

Health Consultation

Groundwater, Subsurface Vapor, Outdoor and Indoor Air Data Review

FORMER NEODESHA OLD REFINERY SITE

NEODESHA, WILSON COUNTY, KANSAS

OCTOBER 10, 2012

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR 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 which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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HEALTH CONSULTATION

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Prepared By:

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

Introduction

The Agency for Toxic Substances and Disease Registry's (ATSDR) top priority is to ensure that the people living near the Neodesha former refinery site located within the Municipality of Neodesha, Kansas have the best information possible to safeguard their health.

In response to a petition from a community member in Neodesha, the Agency for Toxic Substances and Disease Registry (ATSDR) released a Health Consultation titled "Neodesha Refinery (former Amoco Refinery)" for public comment in October 2003 that evaluated potential exposures to environmental contaminants. During the public comment period, numerous comments were received from community members, Kansas Department of Health and Environment (KDHE), city officials, and personnel of BP Products North American Inc. (BP).

Since the release of the document for "Public Comment", additional investigations have been conducted at the site and additional environmental data were available for review. As a result ATSDR has chosen to produce a series of documents that focus on: 1) lead levels at the New Beginnings facility, 2) metals in soil in other areas of the former refinery site 3) metals in soil at the smelter site, and 4) volatile organic compounds (VOCs) in ground water, soil vapor, and ambient and indoor air at the former refinery site. ATSDR released three health consultations regarding the soil contaminations at the New Beginnings facility, in other areas of the former refinery site, and at the former smelter area in April 2006, June 2007, and October 2007, respectively.

This is the fourth document in the series. In this document ATSDR reviews VOC data for groundwater, soil vapor, and indoor and outdoor air to determine if exposures are occurring and if so, the health implications of the exposures.

Conclusions

ATSDR reached the following conclusions in the health consultation:

Conclusion 1

Breathing indoor and outdoor air at the former refinery site in Neodesha, KS is not expected to harm people's health.

Basis for conclusion

The levels of VOCs in the indoor and outdoor air were at levels below that which would result in adverse health effects.

Next steps

The groundwater is contaminated with VOCs at the former refinery. The VOCs in the groundwater may volatilize into the indoor and outdoor air through vapor intrusion. BP and other

potentially responsible parties (PRPs) will continue the groundwater monitoring programs at all affected areas. Soil vapor and air samples will be collected if groundwater VOC levels exceed the screening values in KDHE Risk-based Standards.

Conclusion 2

The general trend in groundwater contamination is decreasing across the site. It appears that the groundwater plume is not spreading but has varied through the years.

Basis for conclusion

ATSDR used the benzene concentrations as an indication of the extent of groundwater contamination at the site. ATSDR compared benzene isoconcentration contours from 2000 to 2007 and evaluated thirty-eight off-site monitoring wells with time series plots to determine the spatial extent of the groundwater contamination.

Next Steps

BP and other PRPs will continue the groundwater monitoring programs at all affected areas, especially at the northeast and southwest corners of the plume where benzene concentrations in monitoring wells 93 and 135 showed an upward trend.

Conclusion 3

Possible vapor intrusion is not expected to result in exposure via indoor air contaminants at levels of health concern for the site

Basis for conclusion

All detected VOC concentrations in soil vapor samples collected at residential and public buildings are below action levels recommended in the EPA draft guidance on indoor vapor intrusion. In addition, indoor air samples did not find elevated levels of VOCs.

Next Steps

ATSDR and KDHE will continue to work with the community, BP and other responsible parties to respond to public health questions and concerns about the site.

**For More
Information**

For further information about this public health assessment, please call ATSDR at 1-800-CDC-INFO and ask for information about the “Neodesha Former Refinery Site”. If you have concerns about your health, you should contact your health care provider.

Background

The former refinery property encompasses approximately 185 acres in the west part of Neodesha, Kansas. The refinery operated for 73 years, from 1897 until 1970. The former refinery property is currently owned by the city of Neodesha, Williams Pipe Line Company, and various other businesses. The area is now occupied by light industries and small businesses. There are a few residences adjacent to the north and northwest site boundaries; the city of Neodesha is directly east.

Since the early 1980s, environmental investigation and remediation activities were conducted by KDHE, BP and other businesses located at the site. Contaminates of concern for the site include a plume of benzene, toluene, ethylbenzene and xylenes (BTEX) in groundwater, metals and petroleum hydrocarbons in the soil.

In October 2003, ATSDR responded to a petition from a community member concerned about exposures to environmental contamination from past refinery operations and released a Health Consultation titled “Neodesha Refinery (former Amoco Refinery)” for public comment [ATSDR 2003a]. Since the release of the document for “Public Comment”, additional investigations were conducted at the site and additional environmental data were available for review. As a result ATSDR has prepared a series of documents that focus on: 1) lead levels at the New Beginnings facility, 2) metals in soil in other areas of the former refinery site 3) metals in soil at the smelter area, and 4) volatile organic compounds in ground water, soil vapor, and ambient and indoor air at the former refinery site.

In April 2006, ATSDR released a health consultation that addressed the New Beginnings facility lead contamination. Lead levels in the surface soil samples collected on and near the New Beginnings facility ranged from 15.6 to 181 mg/kg of soil which are below health-based comparison values and are not likely to result in adverse health effects. ATSDR concluded that the surface soil at New Beginnings facility poses “No Apparent Public Health Hazard” to people working or visiting the facility [ATSDR 2006]. In June 2007, ATSDR released the second health consultation that reviewed available soil metals data in other areas of the former refinery site, and assessed the possible implication of exposures to soil contaminants. ATSDR concluded the areas pose “No Apparent Public Health Hazard” [ATSDR 2007a]

In October 2007, ATSDR released the third health consultation that addressed the soil metals contamination at the former Neodesha smelter area. ATSDR has categorized this area as constituting an “Indeterminate Public Health Hazard” because soil contamination characterization in the residential area is limited and additional soil sampling was recommended to fully characterize the soil contamination [ATSDR 2007b].

This fourth health consultation addresses the volatile organic compounds in ground water, soil vapor, and outdoor and indoor air at the former refinery site.

Community Health Concerns

As part of the response to the petition to investigate exposure to contamination, ATSDR staff participated in many public meetings, reviewed site documents, received numerous calls from

residents, and conducted public availability sessions and public meetings to understand community member's concerns regarding the contamination, investigation, and remediation of the site. ATSDR addressed community concerns regarding soil exposures in the previous three health consultations. Community environmental health concerns related to groundwater contamination include the following:

- Possible vapor intrusion into homes and buildings from BTEX contaminated groundwater and soil vapor ; and
- Potential impact to surface water by recharge from the contaminated groundwater and surface runoff from the site.

ATSDR addresses community concerns related to the groundwater contamination in this health consultation.

Exposure Pathway Analysis

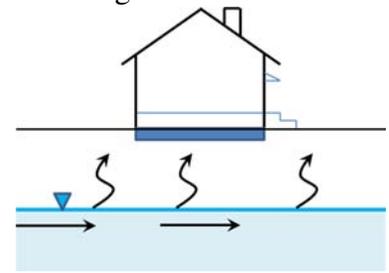
ATSDR evaluates ways that people may come into contact with contaminated media that may lead to people being exposed to the contaminants (exposure pathways). ATSDR provides site-specific public health recommendations based on an evaluation of the toxicological literature, levels of environmental contaminants detected at a site compared to accepted comparison values (CV), and the characteristics of the exposed population and the frequency and duration of exposure. ATSDR used this approach to determine if groundwater contamination at the former refinery site posed a public health hazard.

In general, to select CVs, the hierarchy described in the ATSDR Public Health Guidance manual was used. In some cases professional judgment was used to select the most appropriate CVs for the specific site conditions [ATSDR 2005].

ATSDR used the following CVs for this health consultation: the ATSDR's environmental media evaluation guide (EMEG), reference dose media evaluation guide (RMEG), cancer risk evaluation guide (CREG), and minimal risk levels (MRL); the EPA's screening values from the draft guidance on indoor vapor intrusion, the Regional Screening Level (RSL) and the Maximum Contaminant Level (MCL); and the KDHE Risk-Based Standards for Kansas (RSK) [KDHE, 2010].

Vapor intrusion of contaminants from the soil vapor and groundwater into the indoor air of buildings was identified as a potential exposure pathway. Ingestion (drinking) and dermal (skin) contact exposures were not identified as pathways because: 1) the city drinking water source is surface water from the Fall River, down gradient from the site, 2) no private wells are located in the city of Neodesha, and 3) the city has an ordinance to prohibit the use of groundwater for private wells.

Vapor intrusion is the migration of VOCs from the subsurface- contaminated groundwater and soil through the pore spaces of soil into buildings above. The air within the pore spaces of soil is called subsurface vapor, in some cases also called soil gas or soil vapor [ATSDR 2001a, ATSDR 2008, EPA 2002, and EPA 2008]. Subsurface vapors can enter residences and other buildings through foundation cracks and gaps, mechanical ventilation systems, and leakage areas (for example, utility entry points, construction joints, and drainage systems).



Subsurface vapor levels are affected by many factors, such as water and air movements, temperature variations in soil and atmosphere, molecular diffusion, biodegradation, barometric pressure, precipitation, building structures, and pressure differences between the inside and outside of buildings [Kildiff 2002]. In recent years, subsurface vapor sampling data have been used to qualify and/or quantify indoor air risk through computer modeling. The model (e.g., the Johnson and Ettinger Model) is based on a number of simplifying assumptions regarding contaminant distribution and occurrence, subsurface characteristics, transport mechanisms, and building construction. Therefore, the model can be used only as a screening tool to identify conditions that may warrant additional evaluation [EPA2005]. Soil vapor monitoring and modeling results also do not provide actual measurements of concentrations of contaminants that people may breathe. Subsurface vapors migrating indoors are greatly diluted with outdoor air that enters the home, and by diffusive, advective, or other attenuating mechanisms as the vapor migrates through the soil. Therefore, directly measuring indoor air quality in potentially impacted buildings is often the best approach to evaluate air contamination at points of exposure.

Another potential exposure pathway is surface water if contaminants from surface runoff and groundwater recharge reach the Fall River.

Discussion

Available environmental data for this evaluation and data quality

ATSDR evaluated the available environmental sampling information for potential exposure to groundwater contaminants at the site. Since 1981 numerous investigations of ground water, subsurface vapor, indoor and outdoor air samples were conducted at the former refinery and the city of Nedesha to evaluate the extent of contamination*. The following is a summary of all data used in this evaluation:

- Groundwater semiannual monitoring from 1991 to 2007;
- Subsurface vapor (soil vapor) sampling information in 1999, 2002 and 2008;
- Indoor and outdoor air sampling information from 2000 to 2008; and
- Surface water sampling data from 1992 to 2007.

* Groundwater contamination was also discovered in two other areas adjacent to the original plume. The contamination is associated with two facilities that used chlorinated compounds such as tetrachloroethene (PCE) and trichloroethene (TCE). KDHE and potential responsible parties (PRPs) have carried out investigations since 2002 for those facilities. ATSDR did not review data associated with those two facilities.

ATSDR also reviewed information on Quality Assurance (QA)/Quality Control (QC) specifications for field data quality and laboratory data quality to verify the acceptability and adequacy of data including Chain of Custody sheets, project narratives, and laboratory certifications. The laboratory analysis methods and the QA/QC procedures were appropriate. Therefore the results were considered valid and are included in the evaluation.

Environmental data evaluation and public health impacts

The public health evaluations for groundwater, soil vapor, outdoor and indoor air and surface water data are presented below.

