evaluate any additional air data that may be collected in the future.
- Upon request, CCPEHA will collaborate with the Garfield County to conduct health education and outreach activities.
- CCPEHA will make this document available to the public through the CCPEHA website and through the information repositories located in the community.

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Tables and Figures

Figure 1. Location of Monitoring Sites in Garfield County.

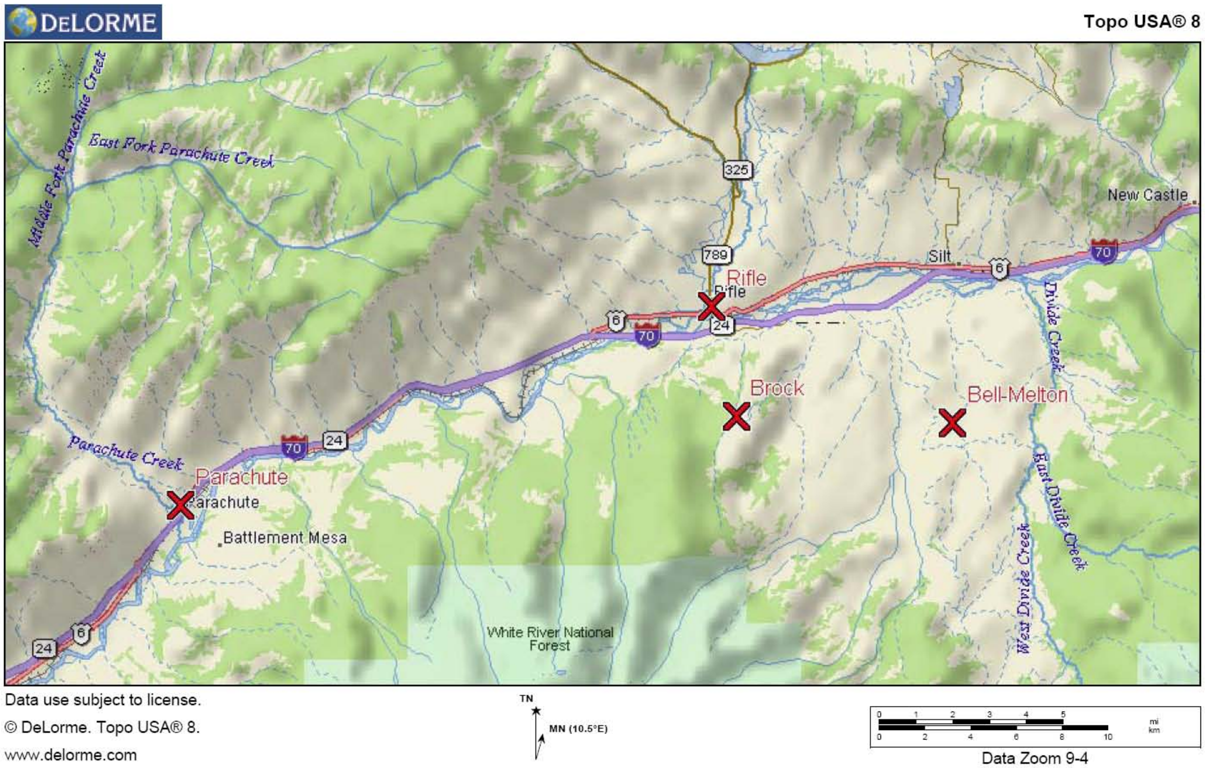

Table 1. Listing of Contaminants Retained for Further Analysis Based on Max Value, by site.

Site Description	Location	Compound
Rural Oil & Gas Development Area	Bell	Acetaldehyde
		Formaldehyde
		1,3-Butadiene
		Benzene
		Crotonaldehyde
		Ethylbenzene
		Toluene
		1,2,4-Trimethylbenzene
		1,3,5-Trimethylbenzene
Rural Oil & Gas Development Area	Brock	Acetaldehyde
		Formaldehyde
		1,3-Butadiene
		Benzene
		Crotonaldehyde
		Ethylbenzene
Urban Oil & Gas Development Area	Parachute	Acetaldehyde
		Formaldehyde
		1,3-Butadiene
		Benzene
		Crotonaldehyde
		Ethylbenzene
		Toluene
		1,2,4-Trimethylbenzene
		1,3,5-Trimethylbenzene
Urban Oil & Gas Development Area	Rifle	Acetaldehyde
		Formaldehyde
		1,3-Butadiene
		Crotonaldehyde
		Benzene
		Ethylbenzene
		1,2,4-Trimethylbenzene
		1,3,5-Trimethylbenzene

Table 2. Theoretical Cancer Risk Estimates for Ambient Air in Garfield County

Site Description	Location	Compound	EPC µg/m³	Cancer Risk	Cumulative Cancer Risk per Site
Rural Oil & Gas Development Area	Bell	Acetaldehyde	0.943	1.16E-06	6.45E-05
		Formaldehyde	1.128	8.1E-06	
		1,3-Butadiene	0.053	8.41E-07	
		Benzene	1.521	6.61E-06	
		Crotonaldehyde	0.155	4.7E-05	
		Ethylbenzene	0.576	8.1E-07	
Rural Oil & Gas Development Area	Brock	Acetaldehyde	0.889	1.1E-06	9.15E-05
		Formaldehyde	1.175	8.39E-06	
		1,3-Butadiene	0.053	8.41E-07	
		Benzene	0.964	4.19E-06	
		Crotonaldehyde	0.253	7.67E-05	
		Ethylbenzene	0.191	2.69E-07	
Urban Oil & Gas Development Area	Parachute	Acetaldehyde	1.201	1.48E-06	6.30E-05
		Formaldehyde	1.865	1.33E-05	
		1,3-Butadiene	0.111	1.76E-06	
		Benzene	2.755	1.2E-05	
		Crotonaldehyde	0.110	3.33E-05	
		Ethylbenzene	0.726	1.0E-06	
Urban Oil & Gas Development Area	Rifle	Acetaldehyde	1.732	2.14E-06	8.5E-05
		Formaldehyde	2.124	1.52E-05	
		1,3-Butadiene	0.148	2.35E-06	
		Benzene	1.862	8.1E-06	
		Crotonaldehyde	0.186	5.64E-05	
		Ethylbenzene	0.526	7.4E-07	

Note:
- µg/m³ = Micrograms per Cubic Meter of Air
- EPC = Exposure Point Concentration
- The cancer risk estimates for crotonaldehyde are considered to be uncertain because they are calculated using EPA's oral cancer toxicity value (i.e., route-to-route extrapolation).

