

Public Health Assessment

Final Release

VIENNA WELLS

MARIES COUNTY, MISSOURI

EPA FACILITY ID: MON000705803

**Prepared by the
Missouri Department of Health and Senior Services**

OCTOBER 20, 2015

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

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment was prepared by ATSDR's Cooperative Agreement Partner pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR's Cooperative Agreement Partner has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate.

In addition, this document has previously been provided to EPA and the affected states in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. The revised document was released for a 30-day public comment period. Subsequent to the public comment period, ATSDR's Cooperative Agreement Partner addressed all public comments and revised or appended the document as appropriate. The public health assessment has now been reissued. This concludes the public health assessment process for this site, unless additional information is obtained by 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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Prepared by:

Missouri Department of Health and Senior Services
Division of Community and Public Health
Section for Environmental Public Health
Bureau of Environmental Epidemiology
under Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

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List of Acronyms

AT	Averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
bgs	below ground surface
BW	body weight
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
C	concentration
CF	conversion factor
cm	centimeter
cm ²	square centimeters
CREG	cancer risk evaluation guide
CV	comparison value
D	dose
DCE	dichloroethylene
DHSS	Missouri Department of Health and Senior Services
DNR	Missouri Department of Natural Resources
ET	exposure time
EMEG	environmental media evaluation guide
EPA	United States Environmental Protection Agency
IR	inhalation rate or ingestion rate
K	volatilization constant
kg	kilograms
L/day	liters per day
L/m ³	liters per cubic meter
LOAEL	lowest observed adverse effect level
MCL	maximum contaminant level
m ³ /day	cubic meters per day
mg/kg	milligrams per kilograms
mg/kg-day	milligrams per kilogram per day
mg/L	milligrams per liter
mg/m ³	milligrams per cubic meter
ND	not determined
P	dermal permeability coefficient
PCE	tetrachloroethylene
RfC	reference concentration
RMEG	reference dose media evaluation guide
RSL	regional screening level
SA	surface area
TCE	trichloroethylene
µg	micrograms
µg/L	micrograms per liter
µg/m ³	micrograms per cubic meter
USGS	United States Geological Survey

VC
VOC

vinyl chloride
volatile organic compound

SUMMARY

INTRODUCTION The Missouri Department of Health and Senior Services (DHSS), in cooperation with the Federal Agency for Toxic Substances and Disease Registry (ATSDR), developed this public health assessment to evaluate the public health impact of tetrachloroethylene (also known as perchloroethylene or PCE) found in groundwater and soil in Vienna, Missouri (MO). The Vienna Wells Site was placed on the United States Environmental Protection Agency (EPA) National Priorities List (NPL) on September 27, 2010, after PCE concentrations in pre-treated drinking water from a Vienna public drinking water well were found to exceed EPA's maximum contaminant level (MCL) for PCE. The Vienna Wells Site consists of the city of Vienna, 3 municipal drinking water wells, and the property of the former Langenberg Hat Company, where PCE was found in subsurface soil.

The health of residents who use water from public and private wells has not likely been impacted by exposure to PCE in the water, because PCE concentrations in public and private well water have not exceeded ATSDR's health-based guidelines, and because a new public well water treatment facility designed to remove 98% of volatile organic compounds (VOCs) was installed in 2012. Individuals are also not likely to be affected by PCE in soil, unless they are digging on the former hat factory property. It is not known if future migration of contaminants in groundwater may impact public health, especially the health of residents who use private well water in their homes or could be exposed to VOCs by vapor intrusion. DHSS recommends continued monitoring of VOCs in public well water and continued efforts to define the extent of contamination at the site, in anticipation of cleanup of the site. If public water demand increases before remediation of the site is complete, DHSS also recommends that the City of Vienna consider expanding its water treatment and distribution system to meet public need.

DHSS is currently preparing a separate public health consultation on the Vienna Wells Site that evaluates results of EPA's recent investigation of VOC vapor intrusion at residences near the hat factory property.

CONCLUSIONS DHSS has reached four conclusions in this health assessment:

Conclusion 1
Public Well Water

DHSS concludes that ingesting (swallowing), inhaling (breathing), and being in dermal (skin) contact with PCE detected in Vienna public well water between March 1997 and February 2012 is not expected to harm people's health. This conclusion applies to past exposures of one year or longer.