Groundwater samples

The former refinery and the city of Neodesha are located north of the confluence of the Verdigris and Fall Rivers. Shallow groundwater occurs primarily in alluvial sand and gravel deposits. The aquifer is sandwiched between surficial clay soils and bedrock on the bottom. Depth to groundwater varies seasonably within a range of approximately 3 to 40 feet below ground surface. The general groundwater flow is to the southwest, south and southeast of the site towards the Fall and Verdigris Rivers [RETEC 2005].

The first groundwater monitoring wells were installed in 1981 at the site. Additional wells were installed throughout the 1980's and 90's. Over 130 monitoring wells were installed on-site and off-site in the city of Neodesha. Numerous temporary groundwater monitoring wells were also operated throughout Neodesha and the site. Figure 1 shows the monitoring well locations on-site and off-site.

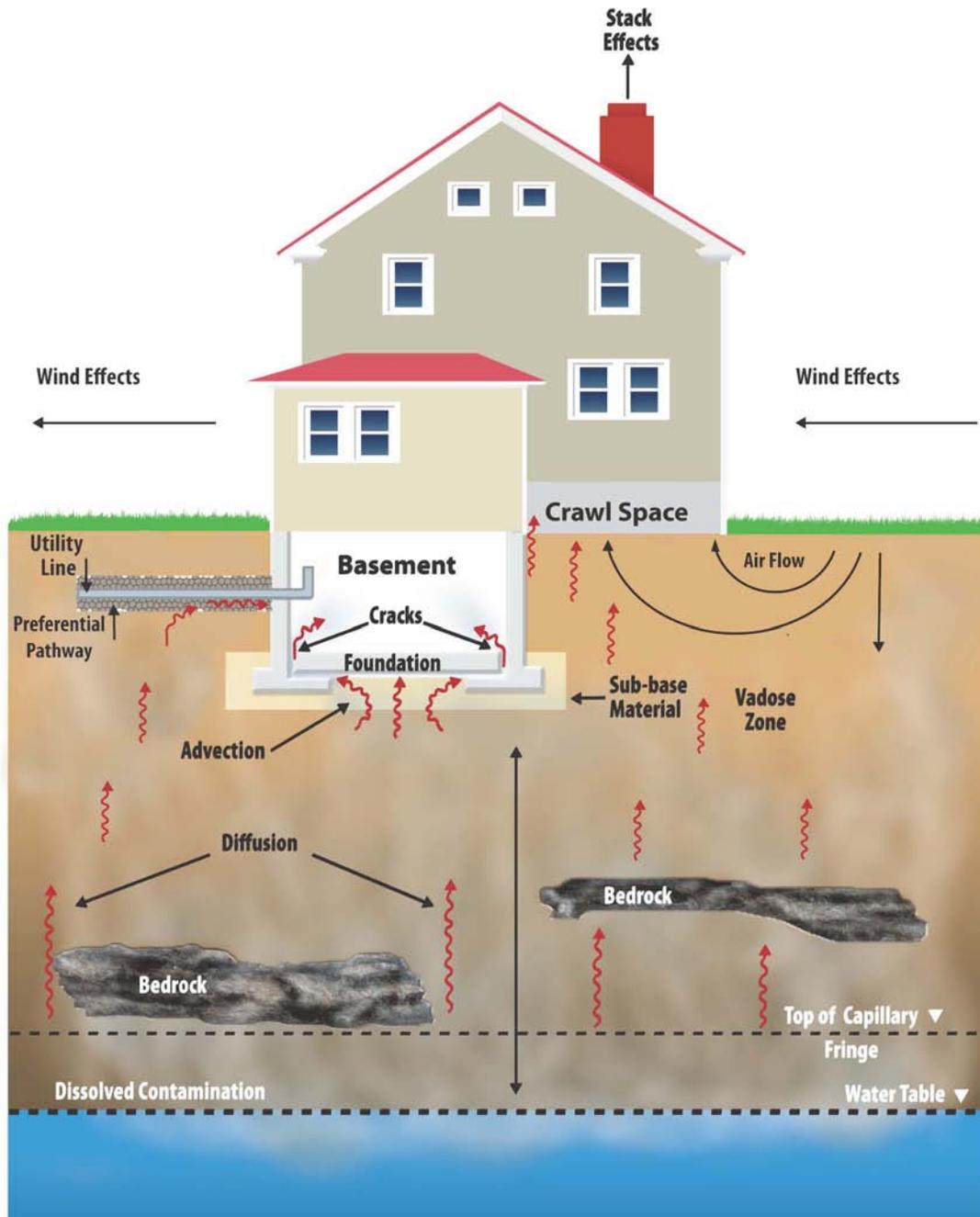
Although a completed human exposure pathway for drinking groundwater does not exist at this site, ATSDR reviewed the groundwater data to identify areas where there may be a potential for vapor intrusion and to address community concerns. Groundwater monitoring well data can be used to define the horizontal and vertical extent of groundwater contamination. In addition, the monitoring well data may indicate areas where indoor air might have been affected and what might happen in the future.

Ongoing sampling of the groundwater occurs on a semi-annual basis since 1999. Samples were analyzed for VOCs and metals using EPA Methods 8260 and 6020, respectively. The historical groundwater quality data provided to ATSDR included six selected chemicals including benzene, ethylbenzene, toluene, total xylenes, naphthalene and lead. Because benzene is commonly found at the site, ATSDR reviewed the benzene data to determine the extent of groundwater contamination and to identify areas of potential vapor intrusion. BP reported a downward trend in benzene concentrations among 17 older off-site wells with more historical data [ENSR 2008]. ATSDR evaluated an additional 21 off-site monitoring wells with the time series plots on benzene concentrations. The general trend in benzene concentrations is downward across the site over time. However, at the southeast tip of the plume, benzene concentrations in monitoring wells 93 and 135 showed an upward trend (see Figure 2).

Regarding the stability of the plume boundaries, Figure 3 shows the benzene concentration contours (5µg/l) in groundwater samples in the monitoring well network from 2000 to 2007. It appears that the groundwater plume is not spreading but some variations exist through the years. The most recent plume contour is smaller compared to the previous years. For example, in fall 2006, BP collected split samples from temporary monitoring wells during a plaintiffs investigation, the estimated benzene contour has expanded at the northeast and southwest corners of the plume compared to previous years. Recent communication with KDHE indicated that the current groundwater monitoring results were similar to the historical data ATSDR evaluated and no significant changes were observed [ATSDR, 2011]. Because concentrations in some wells are increasing, ATSDR recommends continuing the groundwater monitoring programs at all affected areas as a prudent public health practice.

Subsurface Vapor Samples

There are different ways of measuring subsurface vapor concentrations. When subsurface vapor samples are collected exterior to a building at varying depths in the unsaturated zone (vadose zone) they are called soil gas or soil vapor samples. When subsurface vapor samples are collected directly under a building, the samples are often called sub-slab samples. Subfloor vapor concentrations may be measured in building crawlspaces; these samples represent the vapor concentration underlying a building's living space. Crawlspace samples may be evaluated in a manner similar to subsurface vapor samples, although there tends to be less attenuation from crawlspace to indoor air than from subsurface to indoor air [EPA 2008]. Subsurface vapor levels are affected by many factors and do not provide actual levels of contaminants that people may inhale; therefore subsurface vapor levels can be used as screening levels to identify conditions that may warrant additional evaluation.



Vapor Intrusion Exposure Pathways

ATSDR received information on subsurface vapor for four sampling events in 1999, 2002, 2004 and 2008:

- In September and October 1999, BP collected 14 soil vapor samples at different locations in Neodesha to characterize soil vapor concentrations as part of the Phase III Remedial Investigation [ThermoRetec, 2000]. Soil vapor samples were collected from 14 different locations from depths of 4 to 16 feet below ground surface (bgs), respectively. Sampling locations can be seen in Figure 4. All samples were analyzed on site for benzene using Modified EPA Method 8021. Benzene was detected in all soil vapor samples, including

those considered to represent background conditions (samples SV-3 SV-6 and SV-10). These results can be found in Table 1. The average benzene concentration was 54.29 $\mu\text{g}/\text{m}^3$ with a range of 17.86 to 91,889 $\mu\text{g}/\text{m}^3$. Benzene concentrations at two locations (SV-8 and SV-9) exceeded the screening value of 310 $\mu\text{g}/\text{m}^3$ in EPA's Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils [EPA 2002]. Based on this soil vapor investigation, indoor and outdoor air sampling was conducted to assess potential human exposures in 2000.

- In December 2002, seven soil vapor samples were collected from two locations (near MW-31, see Figure 4) on the foundation area of a proposed building on site. Soil vapor samples were collected at 3, 6, and 9 feet bgs. Soil vapor samples were tested for 39 analytes and were screened using target soil vapor concentrations in accordance with EPA's Draft Guidance. Ten of these analytes were detected and eight were detected at concentrations above their respective target soil vapor concentrations [RETEC 2003]. See Table 2 for the maximum detected concentrations of VOCs in the two soil vapor samples. However, the proposed building was not constructed. Therefore human exposure through vapor intrusion at this location is not expected.
- In April 2004, KDHE collected one sub-slab sample in the basement of the Heller Elementary to evaluate the potential vapor intrusion from groundwater contamination of Airosol Company Inc. (Airosol) site. Available information indicated that chlorinated compounds were not detected [KDHE 2008].
- In March 2008, in response to a request by Unified School District, the KDHE Bureau of Environmental Remediation performed a vapor intrusion evaluation from groundwater contamination of the former refinery site and the Airosol site for several school buildings in Neodesha, KS. Three schools were sampled as a part of this evaluation. Eight sub-slab grab samples were collected in one-liter SUMMA™ canisters [KDHE 2008]. In November and December 2008, an additional 15 sub-slab grab samples were collected at 10 locations overlying the Airosol site groundwater plume. All samples were tested for 53 different components, 36 of which were detected [KDHE 2009]. See Table 3 for analytical results for detected chemicals and Figure 4 for sampling locations.

Overall, ATSDR evaluated a total of 45 subsurface vapor samples (soil vapor and sub-slab samples described above) collected from 30 different locations throughout the site and the City of Neodesha. All detected VOC concentrations are below levels recommended in the EPA draft guidance on indoor vapor intrusion except for benzene at two locations (SV-8 and SV-9) [EPA 2002]. Because of the benzene concentrations and community concerns, KDEH and PRPs collected indoor and outdoor air samples in the areas. Those sampling events will be discussed in the next sections.

Outdoor and indoor air samples

Outdoor air

Outdoor air sampling information for 2000, 2004 and 2008 are available for this evaluation.

In February 2000, BP collected a total of 13 outdoor air samples (6 composite and 5 grab samples at five locations on former refinery property and two grab samples near the high school). In May 2000, an additional 20 samples were collected at the same 5 locations on 4 different dates. At each location, a 24-hour sample was collected and analyzed according to EPA method TO-15 [ThermoRetec, 2001]. All samples were tested for benzene, toluene, ethylbenzene, and xylenes (BTEX).

In February 2004, Air Technology Laboratories (ATL) collected five outdoor air samples for BTEX evaluation. All outdoor air samples were collected at three on-site locations. Further, KDHE split two of these samples and performed confirmatory analysis [KDHE 2004].

In February, November, and December 2008, in response to a request by Unified School District, the KDHE Bureau of Environmental Remediation performed vapor intrusion evaluations of several school buildings in Neodesha, KS. As part of the investigations, a total of 10 outdoor air samples were collected at four locations including near the schools and a private residence. Samples were evaluated for 47 different VOCs, including BTEX [KDHE 2008, 2009].