Table 3. Chronic Non-Cancer Hazards for Ambient Air in Garfield County, by site

Site Description	Location	Compound	EPC µg/m³	HQ
Rural Oil & Gas Development Area	Bell	Acetaldehyde	0.943	0.1
		Formaldehyde	1.128	0.1
		1,3-Butadiene	0.053	0.03
		Benzene	1.521	0.05
		Crotonaldehyde	0.155	NA
		Ethylbenzene	0.576	0.0006
		Toluene	9.371	0.002
		1,2,4-Trimethylbenzene	0.304	0.04
		1,3,5-Trimethylbenzene		0. 0.19
		Cumulative Hazard		**0.5**
Rural Oil & Gas Development Area	Brock	Acetaldehyde	0.889	0.1
		Formaldehyde	1.175	0.12
		1,3-Butadiene	0.053	0.03
		Benzene	0.964	0.03
		Crotonaldehyde	0.253	NA
		Ethylbenzene	0.191	0.0002
		Cumulative Hazard		**0.3**
Urban Oil & Gas Development Area	Parachute	Acetaldehyde	1.201	0.1
		Formaldehyde	1.865	0.2
		1,3-Butadiene	0.111	0.06
		Benzene	2.755	0.09
		Crotonaldehyde	0.110	NA
		Ethylbenzene	0.726	0.0007
		Toluene	11.830	0.002
		1,2,4-Trimethylbenzene	1.124	0.2
		1,3,5-Trimethylbenzene	0.765	0.1
		Cumulative Hazard		**0.8**
Urban Oil & Gas Development Area	Rifle	Acetaldehyde	1.732	0.2
		Formaldehyde	2.124	0.2
		1,3-Butadiene	0.148	0.07
		Benzene	1.862	0.06
		Crotonaldehyde	0.186	NA
		Ethylbenzene	0.526	0.0005
		1,2,4-Trimethylbenzene	0.690	0.1
		1,3,5-Trimethylbenzene	0.361	0.06
		Cumulative Hazard		**0.7**

Note:

- $\mu g/m^3$ = Micrograms per Cubic Meter of Air
- EPC = Exposure Point Concentration
- HQ = Noncancer Hazard

Table 4. Chemicals with No Toxicity Values Measured at the Bell Monitoring Site

Compound	Max. µg/m³	% Detected	EPC µg/m³	Compound	Max. µg/m³	% Detected	EPC µg/m³
1,2,3-Trimethylbenzene	0.841	39.0%	0.098	Cyclopentene	0.669	76.3%	0.235
1-Decene	0.057	0.0%	n/a	Ethane	411.389	100.0%	103.400
1-Dodecene	0.998	27.1%	0.175	Ethylene	1.514	100.0%	0.735
1-Heptene	2.484	96.6%	0.781	Isobutane	118.261	100.0%	32.020
1-Hexene	0.221	64.4%	0.102	Isobutene/1-Butene	4.727	79.7%	1.685
1-Nonene	0.426	55.9%	0.117	Isopentane	123.349	93.2%	39.230
1-Octene	1.365	20.3%	0.223	Isoprene	3.332	52.5%	0.724
1-Pentene	0.322	96.6%	0.109				
1-Tridecene	0.133	3.4%	0.121	m-Diethylbenzene	0.530	30.5%	0.118
1-Undecene	0.205	10.2%	0.057	Methylcyclopentane	8.892	100.0%	3.266
2,2,3-Trimethylpentane	1.635	49.2%	0.288	m-Ethyltoluene	1.628	98.3%	0.202
2,2,4-Trimethylpentane	2.155	33.9%	0.394	n-Butane	136.684	100.0%	35.460
2,2-Dimethylbutane	2.338	100.0%	0.776	n-Decane	69.831	100.0%	6.799
2,3,4-Trimethylpentane	1.793	57.6%	0.228	n-Dodecane	71.407	100.0%	9.256
2,3-Dimethylbutane	4.935	100.0%	1.540	n-Heptane	9.543	100.0%	3.231
2,3-Dimethylpentane	1.850	100.0%	0.612				
2,4-Dimethylpentane	1.095	100.0%	0.426	n-Octane	5.665	100.0%	1.868
2-Ethyl-1-butene	0.123	0.0%	n/a	n-Pentane	61.970	100.0%	17.390
2-Methyl-1-butene	2.455	45.8%	0.610				
2-Methyl-1-pentene	0.152	3.4%	0.125	n-Tridecane	3.828	33.9%	0.492
2-Methyl-2-butene	0.417	39.0%	0.136	n-Undecane	254.561	100.0%	31.790
2-Methylheptane	2.926	100.0%	0.820	o-Ethyltoluene	1.202	71.2%	0.247
2-Methylhexane	4.842	100.0%	1.653	p-Diethylbenzene	0.421	18.6%	0.058
2-Methylpentane	20.561	100.0%	6.728	p-Ethyltoluene	0.907	96.6%	0.202
3-Methyl-1-butene	0.200	1.7%	0.064	Propane	315.646	100.0%	82.470
3-Methylheptane	3.533	100.0%	0.544	Propyne	0.350	1.7%	0.063
3-Methylhexane	4.403	100.0%	1.548	trans-2-Butene	3.345	69.5%	0.367
3-Methylpentane	10.574	100.0%	3.501	trans-2-Hexene	0.123	0.0%	n/a
4-Methyl-1-pentene	4.676	20.3%	0.547	trans-2-Pentene	0.318	49.2%	0.081
Acetylene	1.816	100.0%	0.600	2,5-Dimethylbenzaldehyde	0.005	0.0%	n/a
a-Pinene	3.365	79.7%	0.463	Benzaldehyde	0.195	96.8%	0.085
b-Pinene	1.432	3.4%	0.118	Butyraldehyde	0.218	93.5%	0.092
cis-2-Butene	0.153	39.0%	0.063	Hexaldehyde	0.098	74.2%	0.092
cis-2-Hexene	0.700	22.0%	0.146	Isovaleraldehyde	0.113	9.7%	0.026
cis-2-Pentene	0.145	13.6%	0.061	Tolualdehydes	0.251	93.5%	0.094
Cyclopentane	2.937	100.0%	0.907	Valeraldehyde	0.081	48.4%	0.066

Note:
- µg/m³ = Micrograms per Cubic Meter of Air
- EPC = Exposure Point Concentration