Basis for Decision
Public Well Water

PCE was first detected in pre-treated water samples collected from Vienna's main public drinking water well (Well #3) in March 1997. In response to the detection of PCE in Well #3, public well water samples have been collected every 3 months (quarterly) for analysis. PCE concentrations from Well #3 exceeded EPA's MCL of 5 µg/L on several occasions between August 2006 and February 2012. Exceeding an MCL does not mean that a health risk is present; rather, exceedance of the MCL requires additional actions be taken, such as public notification, increased sampling, and evaluation by health agencies.

Between August 2006, when PCE concentrations first exceeded the MCL, and February 2012, the average concentration of PCE in Well #3 was 4.86 µg/L. This average concentration is below ATSDR's health-based guidelines for adult and child exposure to PCE in drinking water, as well as ATSDR's cancer risk evaluation guide (CREG) for PCE. These guidelines were developed by ATSDR to identify concentrations of potential human health concern.

Conclusion 2
Soil

DHSS concludes that inadvertently ingesting (swallowing), inhaling (breathing) and being in dermal (skin) contact with surface soil located at the hat factory property for a year or longer is not expected to harm people's health. This conclusion applies to present and future exposures.

DHSS does not know past concentrations of PCE in surface soil and, therefore, cannot draw conclusions about the health effects of potential exposure in the past, especially prior to 1997, when the hat factory was operating.

DHSS also cannot conclude whether exposure to PCE in soil below the ground surface may harm people's health. However, based on the current use of the hat factory property, exposure to subsurface soil is not expected.

Basis for Decision
Soil

PCE was detected in some soil samples that the Missouri Department of Natural Resources (DNR) collected from 25 borings in areas identified as possible factory waste spill/release points on the former hat factory property. PCE in surface soil that does not evaporate into air will migrate quickly to deeper soils. As expected, PCE concentrations tended to increase with depth on the property. PCE concentrations in soil near the ground surface were well below health-based screening values and, therefore, unlikely to have adverse health effects.

Additional investigation should be conducted prior to any digging or removal of soil on the hat factory property. DHSS recommends that

continued efforts are made to characterize the site and locate the area(s) of concentrated (e.g., non-aqueous phase) PCE in subsurface soil.

Conclusion 3
Private Well Water

DHSS concludes that ingesting (swallowing), inhaling (breathing), and being in dermal (skin) contact with PCE through the use of private drinking water wells in the Vienna area for a year or longer is not expected to harm people's health. This conclusion applies to past and present exposures to water at private wells that have been tested.

PCE may continue to migrate with groundwater from the source area. As a result, DHSS cannot conclude whether future exposure to PCE in private well water may harm people's health. Continuation of efforts to characterize the extent of groundwater contamination at the site and continued private well water testing, as needed, will allow DHSS to determine the future exposure potential and possible future health effects of PCE in private well water.

Basis for Decision
Private Well Water

In April 2007, DNR conducted water sampling of 23 private wells located within a 3-mile radius of the site. These water samples did not contain detectable concentrations of PCE or its chlorinated breakdown products.

In November 2011, the United States Geological Survey (USGS) tested private well water at 54 residences located within a 2-mile radius of the site. Neither PCE nor its breakdown products were detected in water samples from 53 of the wells. A water sample from one private well (MK01) that is located approximately 200 yards southeast the former hat factory contained PCE. The concentration in that well (10 µg/L) exceeded EPA's MCL for PCE (5 µg/L), but the owner of the well stated that municipal water is used in the home.

Currently, there does not appear to be widespread PCE contamination of private well water in and around Vienna. DHSS recommends that continued efforts are made to locate the source of PCE contamination. Cleanup of groundwater at the site may prevent future migration of PCE and its chlorinated breakdown products that can result in contamination of private wells in and around Vienna. Until the site is remediated, DHSS also recommends continued monitoring of private wells, particularly those located in close proximity to the contaminated area. If PCE or its chlorinated breakdown products are detected at levels of health concern, DHSS recommends that the owners of those wells use an alternative water source until the site can be remediated.

Conclusion 4
Vapor Intrusion

DHSS cannot conclude if past exposure to VOCs as a result of vapor intrusion into the hat factory building may harm people's health. DHSS does not expect that present and future VOC

exposure as a result of vapor intrusion into the former factory building will harm people's health.

DHSS is currently in the process of preparing a separate public health consultation to evaluate the results of EPA's recent vapor intrusion investigation at residences located near the former hat factory property. .