Table 4 is a summary of maximum levels for each chemical detected during each of the sampling events described above. Sampling locations can be seen in Figure 5. The levels of detected VOCs in samples are below their respective CVs, with the exception of seven compounds: benzene, methylene chloride, PCE, TCE, 1, 2-dichloroethane, chloroform and dibromochloromethane. The concentrations of the above VOCs exceeded their respective cancer screening values. Further evaluations of those compounds will be discussed in the Public Health implications section.

Indoor air

ATSDR reviewed indoor air data from sampling events in 2000, 2003, 2004, and 2008.

- In May 2000, BP collected 52 indoor air samples in accordance with the environmental assessment plan for the former refinery site. Thirty one samples were collected from homes above the groundwater plume area (defined as the area east of 11th street, south of Granby Avenue, north of Illinois Street, and west of 5th avenue) and 16 samples were collected outside the area for comparison [ThermoRetec 2001]. During this sampling event, BP collected indoor air samples at homes of different construction, which included 2 homes with slabs, 11 homes with crawlspaces, and 7 homes with basements. Three of each type were also sampled outside the plume area. Samples were collected from the primary living space in the lowest living area halfway between the ceiling and the floor, and near the center of the room. KDHE collected co-located samples at 18 homes in the plume area and at 10 other homes. Specifics of sampling locations were not provided in the data report to protect resident privacy. See Figure 6 for a map of the plume area. Residents were asked to close windows and doors for at least 12 hours before the sampling event to reduce contaminant dilution with outdoor air, and to detect worst case exposures. Sampling locations were screened with a Combustible Gas Indicator (CGI) to identify potential natural gas leaks, and a Photo Ionization Detector (PID) to screen for VOCs. Questionnaires were administered to the occupant to determine any other indoor sources of VOCs. Air samples (24-hour composite) were collected following the CGI and PID screening using stainless steel, evacuated canisters. Collected samples were sent to

Severn Trent Laboratories for analysis. All samples were tested for BTEX using EPA Method TO15. Benzene was detected above the CREG in nearly all samples.

- In March 2003, BP took four 24-hour composite indoor air samples [RETEC 2003]. Two samples each were collected from the New Beginnings facility and the day care near the site. The samples were collected according to EPA Method TO-15 and analyzed for BTEX compounds. One sample was analyzed for 50 VOCs and sixteen VOCs were detected.
- In February 2004, Air Technology Laboratories (ATL) collected 16 indoor air samples and KDHE collected 7 indoor air split samples [KDEH 2004]. Indoor air samples were taken from two off-site locations and four on-site locations from residential and public buildings. Sampling locations can be seen in Figure 6. All samples were tested for BTEX compounds using EPA Method TO15.
- In March and November 2008, in response to a request by Unified School District, the KDHE Bureau of Environmental Remediation performed vapor intrusion evaluations of several school buildings in Neodesha, KS [KDHE 2008, 2009]. Three schools and 4 homes were sampled as a part of this investigation. Sampling locations can be seen in Figure 6. All sampling locations were selected based on a variety of different criteria such as presence of floor covering, centrality, and presence of underground utilities. A total number of 52 indoor air samples were collected during the two sampling events. All samples were collected in individually certified six-liter stainless steel evacuated SUMMA™ canisters equipped with flow controllers set for approximately eight-hour samples. All samples were analyzed by Pace Analytical, an off-site contract laboratory and were tested for 57 different components, 29 of which were detected.

In summary, a total of 122 indoor air samples were collected in 36 buildings throughout the site and the City of Neodesha between 2000 and 2008. Confidence in the sampling to detect variability in vapor migration over time is enhanced by the multiple sampling events. Thirty two VOCs were detected among 57 analytes. Concentrations of 6 VOCs exceeded their respective cancer screen values and will be discussed further below. The VOCs are benzene, methylene chloride, PCE, TCE, 1, 2-dichloroethane, and chloroform. The maximum concentrations detected for each chemical detected in each sampling event are presented in Table 5. In general, the indoor air concentrations of detected chemicals are higher than that of outdoor air. Therefore, ATSDR used the indoor air concentrations for discussion of public health implications.

It should be noted that indoor air quality assessment poses several challenges and needs to be treated from a broad perspective. First, in addition to soil vapor, a variety of significant sources of VOCs also contribute to the indoor air quality. A second complication is that indoor inhalation risk is often driven by very low VOC concentrations, which may often be near or below even state-of-the art laboratory analytical detection limits. Third, understanding and defining background indoor VOC concentrations is important but difficult because the reported range is large. For example, the background indoor benzene concentration measured in North American residences since 1990 ranged from non-detect up to 460 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) [EPA 2011]. Additionally, up to a 1,000 fold variability has been documented in sub-slab gas concentrations under individual buildings, and ten-fold variability was found for sub-slab gas in

different seasons (EPA 2008). Therefore, sampling strategies should investigate the influence that space and time can have on air contaminant levels and their migration.

Surface water samples

ATSDR evaluated surface water samples taken from the Fall River and Verdigris River to address community concerns. There were 96 surface water samples collected from 1992 to 2007. Samples were taken at 8 locations up-gradient and down-gradient from the site. All samples were analyzed for lead (potential impact from surface runoff because lead is a contaminant of concern in soil at the site) and about 40 samples analyzed for BTEX. Lead was tested in 28 samples at concentrations ranged from non-detect to 17 μ g/l. Benzene was detected in 4 samples, only one sample exceeded the MCL of 5 μ g/l. Toluene, ethylbenzene and xylene concentrations are all below their respective MCLs. All contaminant concentrations are significantly below concentrations detected in the groundwater plume. Therefore, available surface water data indicated that the contamination from the site is not impacting surface water from a public health perspective. In addition, the benzene concentration contours (5 μ g/l) in groundwater samples in the monitoring well network from 2000 to 2007 indicated the groundwater plume is not spreading (Figure 3). Recent communication with KDHE indicated that the current groundwater and surface water monitoring results were similar to the historical data ATSDR evaluated and no significant changes were observed [ATSDR, 2011].

Public health implications

ATSDR evaluated both cancer and non-cancer health effects for air contaminants at the site. ATSDR compared the indoor air contaminant concentrations to their chronic EMEG/MRLs, the concentrations in air that are unlikely to be associated with any appreciable risk of adverse, non-cancer effects for more than one year of continuous exposure. Benzene was the only chemical detected above non-cancer screening values. Concentrations of six VOCs exceeded their respective cancer screening values. The chemicals above screening values - benzene, methylene chloride, PCE (only detected in public buildings), TCE, 1, 2-dichloroethane, and chloroform - were evaluated further for potential consequences from exposure. ATSDR used conservative risk assumptions to estimate theoretical cancer risks therefore the actual risks of cancer from exposure to the six VOCs at the site are probably even lower than predicted.

Possible cancer effects from residential exposure

Five chemicals (benzene, methylene chloride, TCE, 1, 2-dichloroethane, and chloroform) were detected in residential living spaces. The following text outlines ATSDR's in-depth evaluation of the chemicals.

Benzene

Benzene is a colorless and highly flammable gas that evaporates into air quickly. It is a component of crude oil, gasoline, and cigarette smoke. Benzene has been identified in indoor and outdoor samples of both rural and urban environments. The background levels of benzene in indoor air range from non-detect to 460 μ g/m³, and the 95 percentile ranges from 9.9 to 29 μ g/m³

[EPA 2011]. The major sources of benzene exposure to U.S. residents are 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 1998].

Benzene is the most frequently detected indoor contaminant at the site. There were a total of 50 indoor samples taken from living areas with a maximum benzene concentration of 10.63 $\mu\text{g}/\text{m}^3$. Figure 7 shows the benzene concentrations distribution in the residential samples. Although nationwide background levels, like those in the Neodesha area, can often exceed ATSDR's CVs for benzene, i.e., chronic EMEG/MRL of 10 $\mu\text{g}/\text{m}^3$ and CREG of 0.1 $\mu\text{g}/\text{m}^3$, no adverse health effects, including cancer, would be expected (see the following paragraphs for a more detailed explanation regarding this conclusion). The following text is an approach that integrates the estimate of likely exposure with information about the toxicology and epidemiology of benzene exposure.

Benzene is a known human carcinogen and is leukemogenic. Occupational-level benzene exposures have been specifically linked to acute myelocytic leukemia. The lowest human effect levels reported in ATSDR's Toxicological Profile for benzene [ATSDR 2007c] are 960 $\mu\text{g}/\text{m}^3$ for leukemia [Ott et al. 1978] and 1,838 $\mu\text{g}/\text{m}^3$ for reduced white blood cell and platelet counts [Lan et al. 2004]. These values (960 and 1,838 $\mu\text{g}/\text{m}^3$) represent the lowest measured concentrations in a range of workplace measurements from the two studies.

In some epidemiological and toxicological studies, estimates of benzene exposure were converted to ppm-years, i.e., average benzene levels in parts per million (ppm) multiplied by exposure duration in years, to compare with reported occupational health effects on an equivalent basis. For example, a worker exposed to 2 ppm for 20 years and another one exposed to 20 ppm for 2 years both received the same cumulative exposure (i.e., 40 ppm-years). Epidemiologic data have suggested that there are thresholds for leukemia. Available studies indicate no detectable excess of leukemia below cumulative exposures of 40 ppm-years [Rinsky et al 1987]. This would be numerically, if not biologically, equivalent to about 190 ppb (606.1 $\mu\text{g}/\text{m}^3$), 24 hours a day, over a 70-year lifetime. However, this apparent threshold is most likely an underestimate because it is based on underestimated exposures and the inclusion of all leukemia, not just AML.

ATSDR's CREG is based on an EPA-estimated cancer slope factor which is in turn based on the assumption of a linear dose-response relationship.

A conservative cancer risk estimate (Appendix A) indicated that the predicted slightly increased theoretical cancer risk falls within EPA's general target risk range (between 1 in 1,000,000 and 1 in 10,000). The actual risk of cancer from exposure to benzene at the site is probably even lower than predicted. For the reasons discussed in this section, the estimated benzene exposures in the Neodesha area are not likely to produce any adverse health effects of either a cancerous or non-cancerous nature.

Methylene chloride

Methylene chloride is a colorless liquid widely used as an industrial solvent and as a paint stripper. The chemical can be found in some spray paints, automotive cleaners, pesticide products and other household products. Methylene chloride is the most common laboratory

analysis artifact introduced in laboratory sample preparation [ATSDR 2000]. The background levels of methylene chloride in indoor air range from non-detect to a maximum of 2,100 $\mu\text{g}/\text{m}^3$, and the 95 percentile ranged from 2.9 to 45 $\mu\text{g}/\text{m}^3$ [EPA 2011]. Methylene chloride was found only at 3 residences at the site with concentrations of 55.1, 12.9, and 7 $\mu\text{g}/\text{m}^3$, respectively. The maximum concentration of 55.1 $\mu\text{g}/\text{m}^3$ was found in one residence (can#0116) which also has the highest concentrations of other VOCs (TCE and 1,2-dichloroethane) which are the main contributors to the overall estimated slightly increased theoretical cancer risk. KDHE conducted additional environmental samples at the location and concluded that indoor VOC levels remain below safe levels.