Table 5. Chemicals with No Toxicity Values Measured at the Brock Monitoring Site

Compound	Max. µg/m³	% Detected	EPC µg/m³	Compound	Max. µg/m³	% Detected	EPC µg/m³
1,2,3-Trimethylbenzene	0.135	42.4%	0.070	Cyclopentene	0.825	66.1%	0.218
1-Decene	0.057	0.0%	n/a	Ethane	193.703	100.0%	63.740
1-Dodecene	1.503	22.0%	0.320	Ethylene	1.744	100.0%	0.768
1-Heptene	1.113	91.5%	0.497	Isobutane	32.626	100.0%	12.300
1-Hexene	0.222	67.8%	0.098	Isobutene/1-Butene	5.341	81.4%	2.372
1-Nonene	0.252	44.1%	0.100	Isopentane	32.578	91.5%	12.300
1-Octene	0.232	22.0%	0.101	Isoprene	0.964	52.5%	0.306
1-Pentene	0.256	100.0%	0.107				
1-Tridecene	0.120	1.7%	0.120	m-Diethylbenzene	0.369	27.1%	0.085
1-Undecene	0.349	16.9%	0.070	Methylcyclopentane	4.567	100.0%	1.938
2,2,3-Trimethylpentane	0.281	50.8%	0.129	m-Ethyltoluene	8.739	100.0%	1.727
2,2,4-Trimethylpentane	0.940	52.5%	0.233	n-Butane	34.587	100.0%	13.630
2,2-Dimethylbutane	1.022	100.0%	0.428	n-Decane	1.158	100.0%	0.442
2,3,4-Trimethylpentane	0.280	55.9%	0.086	n-Dodecane	2.049	98.3%	0.598
2,3-Dimethylbutane	1.845	100.0%	0.787	n-Heptane	4.713	100.0%	2.078
2,3-Dimethylpentane	0.820	98.3%	0.383				
2,4-Dimethylpentane	0.509	100.0%	0.263	n-Octane	3.305	100.0%	1.233
2-Ethyl-1-butene	0.123	0.0%	n/a	n-Pentane	35.057	100.0%	8.222
2-Methyl-1-butene	2.903	47.5%	0.647				
2-Methyl-1-pentene	0.123	3.4%	0.123	n-Tridecane	0.463	32.2%	0.147
2-Methyl-2-butene	0.248	50.8%	0.101	n-Undecane	1.871	100.0%	0.707
2-Methylheptane	1.267	98.3%	0.528	o-Ethyltoluene	0.563	59.3%	0.174
2-Methylhexane	2.535	100.0%	1.092	p-Diethylbenzene	0.714	11.9%	0.104
2-Methylpentane	10.339	100.0%	3.619	p-Ethyltoluene	0.274	88.1%	0.110
3-Methyl-1-butene	1.073	8.5%	0.113	Propane	98.602	100.0%	35.500
3-Methylheptane	0.899	100.0%	0.352	Propyne	0.049	0.0%	n/a
3-Methylhexane	2.160	98.3%	1.015	trans-2-Butene	0.262	69.5%	0.120
3-Methylpentane	10.104	100.0%	2.210	trans-2-Hexene	0.123	0.0%	n/a
4-Methyl-1-pentene	0.418	11.9%	0.140	trans-2-Pentene	0.170	52.5%	0.074
Acetylene	1.108	100.0%	0.576	2,5-Dimethylbenzaldehyde	0.005	0.0%	0.005
a-Pinene	1.008	59.3%	0.277	Benzaldehyde	0.217	92.6%	0.094
b-Pinene	1.605	16.9%	0.322	Butyraldehyde	0.177	92.6%	0.085
cis-2-Butene	0.185	54.2%	0.073	Hexaldehyde	0.172	81.5%	0.071
cis-2-Hexene	0.123	11.9%	0.121	Isovaleraldehyde	0.074	3.7%	0.018
cis-2-Pentene	0.079	22.0%	0.057	Tolualdehydes	0.256	100.0%	0.130
Cyclopentane	1.021	100.0%	0.460	Valeraldehyde	0.063	55.6%	0.062

Note:

- µg/m³ = Micrograms per Cubic Meter of Air
- EPC = Exposure Point Concentration

Table 6. Chemicals with No Toxicity Values Measured at the Parachute Monitoring Site

Compound	Max. µg/m³	% Detected	EPC µg/m³	Compound	Max. µg/m³	% Detected	EPC µg/m³
1,2,3-Trimethylbenzene	3.485	91.5%	0.503	Cyclopentene	1.109	76.3%	0.301
1-Decene	0.057	0.0%	n/a	Ethane	318.535	100.0%	116.900
1-Dodecene	7.114	76.3%	1.609	Ethylene	4.210	98.3%	2.039
1-Heptene	2.467	93.2%	1.068	Isobutane	274.556	100.0%	43.190
1-Hexene	0.200	74.6%	0.099	Isobutene/1-Butene	6.483	78.0%	3.691
1-Nonene	1.899	84.7%	0.248	Isopentane	125.120	96.6%	34.020
1-Octene	1.021	32.2%	0.282	Isoprene	1.588	81.4%	0.615
1-Pentene	0.648	96.6%	0.172				
1-Tridecene	0.282	5.1%	0.127	m-Diethylbenzene	2.256	66.1%	0.325
1-Undecene	1.228	16.9%	0.216	Methylcyclopentane	10.040	100.0%	3.858
2,2,3-Trimethylpentane	1.069	89.8%	0.397	m-Ethyltoluene	2.458	100.0%	0.589
2,2,4-Trimethylpentane	3.632	39.0%	0.576	n-Butane	54.317	100.0%	21.710
2,2-Dimethylbutane	1.921	100.0%	0.859	n-Decane	112.893	100.0%	13.150
2,3,4-Trimethylpentane	0.392	78.0%	0.138	n-Dodecane	82.437	100.0%	16.420
2,3-Dimethylbutane	3.713	100.0%	1.512	n-Heptane	19.437	100.0%	5.281
2,3-Dimethylpentane	4.104	100.0%	0.899				
2,4-Dimethylpentane	1.499	100.0%	0.549	n-Octane	12.556	100.0%	4.393
2-Ethyl-1-butene	0.123	0.0%	n/a	n-Pentane	150.498	100.0%	16.640
2-Methyl-1-butene	2.639	78.0%	0.804				
2-Methyl-1-pentene	0.177	10.2%	0.123	n-Tridecane	5.371	57.6%	0.826
2-Methyl-2-butene	1.342	79.7%	0.223	n-Undecane	225.501	100.0%	36.800
2-Methylheptane	4.911	100.0%	1.654	o-Ethyltoluene	6.336	96.6%	0.501
2-Methylhexane	12.002	98.3%	2.760	p-Diethylbenzene	1.751	39.0%	0.232
2-Methylpentane	14.921	100.0%	6.135	p-Ethyltoluene	3.457	100.0%	0.447
3-Methyl-1-butene	0.209	3.4%	0.067	Propane	155.719	100.0%	59.030
3-Methylheptane	3.749	100.0%	1.291	Propyne	0.049	0.0%	n/a
3-Methylhexane	16.920	100.0%	2.894	trans-2-Butene	1.050	94.9%	0.289
3-Methylpentane	8.753	100.0%	3.576	trans-2-Hexene	0.209	6.8%	0.126
4-Methyl-1-pentene	0.254	25.4%	0.129	trans-2-Pentene	0.906	93.2%	0.157
Acetylene	2.498	100.0%	1.302	2,5-Dimethylbenzaldehyde	0.005	0.0%	0.005
a-Pinene	6.018	88.1%	0.472	Benzaldehyde	0.247	100.0%	0.131
b-Pinene	2.017	8.5%	0.270	Butyraldehyde	0.711	93.1%	0.233
cis-2-Butene	0.481	91.5%	0.144	Hexaldehyde	0.221	86.2%	0.102
cis-2-Hexene	0.223	18.6%	0.122	Isovaleraldehyde	0.159	10.3%	0.033
cis-2-Pentene	0.352	66.1%	0.086	Tolualdehydes	0.226	96.6%	0.120
Cyclopentane	2.679	100.0%	0.841	Valeraldehyde	0.113	72.4%	0.060

Note:

- µg/m³ = Micrograms per Cubic Meter of Air
- EPC = Exposure Point Concentration

Table 7. Chemicals with No Toxicity Values Measured at the Rifle Monitoring Site

Compound	Max. µg/m³	% Detected	EPC µg/m³	Compound	Max. µg/m³	% Detected	EPC µg/m³
1,2,3-Trimethylbenzene	0.358	90.0%	0.150	Cyclopentene	0.658	90.0%	0.214
1-Decene	0.057	0.0%	n/a	Ethane	204.772	100.0%	74.860
1-Dodecene	0.981	36.7%	0.203	Ethylene	7.801	98.3%	2.381
1-Heptene	1.675	96.7%	0.655	Isobutane	46.948	100.0%	17.350
1-Hexene	0.182	85.0%	0.101	Isobutene/1-Butene	7.057	85.0%	2.462
1-Nonene	0.410	68.3%	0.117	Isopentane	40.369	95.0%	17.810
1-Octene	0.524	30.0%	0.123	Isoprene	1.817	96.7%	0.579
1-Pentene	0.981	98.3%	0.253				
1-Tridecene	0.120	3.3%	0.120	m-Diethylbenzene	0.708	61.7%	0.144
1-Undecene	0.278	15.0%	0.066	Methylcyclopentane	6.081	100.0%	2.492
2,2,3-Trimethylpentane	0.467	75.0%	0.252	m-Ethyltoluene	0.961	100.0%	0.467
2,2,4-Trimethylpentane	0.940	100.0%	0.213	n-Butane	53.366	100.0%	19.790
2,2-Dimethylbutane	1.439	100.0%	0.596	n-Decane	1.688	100.0%	0.820
2,3,4-Trimethylpentane	0.339	90.0%	0.130	n-Dodecane	3.576	100.0%	0.834
2,3-Dimethylbutane	2.820	100.0%	1.132	n-Heptane	7.025	100.0%	2.644
2,3-Dimethylpentane	1.288	100.0%	0.603				
2,4-Dimethylpentane	0.831	100.0%	0.408	n-Octane	4.684	100.0%	1.825
2-Ethyl-1-butene	0.123	0.0%	n/a	n-Pentane	34.703	100.0%	11.050
2-Methyl-1-butene	4.394	88.3%	0.709				
2-Methyl-1-pentene	0.181	36.7%	0.111	n-Tridecane	0.748	51.7%	0.167
2-Methyl-2-butene	1.819	96.7%	0.417	n-Undecane	3.877	100.0%	0.991
2-Methylheptane	1.962	100.0%	0.783	o-Ethyltoluene	0.484	98.3%	0.257
2-Methylhexane	3.425	100.0%	1.591	p-Diethylbenzene	0.184	48.3%	0.078
2-Methylpentane	11.808	100.0%	5.029	p-Ethyltoluene	0.545	100.0%	0.257
3-Methyl-1-butene	0.314	8.3%	0.088	Propane	128.663	100.0%	42.280
3-Methylheptane	1.314	100.0%	0.584	Propyne	0.049	0.0%	n/a
3-Methylhexane	3.431	100.0%	1.530	trans-2-Butene	1.922	100.0%	0.602
3-Methylpentane	7.167	100.0%	2.800	trans-2-Hexene	0.212	35.0%	0.116
4-Methyl-1-pentene	0.344	25.0%	0.144	trans-2-Pentene	1.790	100.0%	0.354
Acetylene	4.968	100.0%	1.865	2,5-Dimethylbenzaldehyde	0.005	0.0%	n/a
a-Pinene	0.830	88.3%	0.292	Benzaldehyde	0.313	100.0%	0.148
b-Pinene	0.168	1.7%	0.061	Butyraldehyde	0.360	100.0%	0.179
cis-2-Butene	1.876	100.0%	0.519	Hexaldehyde	0.348	100.0%	0.131
cis-2-Hexene	0.363	21.7%	0.140	Isovaleraldehyde	0.134	22.6%	0.076
cis-2-Pentene	0.895	91.7%	0.171	Tolualdehydes	0.246	100.0%	0.162
Cyclopentane	1.721	100.0%	0.652	Valeraldehyde	0.208	80.6%	0.139

Note:

- µg/m³ = Micrograms per Cubic Meter of Air
- EPC = Exposure Point Concentration

APPENDICES

Appendix A. ATSDR Plain Language Glossary of Environmental Health Terms

Absorption: How a chemical enters a person's blood after the chemical has been swallowed, has come into contact with the skin, or has been breathed in.

Acute Exposure: Contact with a chemical that happens once or only for a limited period of time. ATSDR defines acute exposures as those that might last up to 14 days.

Additive Effect: A response to a chemical mixture, or combination of substances, that might be expected if the known effects of individual chemicals, seen at specific doses, were added together.

Adverse Health Effect: A change in body function or the structures of cells that can lead to disease or health problems.

Antagonistic Effect: A response to a mixture of chemicals or combination of substances that is **less** than might be expected if the known effects of individual chemicals, seen at specific doses, were added together.

ATSDR: The **A**gency for **T**oxic **S**ubstances and **D**isease **R**egistry. ATSDR is a federal health agency in Atlanta, Georgia that deals with hazardous substance and waste site issues. ATSDR gives people information about harmful chemicals in their environment and tells people how to protect themselves from coming into contact with chemicals.

Background Level: An average or expected amount of a chemical in a specific environment. Or, amounts of chemicals that occur naturally in a specific environment.

Bioavailability: See **Relative Bioavailability.**

Biota: Used in public health, things that humans would eat - including animals, fish and plants.

Cancer: A group of diseases, which occur when cells in the body become abnormal and grow, or multiply, out of control

Carcinogen: Any substance shown to cause tumors or cancer in experimental studies.

CDPHE: The Colorado Department of Public Health and Environment.

CERCLA: See **C**omprehensive **E**nvironmental **R**esponse, **C**ompensation, and **L**iability **A**ct.

Chronic Exposure: A contact with a substance or chemical that happens over a long period of time. ATSDR considers exposures of more than one year to be *chronic*.

Completed Exposure Pathway: See **Exposure Pathway**.

Comparison Value (CVs): Concentrations or the amount of substances in air, water, food, and soil that are unlikely, upon exposure, to cause adverse health effects. Comparison values are used by health assessors to select which substances and environmental media (air, water, food and soil) need additional evaluation while health concerns or effects are investigated.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA):
CERCLA was put into place in 1980. It is also known as **Superfund**. This act concerns releases of hazardous substances into the environment, and the cleanup of these substances and hazardous waste sites. ATSDR was created by this act and is responsible for looking into the health issues related to hazardous waste sites.

Concern: A belief or worry that chemicals in the environment might cause harm to people.

Concentration: How much or the amount of a substance present in a certain amount of soil, water, air, or food.

Contaminant: See **Environmental Contaminant**.

Delayed Health Effect: A disease or injury that happens as a result of exposures that may have occurred far in the past.

Dermal Contact: A chemical getting onto your skin. (See **Route of Exposure**).

Dose: The amount of a substance to which a person may be exposed, usually on a daily basis. Dose is often explained as "amount of substance(s) per body weight per day".

Dose / Response: The relationship between the amount of exposure (dose) and the change in body function or health that result.