Trichloroethene (TCE)

Trichloroethene (TCE) is a solvent used to remove grease from metals, and in typewriter correction fluid, paint removers, adhesives, and spot removers [ATSDR 2003b]. The background levels of TCE in indoor air range from non-detect to a maximum of 720 $\mu\text{g}/\text{m}^3$, with the 95 percentile ranged from 0.56 to 3.3 $\mu\text{g}/\text{m}^3$ [EPA 2011]. TCE was detected only at one residence with a concentration of 1.7 $\mu\text{g}/\text{m}^3$. Conservative cancer risk estimate (Appendix A) indicated that the predicted slightly increased theoretical cancer risk falls within EPA's general target risk range.

1,2-Dichloroethane

1,2-dichloroethane is a manufactured chemical that is 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. It is also used as a solvent and is added to leaded gasoline to remove lead [ATSDR 2001b]. 1,2-dichloroethane was detected only at two residences with concentrations of 15.1 and 2 $\mu\text{g}/\text{m}^3$, respectively. Conservative cancer risk estimate (Appendix A) indicated that the predicted slightly increased theoretical cancer risk falls within EPA's general target risk range.

Chloroform

Chloroform is a colorless liquid with a pleasant, nonirritating odor and a slightly sweet taste. Most of the chloroform found in the environment comes from industry [ATSDR 1997a]. The background levels of chloroform in indoor air range from non-detect to a maximum of 54 $\mu\text{g}/\text{m}^3$, with the 95 percentile ranged from 4.1 to 7.5 $\mu\text{g}/\text{m}^3$ [EPA 2011]. Chloroform was found in only one residential sample with a concentration of 1.6 $\mu\text{g}/\text{m}^3$. Conservative cancer risk estimate (Appendix A) indicated that the predicted slightly increased theoretical cancer risk falls within EPA's general target risk range. The actual risk of cancer from exposure to methylene chloride at the site is probably even lower than predicted.

Possible cancer effects from public building exposure

Five chemicals (benzene, methylene chloride, PCE, TCE, and chloroform) were detected in some public buildings including school rooms, a church, and the city hall. With the exception of PCE, the other four chemicals were detected at levels similar to those found in the residential samples.

For example, the maximum concentrations of benzene, methylene chloride, TCE, and chloroform were 15.04, 5.8, 2.82 and 2.8 $\mu\text{g}/\text{m}^3$, respectively. Conservative cancer risk estimates (Appendix A) indicated that the predicted slightly increased theoretical cancer risk falls within EPA's general target risk range. The actual risk of cancer from exposure to those chemicals at the site is probably even lower than predicted.

PCE is a chemical used for dry cleaning of fabrics and for metal-degreasing [ATSDR 1997b]. The background levels of PCE in indoor air range from non-detect to a maximum of 660 $\mu\text{g}/\text{m}^3$, with the 95 percentile ranged from 4.1 to 9.5 $\mu\text{g}/\text{m}^3$ [EPA 2011]. The maximum concentration of PCE was found in the one room (high school class room 113) with a concentration of 33.9 $\mu\text{g}/\text{m}^3$ during the February 2008 sampling event. However, PCE was not detected in the second sample taken at the same room in November 2008 sampling event. Operation of the heating system in colder weather conditions of February may account for the hit in February but none in November. In addition, conservative cancer risk estimate (Appendix A) indicated that the predicted slightly increased theoretical cancer risk falls within EPA's general target risk range. The actual risk of cancer from exposure to PCE at the site is probably even lower than predicted.

Evaluating Inhalation Exposures to the Mixture of Multiple Chemicals

The health impact of exposure to chemical mixtures is always a concern at hazardous waste sites. ATSDR followed existing ATSDR protocols for evaluating exposures to multiple chemicals of concern for inhalation exposures at this site (for example, using the hazard index approach for noncancer effects of chemical mixtures) [ATSDR 2004a, ATSDR 2004b].

For non-cancer effects, ATSDR's mixture guidance manual requires the health scientist to estimate an inhalation Hazard Quotient (HQ) for each chemical. The inhalation HQ is then used to determine the inhalation Hazard Index (HI) for the mixture of chemicals. When the HI for a mixture exceeds unity, concern for the potential hazard of the mixture increases. In other words, if the inhalation HI is below 1 (unity), then harmful effects of the mixture are not likely. HI for a mixture is the sum of the inhalation HQ for each chemical in the mixture. If all the inhalation HQs for each chemical are less than 0.1, then interaction among the chemicals in the mixture are unlikely. Whenever an HQ for a mixture of chemicals exceeds 0.1, further evaluation is needed to determine if a concern for possible harmful effects might exist. If only one HQ exceeds 0.1, then interactions between that chemical and other chemicals in the mixture also are unlikely [ATSDR 2004a]. For the Neodesha site, benzene is the only chemical that its HQ exceeded 0.1, therefore, the interaction (i.e., either additive, synergistic, or antagonistic) between benzene and other chemicals in the mixture are unlikely. In addition, the HIs for all chemicals are slightly above 1 for indoor air in residential buildings (1.144) because of benzene. And for indoor air in public buildings, the HIs for all chemicals are below 1 (0.303). See Appendix A for calculations. In addition, all measured levels of contaminants in the indoor air samples in the Neodesha area are below respective no-observed-adverse-effect levels (NOAELs) and all known adverse effect levels published in ATSDR's toxicological profiles. Therefore, ATSDR has concluded that the combined effect of the contaminants detected at the site is not likely to result in adverse health effects. This conclusion is supported by studies that suggest that a mixture produces no adverse noncancer health effects in dosed animals when the components of that mixture are present at

levels below their respective NOAELs [Wade et al. 2002, Feron et al. 1993, Jonker et al. 1990, Jonker et al. 1993a, Jonker et al. 1993b, Groten et al. 1991].

For cancer risks, the ATSDR Interaction Profile for Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX) recommended that the possible hematotoxic and carcinogenic hazard from exposures to BTEX should be evaluated on the basis of benzene alone [ATSDR 2004b]. An evaluation of benzene exposures is presented above in this document. ATSDR concluded that the estimated benzene exposures would not produce any adverse health effects (cancer and/or non-cancer). In addition, the combined cancer risk for the site falls within EPA's general target risk range. Therefore, ATSDR considers that the combined effect of all of these contaminants is not expected to be of public health concern.

Because relatively few chemical mixtures studies have assessed toxic interactions in low dose ranges and because several carcinogenic chemicals exhibited significant spatial trends, ATSDR recognizes there are uncertainties in evaluating the cumulative effects of chemical mixtures. ATSDR considers it a prudent public health measure to reduce or eliminate releases of chemicals into residential homes wherever possible.

Conclusions

ATSDR concludes that breathing indoor and outdoor air at the former refinery site in Neodesha, KS is not expected to harm people's health. This conclusion is based on the evaluation of ground water, soil vapor, indoor air, and outdoor air sampling data at the former refinery site and nearby areas. ATSDR determined that the amount of VOCs that could get into a child or adult's body as a result of working on site or living near the site is below levels that would harm their health.

The general trend in groundwater contamination as indicated by benzene concentrations is downward across the site over time. It appears that the groundwater plume is not spreading but has variations through the years.

All detected VOC concentrations in soil vapor samples taken at residential and public buildings are below levels recommended in the EPA draft guidance on indoor vapor intrusion. Therefore possible vapor intrusion processes are not expected to result in indoor air contaminants at levels of health concern.

Available surface water data indicated that the contamination from the site is not impacting surface water of the Fall River and Verdigris River from a public health perspective because all contaminant concentrations are significantly lower than their respective MCLs.

Recommendations

No recommendations at this time.

Public Health Action Plan

The Public Health Action Plan for the site contains a description of actions that have been or will be taken by ATSDR and/or other government agencies at the site. The purpose of the Public Health Action Plan is to ensure that this public health consultation not only identifies 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. Included is a commitment on the part of ATSDR to follow up on this plan to ensure its implementation.

Actions Taken:

ATSDR conducted site visits in June, July and September, 2002, March 2003, and April 2006. ATSDR released a health consultation for the former refinery site for public comment and held a public meeting in October and November 2003.

BP completed corrective action study revision 1 in February 2005.

ATSDR released a health consultation that addressed the New Beginnings facility lead contamination in April 2006.

ATSDR released a health consultation that reviewed available soil metals data in other areas of the former refinery site in June 2007.

ATSDR released the third health consultation that addressed the soil metals contamination at the former Neodesha smelter area in October 2007.

KDEH completed vapor intrusion evaluations of Neodesha public schools in 2008 and released final report on February 2009.

BP is operating their Phase 2 Interim Remedial Measures in the Neodesha community.

Actions Planned:

KDHE and ATSDR will continue to work with the community respond to public health questions and concerns about the site.

BP and other PRPs continue the groundwater monitoring programs at all affected areas, especially at the northeast and southwest corners of the plume to monitor the benzene contour.

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Figure 1. Former Neodesha Smelter Area Monitoring Well Network Map

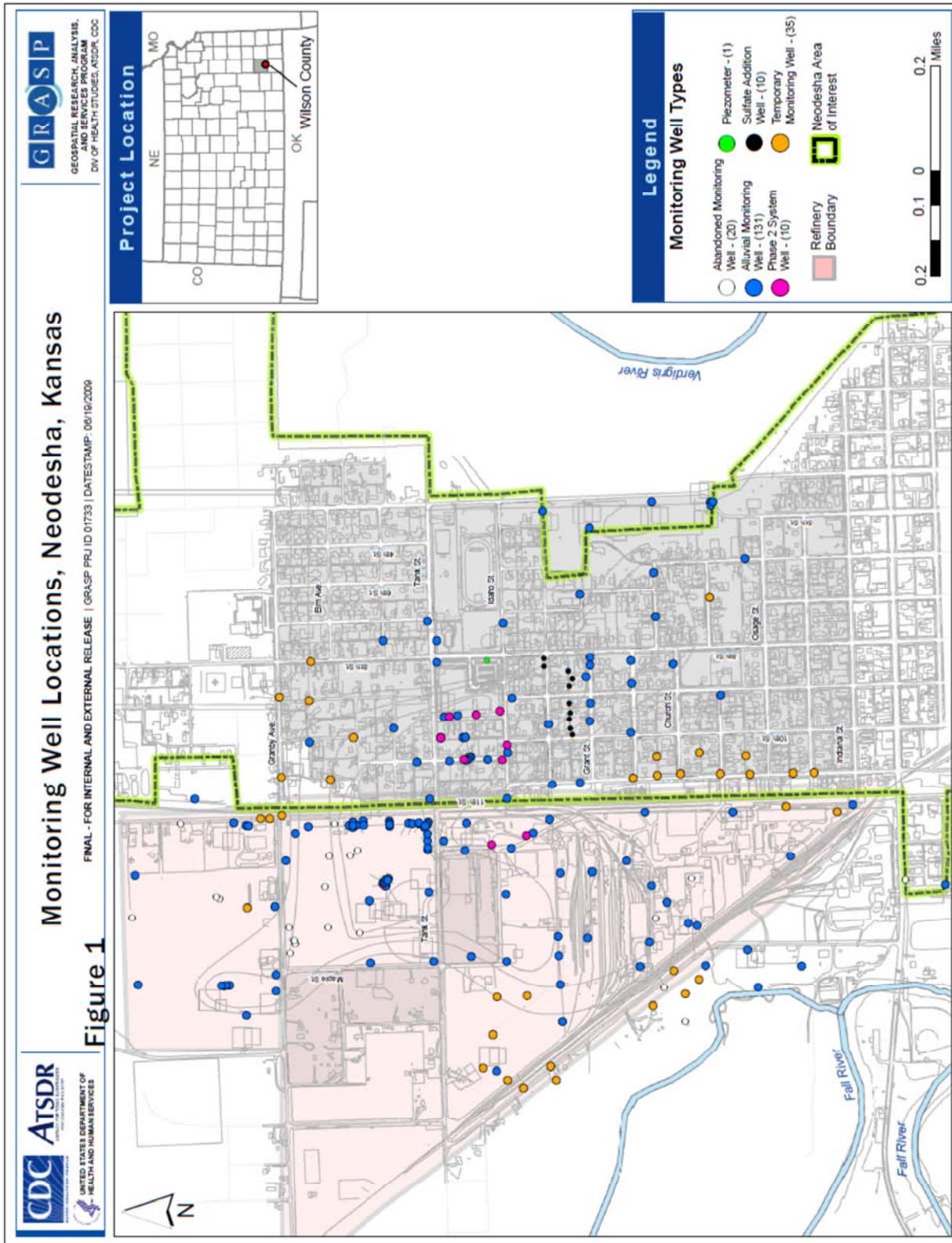


Figure 2.