Duration: The amount of time (days, months, years) that a person is exposed to a chemical.

EES: Environmental Epidemiology Section within the Colorado Department of Public Health and Environment.

Environmental Contaminant: A substance (chemical) that gets into a system (person, animal, or the environment) in amounts higher than that found in **Background Level**, or what would be expected.

Environmental Media: Usually refers to the air, water, and soil in which chemical of interest are found. Sometimes refers to the plants and animals that are eaten by humans. **Environmental Media** is the second part of an **Exposure Pathway**.

U.S. Environmental Protection Agency (EPA): The federal agency that develops and enforces environmental laws to protect the environment and the public's health.

Exposure: Coming into contact with a chemical substance. (For the three ways people can come in contact with substances, see **Route of Exposure**.)

Exposure Assessment: The process of finding the ways people come in contact with chemicals, how often and how long they come in contact with chemicals, and the amounts of chemicals with which they come in contact.

Exposure Pathway: A description of the way that a chemical moves from its source (where it began) to where and how people can come into contact with (or get exposed to) the chemical.

ATSDR defines an exposure pathway as having 5 parts:

- Source of Contamination,
- Environmental Media and Transport Mechanism,
- Point of Exposure,
- Route of Exposure; and,
- Receptor Population.

When all 5 parts of an exposure pathway are present, it is called a **Completed Exposure Pathway**. Each of these 5 terms is defined in this Glossary.

Frequency: How often a person is exposed to a chemical over time; for example, every day, once a week, and twice a month.

Hazardous Waste: Substances that have been released or thrown away into the environment and, under certain conditions, could be harmful to people who come into contact with them.

Health Effect: ATSDR deals only with **Adverse Health Effects** (see definition in this Glossary).

Indeterminate Public Health Hazard: The category is used in Public Health Assessment documents for sites where important information is lacking (missing or has not yet been gathered) about site-related chemical exposures.

Ingestion: Swallowing something, as in eating or drinking. It is a way a chemical can enter your body (See **Route of Exposure**).

Inhalation: Breathing. It is a way a chemical can enter your body (See **Route of Exposure**).

LOAEL: **L**owest **O**bserved **A**dverse **E**ffect **L**evel. The lowest dose of a chemical in a study, or group of studies, that has caused harmful health effects in people or animals.

MRL: **M**inimal **R**isk **L**evel. An estimate of daily human exposure - by a specified route and length of time -- to a dose of chemical that is likely to be without a measurable risk of adverse, noncancerous effects. An MRL should not be used as a predictor of adverse health effects.

NPL: The **N**ational **P**riorities **L**ist. (Which is part of **Superfund**.) A list kept by the U.S. Environmental Protection Agency (EPA) of the most serious, uncontrolled or abandoned hazardous waste sites in the country. An NPL site needs to be cleaned up or is being looked at to see if people can be exposed to chemicals from the site.

NOAEL: **N**o **O**bserved **A**dverse **E**ffect **L**evel. The highest dose of a chemical in a study, or group of studies, that did not cause harmful health effects in people or animals.

No Apparent Public Health Hazard: The category is used in ATSDR's Public Health Assessment documents for sites where exposure to site-related chemicals may have occurred in the past or is still occurring but the exposures are not at levels expected to cause adverse health effects.

No Public Health Hazard: The category is used in ATSDR's Public Health Assessment documents for sites where there is evidence of an absence of exposure to site-related chemicals.

PHA: **P**ublic **H**ealth **A**ssessment. A report or document that looks at chemicals at a hazardous waste site and tells if people could be harmed from coming into contact with those chemicals. The PHA also tells if possible further public health actions are needed.

Point of Exposure: The place where someone can come into contact with a contaminated environmental medium (air, water, food or soil). Some examples include: the area of a playground that has contaminated dirt, a contaminated spring used for drinking water, the location where fruits or vegetables are grown in contaminated soil, or the backyard area where someone might breathe contaminated air.

Population: A group of people living in a certain area; or the number of people in a certain area.

Public Health Assessment(s): See **PHA**.

Public Health Hazard: The category is used in PHAs for sites that have certain physical features or evidence of chronic, site-related chemical exposure that could result in adverse health effects.

Public Health Hazard Criteria: PHA categories given to a site which tell whether people could be harmed by conditions present at the site. Each is defined in the Glossary. The categories are:

- o Urgent Public Health Hazard
- o Public Health Hazard
- o Indeterminate Public Health Hazard
- o No Apparent Public Health Hazard
- o No Public Health Hazard

Receptor Population: People who live or work in the path of one or more chemicals, and who could come into contact with them (See **Exposure Pathway**).

Reference Dose (RfD): An estimate, with safety factors (see **safety factor**) built in, of the daily, lifetime exposure of human populations to a possible hazard that is not likely to cause harm to the person.

Relative Bioavailability: The amount of a compound that can be absorbed from a particular medium (such as soil) compared to the amount absorbed from a reference material (such as water). Expressed in percentage form.

Route of Exposure: The way a chemical can get into a person's body. There are three exposure routes:

- o Breathing (also called inhalation),
- o Eating or drinking (also called ingestion), and/or
- o Getting something on the skin (also called dermal contact).

Safety Factor: Also called **Uncertainty Factor**. When scientists don't have enough information to decide if an exposure will cause harm to people, they use "safety factors" and formulas in place of the information that is not known. These factors and formulas can help determine the amount of a chemical that is not likely to cause harm to people.

SARA: The **S**uperfund **A**mendments and **R**eauthorization **A**ct in 1986 amended CERCLA and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from chemical exposures at hazardous waste sites.

Sample: A small number of people chosen from a larger population (See **Population**).

Source (of Contamination): The place where a chemical comes from, such as a landfill, pond, creek, incinerator, tank, or drum. Contaminant source is the first part of an **Exposure Pathway**.

Special Populations: People who may be more sensitive to chemical exposures because of certain factors such as age, a disease they already have, occupation, sex, or certain behaviors (like cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Statistics: A branch of the math process of collecting, looking at, and summarizing data or information.

Superfund Site: See **NPL**.

Survey: A way to collect information or data from a group of people (**population**). Surveys can be done by phone, mail, or in person. ATSDR cannot do surveys of more than nine people without approval from the U.S. Department of Health and Human Services.

Synergistic effect: A health effect from an exposure to more than one chemical, where one of the chemicals worsens the effect of another chemical. The combined effect of the chemicals acting together is greater than the effects of the chemicals acting by themselves.

Toxic: Harmful. Any substance or chemical can be toxic at a certain dose (amount). The dose is what determines the potential harm of a chemical and whether it would cause someone to get sick.

Toxicology: The study of the harmful effects of chemicals on humans or animals.

Tumor: Abnormal growth of tissue or cells that have formed a lump or mass.

Uncertainty Factor: See **Safety Factor**.

Urgent Public Health Hazard: This category is used in ATSDR's Public Health Assessment documents for sites that have certain physical features or evidence of short-term (less than 1 year), site-related chemical exposure that could result in adverse health effects and require quick intervention to stop people from being exposed.

Appendix B. Data Summary and Selection of Contaminants of Potential Concern (COPCs)

Table B1. Summary of 21chemicals with available toxicity values

Compound	BELL			BROCK			PARACHUTE			RIFLE		
	Max. µg/m³	% Detected	EPC µg/m³	Max. µg/m³	% Detected	EPC µg/m³	Max. µg/m³	% Detected	EPC µg/m³	Max. µg/m³	% Detected	EPC µg/m³
Acetaldehyde	1.964	100.0%	0.943	1.591	100.0%	0.889	1.838	100.0%	1.201	2.901	100.0%	1.732
Acetone	5.392	100.0%	3.113	6.366	100.0%	3.269	5.915	100.0%	3.709	6.746	100.0%	3.988
Formaldehyde	2.237	100.0%	1.128	2.102	100.0%	1.175	3.257	100.0%	1.865	4.818	100.0%	2.124
1,3-Butadiene	0.053	5.1%	0.053	0.053	1.7%	0.053	0.033	52.5%	0.111	0.486	81.7%	0.148
Benzene	13.631	100.0%	1.521	2.401	100.0%	0.964	11.076	100.0%	2.755	4.079	100.0%	1.862
Crotonaldehyde	0.467	93.5%	0.155	0.519	100.0%	0.253	0.238	100.0%	0.110	0.436	100.0%	0.186
Cyclohexane	104.985	100.0%	5.010	5.347	100.0%	2.413	13.080	100.0%	4.721	7.401	100.0%	2.811
Ethylbenzene	4.337	96.6%	0.576	0.482	96.6%	0.191	2.616	100.0%	0.726	1.167	100.0%	0.526
n-Hexane	22.089	100.0%	7.319	24.262	100.0%	4.606	18.799	100.0%	6.940	15.920	100.0%	5.110
Isopropylbenzene	0.298	22.0%	0.09	0.094	18.6%	0.084	0.250	40.7%	0.099	0.120	51.7%	0.080
Methylcyclohexane	21.973	100.0%	6.812	9.810	100.0%	4.855	35.283	100.0%	11.300	14.343	100.0%	5.494
n-Nonane	2.501	100.0%	0.786	1.463	100.0%	0.487	13.348	100.0%	2.727	2.285	100.0%	0.916
Propionaldehyde	0.204	96.8%	0.097	0.183	100.0%	0.091	0.283	93.1%	0.134	0.371	93.5%	0.192
Propylene	0.597	100.0%	0.287	0.757	100.0%	0.295	1.417	100.0%	0.765	2.782	100.0%	0.973
n-Propylbenzene	0.710	81.4%	0.101	0.164	76.3%	0.074	1.092	96.6%	0.213	0.326	95.0%	0.164
Styrene	3.445	5.1%	0.374	0.431	15.3%	0.088	1.917	15.3%	0.258	0.352	28.3%	0.090
Toluene	79.140	100.0%	9.371	4.883	100.0%	2.226	118.441	100.0%	11.830	15.020	100.0%	4.890
1,2,4-Trimethylbenzene	3.091	100.0%	0.304	0.661	100.0%	0.211	7.374	100.0%	1.124	1.595	100.0%	0.690
1,3,5-Trimethylbenzene	0.836	84.7%	0.185	0.412	72.9%	0.159	5.347	98.3%	0.765	0.803	100.0%	0.361
m-Xylene/p-Xylene	9.879	100.0%	1.608	3.707	100.0%	1.179	11.833	100.0%	4.543	5.916	100.0%	2.612
o-Xylene	3.610	100.0%	0.577	0.522	100.0%	0.232	3.175	100.0%	0.911	1.623	100.0%	0.709

Note:

- µg/m^3 = Micrograms per Cubic Meter of Air
- EPC = Exposure Point Concentration
- Max. = Maximum concentration

Table B3. COPC Selection at the Bell Site in the Rural Oil & Gas Development Area.

Compound	Max. Concentration µg/m³	% Samples Detected	ATSDR Comparison Value Chronic CREG/EMEG (µg/m³)	Regional Screening Level (µg/m³)	Selected COPCs
Acetaldehyde	1.964	100.0%	0.5	1.1	Y
Acetone	5.392	100.0%	30,000	32000	N
Formaldehyde	2.237	100.0%	0.08/10	0.19	Y
1,3-Butadiene	0.053	5.1%	0.03	0.081	Y
Benzene	13.631	100.0%	0.1/10	0.31	Y
Crotonaldehyde	0.467	93.5%	NA	0.0035	Y
Cyclohexane	104.985	100.0%	NA	6300	N
Ethylbenzene	4.337	96.6%	1,000	0.97	Y
n-Hexane	22.089	100.0%	2,000	730	N
Isopropylbenzene	0.298	22.0%	NA	400	N
Methylcyclohexane	21.973	100.0%	NA	NA	N
Nonane	2.501	100.0%	NA	200	N
Propionaldehyde	0.204	96.8%	NA	8.3	N
Propylene	0.597	100.0%	NA	NA	N
Propylbenzene	0.710	81.4%	NA	3000	N
Styrene	3.445	5.1%	900	1000	N
Toluene	79.140	100.0%	300	5200	Y
1,2,4-Trimethylbenzene	3.091	100.0%	NA	7.3	Y
1,3,5-Trimethylbenzene	0.836	84.7%	NA	6.3	Y
m-Xylene/p-Xylene	9.879	100.0%	200	730	N
o-Xylene	3.610	100.0%	200	730	N

Note:

- µg/m^3 = Micrograms per Cubic Meter of Air
- EPC = Exposure Point Concentration
- CREG = Cancer Risk Evaluation Guide
- EMEG = Environmental Media Evaluation Guide
- COPC = Contaminant of Potential Concern
- Crotonaldehyde was selected as a COPC based on the EPA Region 9 Screening Level
- EPA Regional screening levels based on EPA methodology. Available at http://www.epa.gov/reg3hwmd/risk/human/rbconcentration_table/Generic_Tables/index.htm

Table B4. COPC Selection at the Brock Site in the Rural Oil & Gas Development Area.

Compound	Max. Concentration µg/m³	% Samples Detected	ATSDR Comparison Value Chronic CREG/EMEG (µg/m³)	Regional Screening Level (µg/m³)	Selected COPCs
Acetaldehyde	1.591	100.0%	0.5	1.1	Y
Acetone	6.366	100.0%	30,000	32000	N
Formaldehyde	2.102	100.0%	0.08/10	0.19	Y
1,3-Butadiene	0.053	1.7%	0.03	0.081	Y
Benzene	2.401	100.0%	0.1/10	0.31	Y
Crotonaldehyde	0.519	100.0%	NA	0.0035	Y
Cyclohexane	5.347	100.0%	NA	6300	N
Ethylbenzene	0.482	96.6%	1,000	0.97	Y
n-Hexane	24.262	100.0%	2,000	730	N
Isopropylbenzene	0.094	18.6%	NA	400	N
Methylcyclohexane	9.810	100.0%	NA	NA	N
Nonane	1.463	100.0%	NA	200	N
Propionaldehyde	0.183	100.0%	NA	8.3	N
Propylene	0.757	100.0%	NA	NA	N
Propylbenzene	0.431	15.3%	NA	3000	N
Styrene	0.431	15.3%	900	1000	N
Toluene	4.883	100.0%	300	5200	N
1,2,4-Trimethylbenzene	0.661	100.0%	NA	7.3	N
1,3,5-Trimethylbenzene	0.412	72.9%	NA	6.3	N
m-Xylene/p-Xylene	3.707	100.0%	200	730	N
o-Xylene	0.522	100.0%	200	730	N