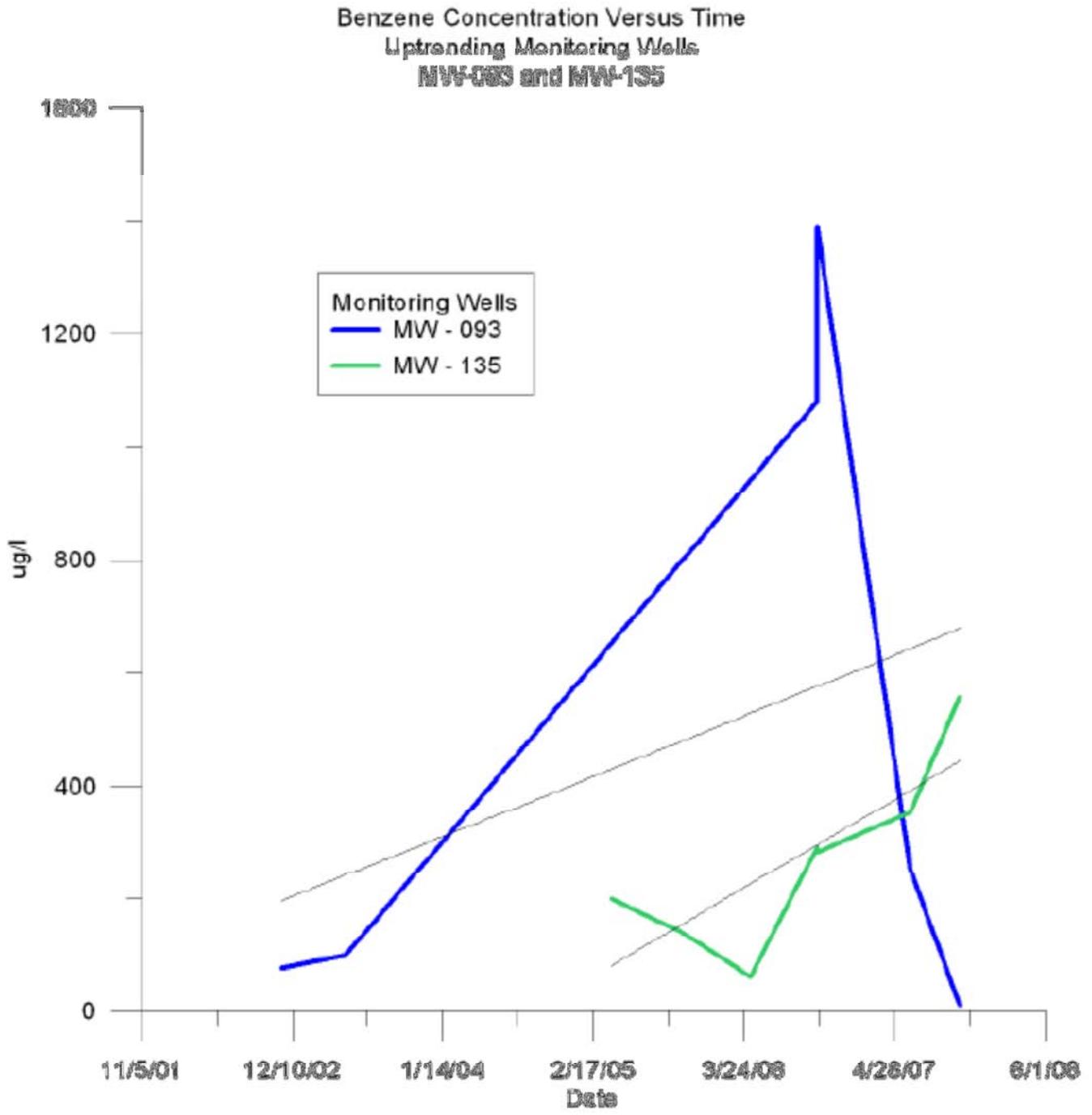


Figure 3.

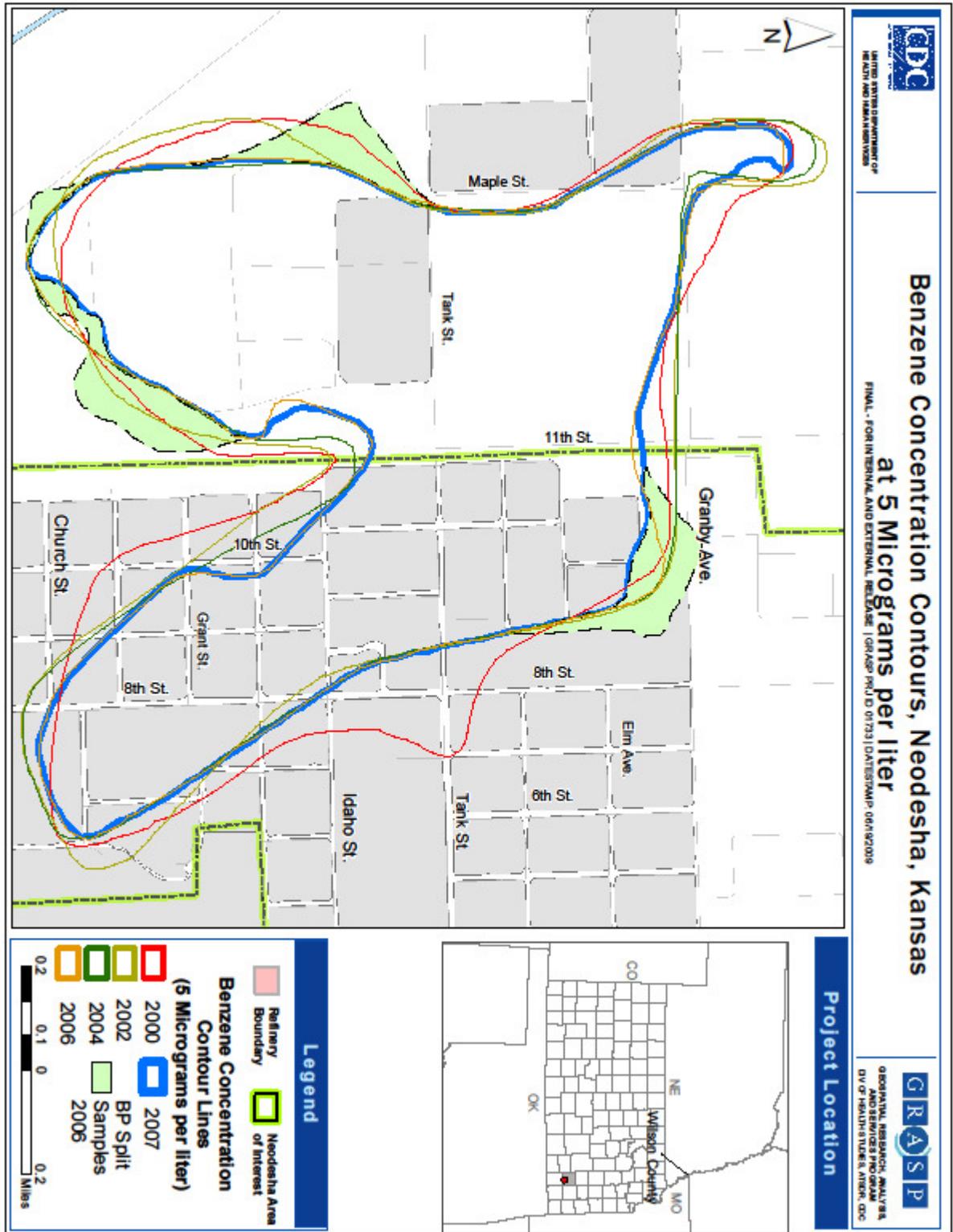
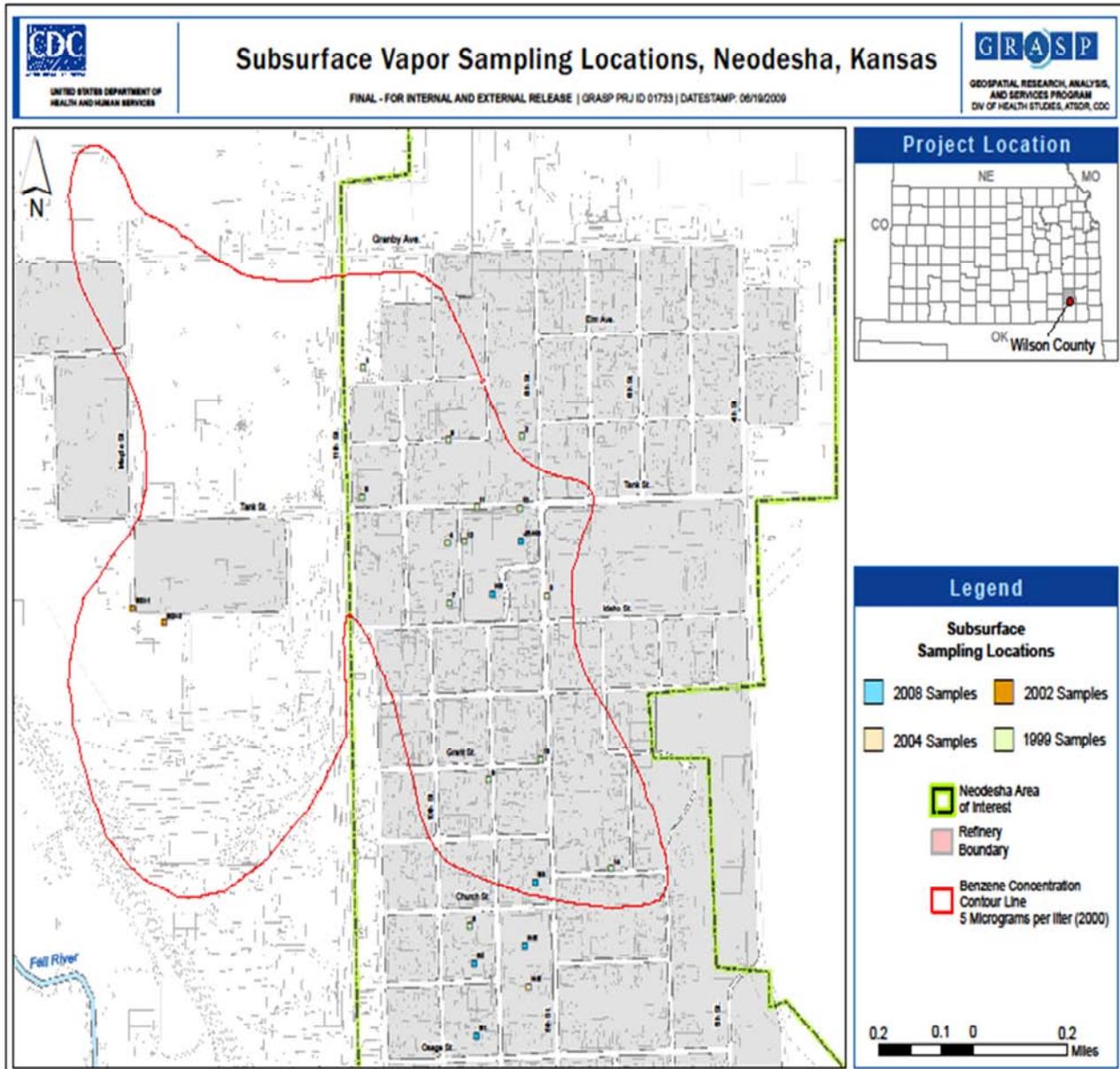


Figure 4.



Outdoor Sampling Locations, Neodesha, Kansas

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FIGURE 5

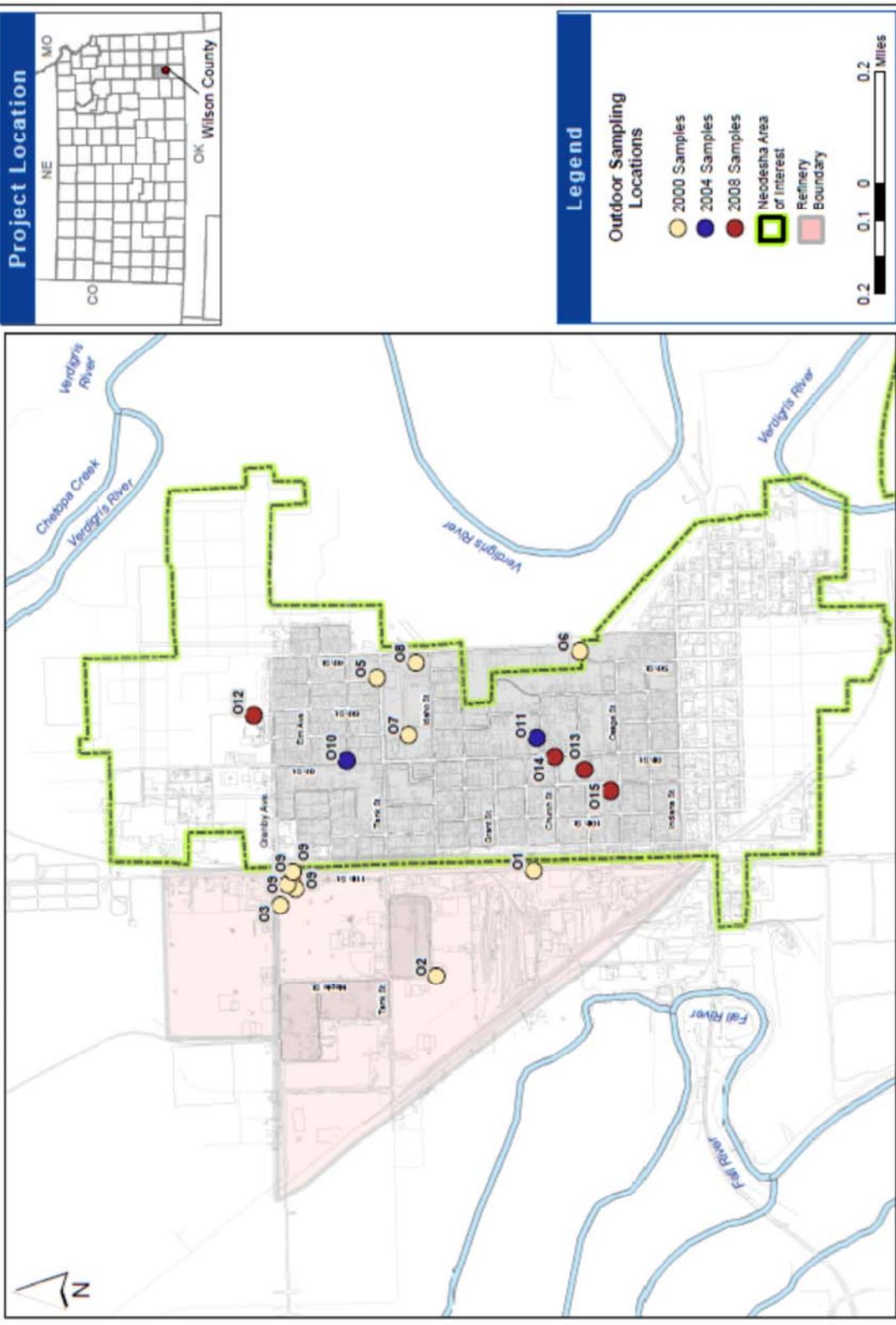


Figure 6

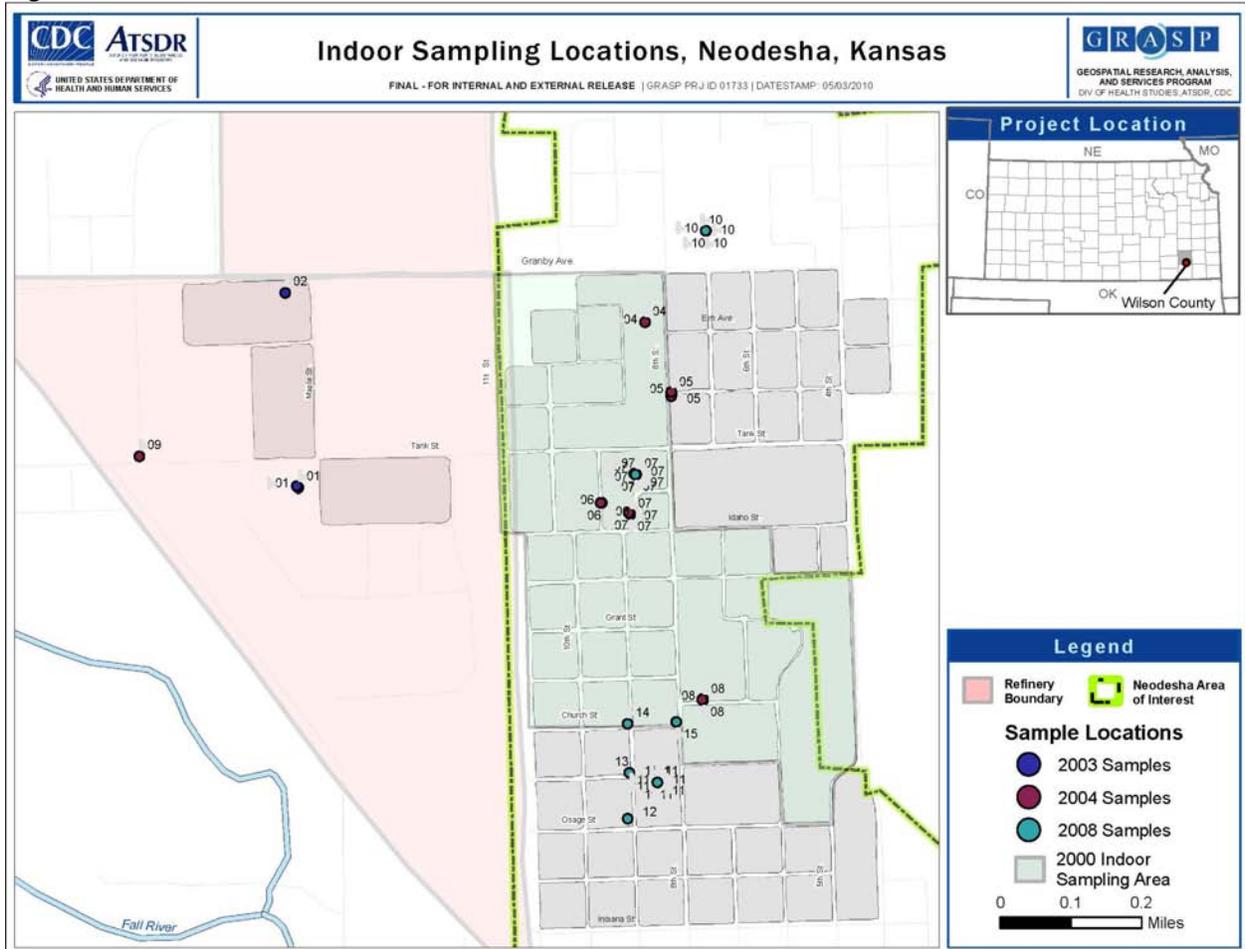


Figure 7.

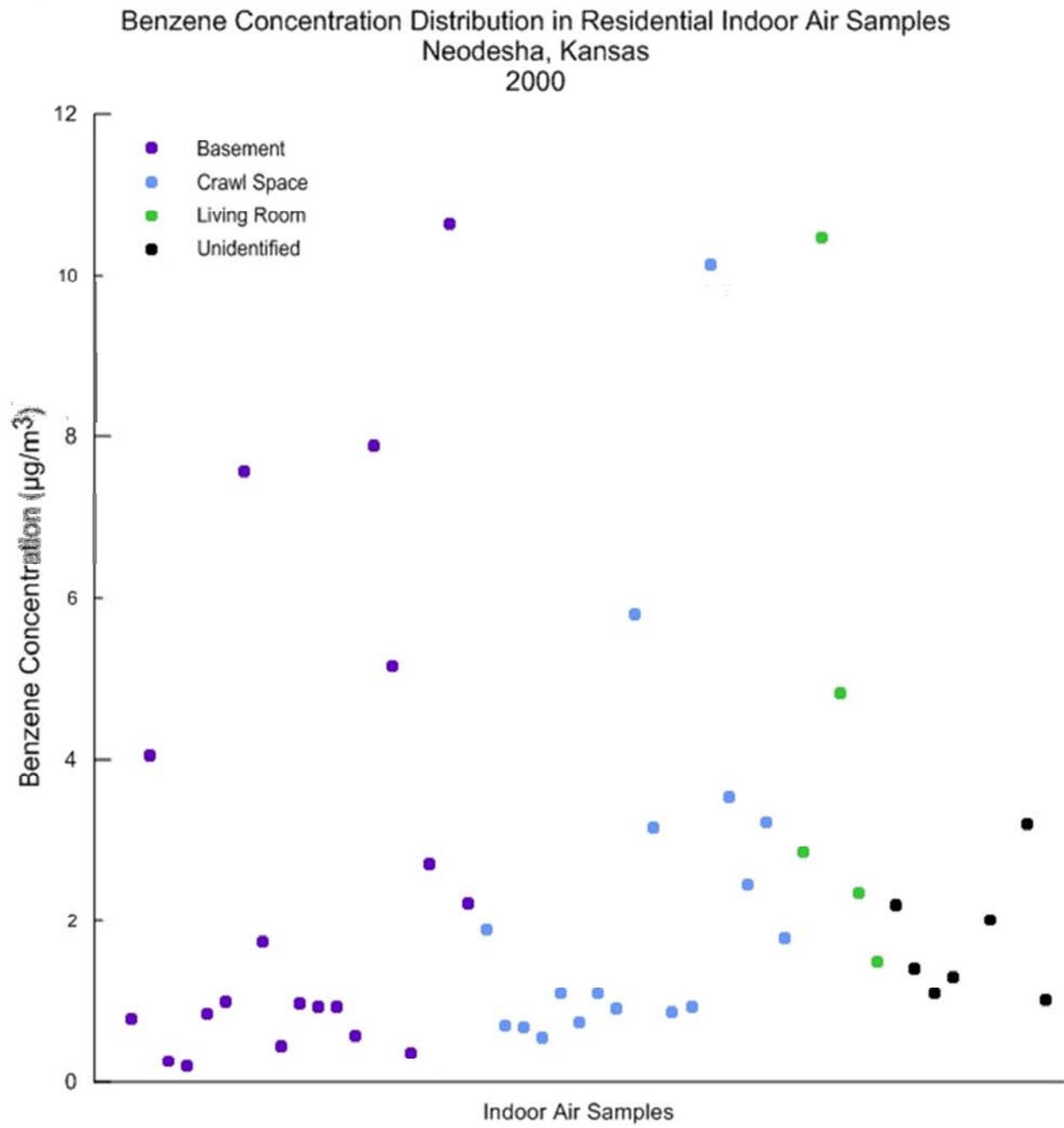


Table 1—Summary of soil vapor benzene results, October 1999. Neodesha, KS

Sample ID	Depth of Sample(ft)	Benzene (ppb)	Benzene ($\mu\text{g}/\text{m}^3$)
SV-1	8.0	5.5	17.86
	16.0	No vapor	NA
SV-2	8.0	No vapor	NA
SV-3	8.0	9.09	29.03
SV-4	8.0	No vapor	NA
SV-5	8.0	No vapor	NA
	14.5	18.5	59.08
SV-6	8	No vapor	NA
	14.5	25.4	81.11
SV-7	6	No vapor	NA
SV-8	8.0	13360	42663.52
	14.0	28755	91889.42
SV-9	8.0	502	1603.08
	12.0	96.5	308.16
SV-10	4.0	16.5	52.69
SV-11	5.0	15.7	50.14
SV-12	4.0	11.9	38.00
SV-13	8.0	22.8	72.81
SV-14	8.0	94.8	302.73