Note:

- µg/m^3 = Micrograms per Cubic Meter of Air
- EPC = Exposure Point Concentration
- CREG = Cancer Risk Evaluation Guide
- EMEG = Environmental Media Evaluation Guide
- COPC = Contaminant of Potential Concern
- Crotonaldehyde was selected as a COPC based on the EPA Region 9 Screening Level
- EPA Regional screening levels based on EPA methodology. Available at http://www.epa.gov/reg3hwmd/risk/human/rbconcentration_table/Generic_Tables/index.htm

Table B5. COPC Selection at the Parachute Site in the Urban Oil & Gas Development Area

Compound	Max. Concentration µg/m³	% Samples Detected	ATSDR Comparison Value Chronic CREG/EMEG (µg/m³)	Regional Screening Level (µg/m³)	Selected COPCs
Acetaldehyde	1.838	100.0%	0.5	1.1	Y
Acetone	5.915	100.0%	30,000	32000	N
Formaldehyde	3.257	100.0%	0.08/10	0.19	Y
1,3-Butadiene	0.033	52.5%	0.03	0.081	Y
Benzene	11.076	100.0%	0.1/10	0.31	Y
Crotonaldehyde	0.238	100.0%	NA	NA/ 0.0035	Y
Cyclohexane	13.080	100.0%	NA	6300	N
Ethylbenzene	2.616	100.0%	1,000	0.97	Y
n-Hexane	18.799	100.0%	2,000	730	N
Isopropylbenzene	0.250	40.7%	NA	400	N
Methylcyclohexane	35.283	100.0%	NA	NA	N
Nonane	13.348	100.0%	NA	200	N
Propionaldehyde	0.283	93.1%	NA	8.3	N
Propylene	1.417	100.0%	NA	NA	N
Propylbenzene	1.092	96.6%	NA	3000	N
Styrene	1.917	15.3%	900	1000	N
Toluene	118.441	100.0%	300	5200	Y
1,2,4-Trimethylbenzene	7.374	100.0%	NA	7.3	Y
1,3,5-Trimethylbenzene	5.347	98.3%	NA	6.3	Y
m-Xylene/p-Xylene	11.833	100.0%	200	730	N
o-Xylene	3.175	100.0%	200	730	N

Note:

- µg/m^3 = Micrograms per Cubic Meter of Air
- EPC = Exposure Point Concentration
- CREG = Cancer Risk Evaluation Guide
- EMEG = Environmental Media Evaluation Guide
- COPC = Contaminant of Potential Concern
- Crotonaldehyde was selected as a COPC based on the EPA Region 9 Screening Level
- Regional screening levels based on EPA methodology. Available at http://www.epa.gov/reg3hwmd/risk/human/rbconcentration_table/Generic_Tables/index.htm

Table B6. COPC Selection at the Rifle Site in the Urban Oil & Gas Development Area

Compound	Max. Concentration µg/m³	% Samples Detected	ATSDR Comparison Value Chronic CREG/EMEG (µg/m³)	Regional Screening Level (µg/m³)	Selected COPCs
Acetaldehyde	2.901	100.0%	0.5	1.1	Y
Acetone	6.746	100.0%	30,000	32000	N
Formaldehyde	4.818	100.0%	0.08/10	0.19	Y
1,3-Butadiene	0.486	81.7%	0.03	0.081	Y
Benzene	4.079	100.0%	0.1/10	0.31	Y
Crotonaldehyde	0.436	100.0%	NA	0.0035	Y
Cyclohexane	7.401	100.0%	NA	6300	N
Ethylbenzene	1.167	100.0%	1,000	0.97	Y
n-Hexane	15.920	100.0%	2,000	730	N
Isopropylbenzene	0.120	51.7%	NA	400	N
Methylcyclohexane	14.343	100.0%	NA	NA	N
Nonane	2.285	100.0%	NA	200	N
Propionaldehyde	0.371	93.5%	NA	8.3	N
Propylene	2.782	100.0%	NA	NA	N
Propylbenzene	0.326	95.0%	NA	3000	N
Styrene	0.352	28.3%	900	1000	N
Toluene	15.020	100.0%	300	5200	N
1,2,4-Trimethylbenzene	1.595	100.0%	NA	7.3	Y
1,3,5-Trimethylbenzene	0.803	100.0%	NA	6.3	Y
m-Xylene/p-Xylene	5.916	100.0%	200	730	N
o-Xylene	1.623	100.0%	200	730	N

Note:

- µg/m³ = Micrograms per Cubic Meter of Air
- EPC = Exposure Point Concentration
- CREG = Cancer Risk Evaluation Guide
- EMEG = Environmental Media Evaluation Guide
- COPC = Contaminant of Potential Concern
- Crotonaldehyde was selected as a COPC based on the EPA Region 9 Screening Level
- Regional screening levels based on EPA methodology. Available at http://www.epa.gov/reg3hwmd/risk/human/rbconcentration_table/Generic_Tables/index.htm

Appendix C. Exposure Parameters, Estimation of Exposure Dose, Derivation of Risk Based Concentration, and Risk Estimation

Estimation of Exposure Point Concentration

The Exposure Point Concentration (EPC) is a high-end, yet reasonable concentration of a contaminant that people could be exposed to based on the available environmental data. The standard procedure for calculating EPCs is to use the 95% Upper Confidence Limit on the mean of the data for each COPC. EPA's statistical software package, ProUCL Version 4.0, was used to calculate the EPCs. The 2008 data for ambient outdoor air in Garfield County was analyzed by this method and thus, the EPCs in these locations is the 95% UCL for normally distributed data. For non-detects, ½ the detection limit was used to calculate EPCs.

If the data is not normally distributed, ProUCL recommends an alternative value to use in lieu of the 95% UCL depending on the type of data distribution. There were a number of instances where the data was not normally distributed and the alternate value was accepted instead of the 95% UCL. Furthermore, when there were less than ten samples available per site, the maximum value was used to represent the EPC instead of the 95%UCL.

Estimation of Exposure Dose and Risk Estimation

Exposure doses are estimates of the concentration of contaminants that people may come into contact with or be exposed to under specified exposure conditions. These exposure doses are estimated using: (1) the estimated exposure point concentration as well as the intake rate; and (2) the length of time and frequency of exposure to site contaminants.

Assumptions made for the residents of Garfield County included exposure duration of 24 hours per day for 350 days per year for 30 years using an age adjustment for 24 years as an adult and 6 years as a child. In today's mobile society, it is unlikely that people will spend this much time in the county at one location and therefore the calculated risk estimates are conservative.