Note:

NA: not applicable

$\mu\text{g}/\text{m}^3$: microgram per cube meters

ppb: parts per billion

Data Source: ThermoRetec Consulting Corporation. Phase III Remedial Investigation Report. BP Amoco Neodesha Former Refinery, Neodesha, Kansas. Golden, Colorado. June 2000.

Table 2 — Summary of Soil Vapor Samples Results, December 2002. Neodesha, KS

Detected Analyte	MDC (SGI-1) ($\mu\text{g}/\text{m}^3$)	Depth of Sample(ft)	MDC (SGI-2) ($\mu\text{g}/\text{m}^3$)	Depth of Sample (ft)
1,2,4-Trimethyl benzene	10,337	6	98,444	6
1,2-Dichloropropane	1,619	6	2,869	6
1,3,5-Trimethyl benzene	5,414	6	43,807	9
Benzene	17,592	9	217,500	9
Ethylbenzene	2,782	6	56,519	9
1,1-Dichloroethane	1,094	6	527	NA
m&p-xylene	8,695	6	165,210	9
o-xylene	739	6	32,173	9
Toluene	2,490	6	83,009	9
Tetrachloroethylene (PCE)	<951	NA	1,426	9
Styrene	587	NA	1194	9

Note:

The samples were taken from a proposed building location and the proposed building was not constructed. Therefore human exposure through vapor intrusion at this location is not expected.

MDC: maximum detected concentration. There were 4 samples taken at location SGI-1 and 3 samples taken at SGI-2. Only the MDC are listed in the table.

$\mu\text{g}/\text{m}^3$: microgram per cube meters

NA: not available

< : less than

Data Source: The RETEC Group, Inc. Risk Assessment Report, Neodesha Former Refinery Site, Neodesha, Kansas. Fort Collins, Colorado. May 8, 2003. Revision 1: June 11, 2003.

Table 3— Summary Sub-slab Vapor Sampling VOC Results, March, November and December 2008 ($\mu\text{g}/\text{m}^3$)

Detected Chemicals	CV	Maximum concentration	Maximum concentration location	# of samples
Acetone	3,500	170 E	Heller Custodial Rm	17_
Benzene	310	3.15	High School Rm212 closet	17
2-Butanone(MEK)	10,000	16.5	High School Rm212 closet/Jr.High Storage Rm	17
Carbon Disulfide	7,000	20.9	Heller Castodial Rm	12
Chloromethane	900	12.2	Heller Basement	13_
Cyclohexane	6,000 (RfC)	8.4	Jr.High Storage Rm	17
1,4-dichlorobenzene	8,000	ND(5.4)	High School Rm212 closet/Jr.High Storage Rm	17
Dichlorodifluoromethane	2,000	568	High School Custodial Rm.Clos.	17
1,1-Dichloroethane	5,000	771	Church SS East/Can/#0869	19_
cis-1,2-Dichloroethene (DCE)	2,000	25.4	Heller Basement	14
Ethylbenzene	2,200	NA	NA	13_
4-Ethyltoluene	4000 (Toluene)	6.1	High School Custodial Rm	13
n-Heptane	NE	6.67	High School Rm212 closet	17_
n-Hexane	2,000	5.73	Heller Basement	17
2-Hexanone (MBK)		5	Jr.High Storage Rm	8_
Methylene chloride	900	94	Church SS West/Can/#1348	17
4-methyl,2-pentanone (MIBK)	NE	NA	NA	8
Methyl-tert-butyl-ether (MTBE)	30,000	NA	NA	12

Styrene	10,000	NA	NA	8_
Tetrachloroethene (PCE)	810	281	Church SS East/Can/#0869	19
Toluene	4,000	202	High School Custodial Rm	17_
1,1,1-Trichloroethane	22,000	90	Church SS East/Can/#0869	17
Trichloroethene (TCE)	220	69.4	Heller Basement	19_
Trichlorofluoromethane	7,000	12600E	Church SS East/Can/#0869	17
1,1,2-Trichlorotrifluoroethane	300,000	2870	Church SS East/Can/#0869	12
1,2,4-Trimethyl benzene	60	20	High School Rm212 closet	13
1,3,5-Trimethyl benzene	60	NA	NA	13_
Vinyl acetate	2,000	6.8	Heller Kit.Storage Rm.	8
m&p-xylene	70,000	65.3	High School Custodial Rm	13_
o-xylene	70,000	26.4	High School Custodial Rm	13
1,1-Dichloroethene	2,000	99.7	Church SS East/Can/#0869	4
1,2-Dichloropropane	40	NA	NA	9
Tetrahydrofuran	NE	2	Church SS West/Can/#1348	4_
1,2-Dichloroethane	5,000	6.2	Church SS East/Can/#0869	4
Chloroform	110	6.8	Church SS East/Can/#0869	4_
Ethyl Acetate	32,000	4.3	High School Rm212 closet	4

Note:

ND: Not detected. Values in paretis are detection limits.

NA: Not applicable.

NE: Not established.

CV: Comparison values. (EPA Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance). November 2002.

RfC: EPA Reference concentration.

E: Analyte concentration exceeded the calibration range. The reported result is estimated.

Table 4 —Summary of Outdoor Air sampling Results, 2000, 2004 and 2008($\mu\text{g}/\text{m}^3$)

Detected Chemicals ($\mu\text{g}/\text{m}^3$)	CV	Maximum concentration 2000	Maximum concentration 2004	Maximum concentration 2008	
Acetone	30,000 MRL	43.09	NA	73.35	
Benzene	0.1 CREG	1.45	2.61	2.3	
2-Butanone(MEK)	5120 RSK	4.5	NA	13.29	
Carbon Disulfide	900 MRL	7.1	NA	3.17	
Chloromethane	100 MRL	1.2	NA	1.08	
Cyclohexane	6,300 RSL	NT	NA	3.78	
1,4-dichlorobenzene	60 MRL	ND(1.2)	NA	2.4	
Dichlorodifluoromethane	210 RSL	3.59	NA	179	
1,1-Dichloroethane	1.5 RSL	ND((0.8)	NA	1.18	
cis-1,2-Dichloroethene (DCE)	36.5 RSK	ND(0.8)	NA	1.2	
Ethylbenzene	300 MRL	2.84	1.05	1.27	
4-Ethyltoluene	NE	1.98	NA	3.57	
n-Heptane	35,000 NIOSH	NT	NA	2.07	
n-Hexane	2,000MRL	NT	NA	6.2	
2-Hexanone	31 RSL	1.16	NA	3.47	
Methylene chloride	2 CREG	49.01	NA	38.4	
4-methyl,2-pentanone (MIBK)	3,100 RSL	ND(4.1)	NA	1.56	
Methyl-tert-butyl-ether (MTBE)	2000 MRL	NT	NA	1.05	
Styrene	900 MRL	19	NA	4.16	
Tetrachloroethene (PCE)	0.2 CREG	9.57	NA	ND(2.2)	
Toluene	300 MRL	64.57	8.74	11	
1,1,1-Trichloroethane	5200 RSL	1.1	NA	1.9	
Trichloroethene (TCE)	0.5 CREG	2.98	NA	4.7	

Trichlorofluoromethane	730 RSL	1.87	NA		
1,1,2-Trichlorotrifluoroethane	3,100 RSL	ND(3.0)	NA	74.1	
1,2,4-Trimethyl benzene	7.3 RSL	2.13	NA		
1,3,5-Trimethyl benzene	36.5 RSK	0.64	NA	3.57	
Vinyl acetate	210 RSL	NT	NA		
Xylene (total)	200 MRL	8.75	7.79	NA	
m&p-xylene	730 RSL	7.88	NA		
o-xylene	730 RSL	2.41	NA	ND(1.5)	
1,2-Dichloroethane	0.04 CREG	ND(0.8)	NA		
Chloroform	0.04 CREG	ND(1.0)	NA	1.5	
Carbon Tetrachloride	200 MRL	0.56	NA		
1,2-dichlorobenzene	210 RSL	0.73	NA	NT	
Bromomethane	5.2 RSL	ND(0.8)	NA		
Chlorobenzene	52 RSL	ND(0.9)	NA	3.1	
Dibromochloromethane	0.09 RSL	ND(1.7)	NA		

Note:

ND: Not detected. Values in paretis are detection limits

NA: Not applicable

NE: Not established

NT: Not tested

CV: Comparison values.

CREG:

RSL: EPA Regional Screening Level. 2009

RSK: KDHE Risk-Based Standards for Kansas. 2007

NIOSH: National Institution of Occupational Health and Safety.