Calculation of the Noncancer hazard quotient (HQ) for Inhalation of Non-carcinogenic COPCs by Nearby Residents

$$\textbf{Noncancerous HQ} = \frac{\text{Ambient Air concentration (EPC)}}{\text{ATSDR MRL or EPA IRIS RfC}}$$

Calculation of Theoretical Cancer Risk for Inhalation of Carcinogenic COPCs by Nearby Residents

$$\textbf{Cancer Dose} = \frac{\text{CAxIRxETxEFxED}}{\text{BW x AT}}$$

CA= COPC Concentration in Ambient air (mg/m3)

IR= Inhalation Rate (adult= 20 m3/day; child= 12 m3/day)

ET= Exposure Time (24 hr/day)

EF= Exposure Frequency (350 days/year)

ED= Exposure Duration = 30 years (adult=24 years; child=6years)

BW = Body Weight (adult=70 kg; child=15 kg)

AT= Averaging Time (70 years x365 days = 25550 days)

Cancer risk = cancer dose x Inhalation cancer slope factor (given in Table D.1)

Please note that cancer risks are calculated for 24 years as an adult and 6 years as a child.

Appendix D. Toxicological Evaluation

The basic objective of a toxicological evaluation is to identify what adverse health effects a chemical causes, and how the appearance of these adverse effects depends on dose. In addition, the toxic effects of a chemical frequently depend on the route of exposure (oral, inhalation, dermal) and the duration of exposure (acute, subchronic, chronic or lifetime). It is important to note that estimates of human health risks may be based on evidence of health effects in humans and/or animals depending on the availability of data. This evaluation, like most other toxicity assessments, is divided into two parts: the cancer effects and the non-cancer effects of the chemical.

The COPCs selected in this evaluation can cause a wide range of symptoms as shown in Table D.1.

It should be noted that uncertainties in the EPA cancer toxicity value (i.e., IURs or cancer slope factor) for crotonaldehyde are notable. The EPA Integrated Risk Information System (IRIS) has not calculated an inhalation cancer toxicity value (IUR) for crotonaldehyde. However, crotonaldehyde is evaluated using a cancer toxicity value derived in the EPA Health Effects Assessment Summary Tables from oral exposure studies. Crotonaldehyde is classified as a possible human carcinogen (Category C). This classification was assigned based on the increased incidence of hepatic neoplastic nodules and hepatocellular carcinomas in only one available animal carcinogenicity study that was limited by only one sex of one species. There is insufficient evidence that inhalation is a route that results in crotonaldehyde- induced liver lesions or neoplastia.

EPA, IARC, and the Department of Health and Human Services have concluded that benzene is a human carcinogen. The Department of Health and Human Services determined that benzene is a known carcinogen based on human evidence showing a causal relationship between exposure to benzene and cancer. IARC classified benzene in Group 1 (carcinogenic to humans) based on sufficient evidence in both humans and animals. EPA classified benzene in Category A (known human carcinogen) based on convincing evidence in humans supported by evidence from animal studies. Under EPA's most recent guidelines for carcinogen risk assessment, benzene is characterized as a known human carcinogen for all routes of exposure. Based on human leukemia data, EPA derived a range of inhalation unit risk values of 2.2x10-6– 7.8x10-6 $(\mu g/m3)^{-1}$ for benzene. For cancer risks ranging from $1x10^{-4}$ to $1x10^{-6}$, the corresponding the corresponding air concentrations ranges from 13.0–45.0 μg/m3 (4–14 ppb) to 0.013–0.045 μg/m3 (0.004–0.014 ppb), respectively. The high-end unit risk factor corresponds to the cancer slope factor of 0.027 per mg/kg/day. The consensus conclusion that benzene is a human carcinogen is based on sufficient inhalation data in humans supported by animal evidence, including the oral studies in animals. The human cancer induced by inhalation exposure to benzene is predominantly acute nonlymphocytic (myelocytic) leukemia, whereas benzene is a multiple site carcinogen in animals by both the inhalation and oral routes (ATSDR, 2005).

The above noted high-end cancer slope factor is used to calculate cancer risk in this evaluation.

ATSDR has derived acute, chronic, and intermediate duration inhalational minimal risk levels (MRLs) or health guidelines to assess noncancer hazards. An MRL is the dose of a compound that is the estimate of daily human exposure that is likely to be without an appreciable risk of adverse non-cancerous health effects for each specified exposure duration. The acute, intermediate, and chronic MRLs address exposures of 14 days or less, 14-365 days, and 1 year –lifetime, respectively. Here, benzene is the only contaminant evaluated for acute health effects by using the acute MRL of 30 µg/m^3.

Table D.1. Toxicty values of COPCs

Compound	Cancer		Noncancer	
	Inhalation Cancer Slope factor 1/mg/kg/day	Cancer classification	Chronic RfC (µg/m³)	Target organ (*Critical effect*)
Acetaldehyde	0.0077 I	Probable human carcinogen(B2) *Nasal and laryngeal tumors in animals*	9.0 I	Respiratory *(Degenration of Olfactory epithelium)*
Acetone	NC	NC	30000.0 A	Neurological *(delayed visual reaction, general weakness, headache)*
1,3-Butadiene	0.1 I	Known human carcinogen(A) *Lymphohematopoietic cancer and leukemia in humans*	2.0 I	Reproductive *(Ovarian atrophy)*
Benzene	0.027 I	Known human carcinogen (A) Leukemia in humans	10.0 A	Immunological *(Decreased lymphocyte count)*
Crotonaldehyde	1.9 [a] H	Possible human carcinogen (C) *Hepatic neoplastic nodules and hepatocellular carcinoma in animals (oral study)*	NA	NA
Ethylbenzene	0.00875 C	Probable human carcinogen(B2) Renal tumors in animals (oral study)	1000.0 I	Developmental *(Kit mortality)*
Formaldehyde	0.0455 I	Probable human carcinogen(B1) *Nasopharyngeal and lung cancer in humans (limited) and nasal cancer in animals*	9.8 A	Respiratory *(Histopathological changes in nasal tissue in humans)*
Toluene	NC		5000.0 I	Neurological and respiratory *(Neurological effects; other effects: degeneration of nasal epithelium)*
1,2,4-Trimethylbenzene	NC		7.0 I	Neurologic, Respiratory, Immunologic *(Vertigo, headaches, drowsiness, anemia, altered blood clotting, chronic asthma-like bronchitis)*
1,3,5-Trimethylbenzene	NC		6.0 I	Neurologic, Respiratory, Immunologic *(Vertigo, headaches, drowsiness, anemia, altered blood clotting, chronic asthma-like bronchitis)*

Note: Sources of toxicity values: A= ATSDR –Minimal Risk Level (MRL); C = Cal EPA; H= EPA-Heast; I- EPA IRIS
[a] Based on route -to-route extrapolation of EPA's oral cancer slope factor
NC = Non Carcinogen; NA= Not Available

CERTIFICATION

This Garfield County Health Consultation was prepared by the Colorado Department of Public Health and Environment under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved methodology and procedures at the time the health consultation was conducted. Editorial review was completed by the cooperative agreement partner.

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The Division of Health Assessment and Consultation, ATSDR, has reviewed this Health Consultation and concurs with its findings.

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