Table 5 – Indoor Air Sampling Results Summary, 2000, 2003, 2004, and 2008

Detected Chemicals ($\mu\text{g}/\text{m}^3$)	CV (Lowest)	Maximum concentration 2000	Maximum concentration 2003	Maximum concentration 2004	Maximum Concentration 2008
Acetone	30,000 MRL		90.97		354.82
Benzene	0.1 CREG	10.63	2.19	27	3.54
2-Butanone(MEK)	5120 RSK		11.3		12.69
Carbon Disulfide	900 MRL		14.12		4.40
Chloromethane	100 MRL		2.29		2.02
Cyclohexane	6,300 RSL		NA		17
1,4-dichlorobenzene	60 MRL		NA		30.9
Dichlorodifluoromethane	210 RSL		1.35		49.40
1,1-Dichloroethane	1.5 RSL		NA		1.51
cis-1,2-Dichloroethene (DCE)	36.5 RSK		NA		1.52
Ethylbenzene	300 MRL	28.88	1.23	30.19	8.27
4-Ethyltoluene	NE		1.44		23.53
n-Heptane	35,000 NIOSH		NA		10.40
n-Hexane	2,000 MRL		NA		51.51
2-Hexanone	31 RSL		NA		3.72
Methylene chloride	2 CREG		42.01		55.10
4-methyl,2-pentanone (MBK)	3,100 RSL		NA		3.11
Methyl-tert-butyl-ether (MTBE)	2,000 MRL		NA		11.08
Styrene	900 MRL		2.01		9.96
Tetrachloroethene (PCE)	0.2 CREG		NA		33.90
Toluene	300 MRL	205.09	23.55	140.53	201.30
1,1,1-Trichloroethane	5,200 RSL		NA		18.53
Trichloroethene (TCE)	0.5 CREG		NA		2.8
Trichlorofluoromethane	730 RSL		2.32		31.10
1,1,2-Trichlorotrifluoroethane	3,100 RSL		NA		239.43
1,2,4-Trimethyl benzene	7.3 RSL		3.02		15.7

1,3,5-Trimethyl benzene	36.5 RSK		NA		7.4
Vinyl acetate	210 RSL		NA		
Xylene (total)	200 MRL	135.65	NA	161.03	NA
m&p-xylene	730 RSL		4.03		
o-xylene	730 RSL		1.23		13.08
1,2-Dichloroethane	0.04 CREG		NA		
Chloroform	0.04 CREG		7.38		2.80
1,2-Dichloropropane	210 RSL		NA		
Tetrahydrofuran	590,000 NIOSH		NA		16.5
Ethyl Acetate	1,400,000 NIOSH		NA		
1,4-dichlorobenzene	210 RSL		NA		18.80

Note:

NA: Not applicable

NE: Not established

Blank cells : Not tested

CV: Comparison values.

CREG:

RSL: EPA Regional Screening Level. 2009

RSK: KDHE Risk-Based Standards for Kansas. 2010

NIOSH: National Institution of Occupational Health and Safety.

Appendix A. Mixture and Cancer Risk Estimation for VOCs Indoor Air Exposure

The major exposure pathway by which residents can be exposed to VOCs at the site is inhale contaminated indoor air. A total of 36 buildings where indoor samples were taken and a total number of 122 indoor air samples were collected throughout the site and the City of Neodesha between 2000 and 2008. Thirty two VOCs were detected among 57 analytes. Concentrations of six VOCs exceeded their respective CVs. The VOCs are benzene, methylene chloride, PCE, TCE, 1, 2-dichloroethane, and chloroform. ATSDR designated indoor air samples into residential and public building (school/church, etc.) exposure unites to further evaluate the exposure situations. ATSDR followed existing ATSDR protocols for evaluating exposures to multiple chemicals of concern for inhalation exposures at this site.

Cancer risk evaluation:

The following conservative assumptions were made to estimate the potential cancer risks:

- (1) Resident exposure time is 24 hours/day
- (2) Resident exposure duration is 33 years
- (3) Resident exposure frequency is 365 days/year
- (4) School/office personal and students exposure time is 8 hours/day (public buildings)
- (5) School /office personal and students exposure durations are 25 years(public buildings)
- (6) School /office personal and students exposure frequency is 5 days/week for 40 weeks per year(public buildings)
- (7) Life time expectancy is 78 years for general U.S. population
- (8) Formula used for cancer risk calculation:

$$\text{Risk} = \text{Inhale Unit risk } (\mu\text{g}/\text{m}^3)^{-1} \times \text{Exposure Concentration } (\mu\text{g}/\text{m}^3)$$

$$\text{EC} = (\text{CA} \times \text{ET} \times \text{EF} \times \text{ED})/\text{AT} \quad \text{where}$$

CA ($\mu\text{g}/\text{m}^3$) = contaminant concentration in air

ET (hours/day) = exposure time

EF (days/year) = exposure frequency

ED (years) = Exposure duration

AT (lifetime in years x 365/days/year x 24 hours/day) = average time

VOC	CREG/CV ($\mu\text{g}/\text{m}^3$)	Inhale Unit risk ($\mu\text{g}/\text{m}^3$) ⁻¹	Maximum Concentration (Residential) ($\mu\text{g}/\text{m}^3$)	EC($\mu\text{g}/\text{m}^3$)	Estimated cancer risk	Maximum Concentration (public building) ($\mu\text{g}/\text{m}^3$)	EC($\mu\text{g}/\text{m}^3$)	Estimated cancer risk
Benzene	0.1	2.2E-06 to 7.8E-06	10.63	4.49	9.8E-06 to 3.5E-05	15.04	0.88	1.9E-06 to 6.8E-06
Methylene chloride	2	1.0E-08	55.1	23.31	1.9E-06	5.8	0.33	2.6E-08
PCE	0.2	2.6E-07	NA	NA	NA	33.9	1.98	5.1E-07
TCE	0.5	4.1E-06	1.7	0.71	2.9E-06	2.82	0.16	6.5E-07
1,2-Dichloroethane	0.04	2.6E-05	15.1	6.38	1.6E-04	ND	NA	NA
Chloroform	0.04	2.3E-05	1.6	0.67	1.5E-05	2.8	0.16	3.7E-06

Note:

Only samples taken from residential and public building living spaces were used to identify the maximum concentrations.

Maximum benzene concentration was obtained by averaging sampling results when split samples were taken.

PCE CREG and inhale unit risk were adopted from the California EPA per ATSDR's Division of Health Assessment and Consultation interim guidance for health assessors.

TCE CREG was adopted from the California EPA per ATSDR's Division of Health Assessment and Consultation interim guidance for health assessors. TCE inhale unit risk is adopted from EPA's IRIS. <http://www.epa.gov/oswer/riskassessment/ragsf/index.htm>

Mixture exposure evaluation:

For non-cancer effects, ATSDR's mixture guidance manual requires the health scientist to estimate an inhalation Hazard Quotient (HQ) for each chemical. The inhalation HQ is then used to determine the inhalation Hazard Index (HI) for the mixture of chemicals. When the HI for a mixture exceeds unity, concern for the potential hazard of the mixture increases. In another word, if the inhalation HI is below 1 (unity), then harmful effects of the mixture are not likely. HI for a mixture is the sum of the inhalation HQ for each chemical in the mixture. If all the inhalation HQs for each chemical are less than 0.1, then interaction among the chemicals in the mixture are unlikely. Whenever an HQ for a mixture of chemicals exceeds 0.1, further evaluation is needed to determine if a concern for possible harmful effects might exist. If only one HQ exceeds 0.1, then interactions between that chemical and other chemicals in the mixture also are unlikely.

For the Nedesha site, benzene is the only chemical that its HQ exceeded 0.1, therefore, the interaction (i.e., either additive, synergistic, or antagonistic) between benzene and other chemicals in the mixture are unlikely. In addition, the HIs for all chemicals are

slightly above 1 for residential buildings (1.144) because of benzene. For public buildings, the HIs for all chemicals are below 1 (0.303). ATSDR has concluded that the combined effect of the contaminants detected at the site is not likely to result in adverse health effects. Additional discussions are in the mixture section of this document.

<i>VOC</i>	<i>MRL(μg/m³)</i>	<i>Maximum Concentration (Residential) (μg/m³)</i>	<i>HQ</i>	<i>Maximum Concentration (public building) (μg/m³)</i>	<i>EC(μg/m³) (public building)</i>	<i>HQ</i>
Benzene	10	10.63	1.063	15.04	2.77	0.277
Methylene chloride	1000	55.1	0.055	5.8	1.04	0.004
PCE	300	NA	NA	33.9	6.10	0.020
TCE	500	1.7	0.0034	2.82	0.50	0.001
1,2-Dichloroethane	2000	15.1	0.0075	ND	NA	NA
Chloroform	100	1.6	0.016	2.8	0.50	0.001
HI			1.144			0.303

Note:

MRL: minimal risk level

NA: not applicable

ND: not detected

HQ: hazard quotient = Maximum concentration for residential exposure (Estimated concentration for public building exposure) ÷ MRL

HI: hazard index = sum of individual HQ

EC = (CA x ET x EF x ED)/AT where

CA (μg/m³) = contaminant concentration in air

ET (hours/day) = exposure time = 8 hours/day (public building exposures)

EF (days/year) = exposure frequency = 5 days/week for 40 weeks/ year (public building exposures)

ED (years) = Exposure duration= 25 years (public building exposures)

AT (ED in years x 365/days/year x 24 hours/day) = average time

Appendix B. ATSDR's comparison values and definitions

ATSDR comparison values (CVs) are media-specific concentrations considered safe under default exposure scenario. ATSDR uses them as screening values to identify contaminants (site-specific substances) that require further evaluation to determine the potential for adverse health effects.

Generally, a chemical at a site requires further evaluation when its maximum concentration in air, water, or soil exceeds one of ATSDR's comparison values. Comparison values are *not*, however, thresholds of toxicity. While concentrations at or below the relevant comparison value may reasonably be considered safe, it does not automatically follow that any environmental concentration that exceeds a comparison value would be expected to produce adverse health effects. Indeed, the purpose behind these highly conservative, health-based standards and guidelines is to enable health professionals to recognize and resolve potential public health problems *before* they become actual health hazards. The probability that adverse health outcomes will actually occur as a result of exposure to environmental contaminants depends on individual lifestyles and genetic factors and site-specific conditions that affect the route, magnitude, and duration of actual exposure, and not on environmental concentrations alone.

ATSDR derives screening values on the basis of noncancerous effects by dividing a NOAEL (no observed adverse effect level) by LOAELs (lowest observed adverse effect level). These levels stem from animal or human studies and include cumulative safety margins (variously called safety factors, uncertainty factors, or modifying factors) that typically range from 10 to 1,000 or more.

By contrast, cancer-based screening values come from linear extrapolations from animal data obtained at high doses because human cancer incidence data for very low levels of exposure simply do not exist, and probably never will.

Listed below are the comparison values that ATSDR uses to select chemicals for further evaluation, along with the abbreviations for the most common units of measure.

EMEG = environmental media evaluation guides

RMEG = reference dose media evaluation guide

MRLs = minimal risk levels

ppm = parts per million, e.g., mg/L or mg/kg

ppb = parts per billion, e.g., µg/L or µg/kg

kg = kilogram (1,000 gram)

mg = milligram (0.001 gram)

µg = microgram (0.000001 gram)

L = liter

m³ = cubic meter (= 1,000 liters)

acute exposure: exposure to a chemical for duration of 14 days or less.

cancer risk evaluation guide (CREG): estimated contaminant concentration in water, soil, or air that would be expected to cause no more than one excess case of cancer in a million persons exposed over a lifetime. CREGs are calculated from EPA's cancer slope factors.

chronic exposure: exposure to a chemical for 365 days or more.

environmental media evaluation guide (EMEG): concentration of a contaminant in water, soil, or air unlikely to produce any appreciable risk of adverse, non-cancer effects over a specified duration of exposure. EMEGs are derived from ATSDR minimal risk levels by factoring in default body weights and ingestion rates. ATSDR computes separate EMEGs for acute (≤ 14 days), intermediate (15–364 days), and chronic (> 365 days) exposures.

intermediate exposure: exposure to a chemical for duration of 15–364 days.

lowest observed adverse effect level (LOAEL): The lowest exposure level of a chemical in a study or group of studies that produces statistically or biologically significant increase(s) in frequency or severity of adverse health effects between the exposed and control populations.

minimal risk level (MRL): estimate of daily human exposure to a hazardous substance that is not likely to pose an appreciable risk of adverse noncancer health effects over a specified route and duration of exposure.

no observed adverse effect level (NOAEL): The dose of a chemical at which no statistically or biologically significant increases in frequency or severity of adverse health effects were seen between the exposed population and its appropriate control. Effects may be produced at this dose, but they are not considered to be adverse.

uncertainty factor (UF): a factor used in deriving the MRL or reference dose or reference concentration from exposure data.