Basis for Decision
Vapor Intrusion

VOCs in groundwater or soil may evaporate into soil gas that can seep through the foundations of homes or other buildings and build up to levels in indoor air that may pose a health risk.

PCE concentrations inside the factory building between 1952 and 1996, while the factory was in operation, are not known. PCE concentrations in indoor air inside the currently standing sections of the former factory building have not been investigated, as the building is currently dilapidated. It is expected that vapors might only accumulate in a small sections of the building that remain intact, where individuals working or trespassing on the property would not be expected to remain for extended periods of time.

DHSS recommends testing for vapor intrusion at residences located in close proximity to VOC-contaminated areas (i.e., generally within 100 feet of a defined contaminant plume). In July 2014, EPA performed a vapor intrusion investigation at 17 residences located near the former hat factory property. DHSS is currently evaluating the data from that investigation.

Conclusion 5
Physical Hazards

DHSS concludes that visiting or trespassing on the site may currently pose physical health hazards. DHSS cannot draw a conclusion about physical hazards of visiting or trespassing on the site in the past.

Basis for Decision
Physical Hazards

The former hat factory building is dilapidated, and sections of the building have been demolished. Currently, access to the site is unrestricted, and visitors or trespassers on the site could have easy access to the building. DHSS does not know when the factory building began posing physical hazards, after operations ceased in 1996. DHSS recommends removal of any physical hazards from the site.

Next Steps

To protect public health:

1. DHSS recommends continued quarterly monitoring of public well water, along with regular monitoring of the VOC removal efficiency of the public water treatment system. DHSS recommends that the City of Vienna continues to work with DNR and other agencies and provide well water samples for testing.

2. DHSS recommends that the City of Vienna considers coordinating expansion of the new water treatment and distribution system to meet increased demand for clean water, if the population of the city increases in the future. The City of Vienna coordinated construction of a public drinking water treatment facility designed to significantly reduce VOCs in the public drinking water. The City of Vienna also coordinated the installation of a new water distribution system. These projects were completed in 2012.
3. DHSS recommends that USGS, EPA, and other agencies continue to define currently suspected sources of PCE contamination, identify potential additional sources of PCE, and characterize contaminant plumes in anticipation of cleaning up the site.
4. DHSS recommends continued monitoring of private wells located in close proximity to contaminated areas. If VOCs are detected at levels of health concern, DHSS recommends that the owners of those wells use an alternative water source until the site can be remediated.
5. DHSS recommends that EPA and other agencies investigate potential vapor intrusion into homes or buildings that are found to be in close proximity to VOC-contaminated soil gas and/or groundwater.
6. DHSS recommends that the owner(s) of the former hat factory remove any physical hazards from the site.
7. DHSS will coordinate with the City of Vienna, USGS, DNR, and EPA to address community health concerns and questions as they arise by providing health professional and community education.
8. DHSS will coordinate with the City of Vienna, USGS, DNR, and EPA to implement the recommendations in this public health assessment.
9. DHSS will review and comment on any additional data from environmental samples collected by USGS, EPA, DNR, or other agencies as they become available.

PURPOSE AND HEALTH ISSUES

The Missouri Department of Health and Senior Services (DHSS), in cooperation with the Agency for Toxic Substances and Disease Registry (ATSDR), is evaluating the public health impact of the Vienna Wells Site. ATSDR is a federal agency within the United States Department of Health and Human Services and is authorized by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) to conduct public health assessments at hazardous waste sites.

The primary contaminant of concern at the Vienna Wells Site is tetrachloroethylene (also known as perchloroethylene or PCE), which has been detected in the public drinking water supply as a result of groundwater contamination. PCE has also been found in soil at the property of a former hat factory and in private well water. The purpose of this public health assessment is to determine if exposures to PCE have occurred in the past or present or might occur in the future at a level of public health concern and to recommend actions to reduce or prevent possible adverse health effects. The top priority of DHSS in performing this evaluation is to provide the Vienna community with the best information possible to safeguard its health.

BACKGROUND

Site Description and History

The Vienna Wells Site is located at Vienna, Missouri (MO), in the center of Maries County. Vienna is located at the intersection of Highway 63 and Highway 42 between Jefferson City, MO, and Rolla, MO. The city covers approximately 1.1 square miles. According to the 2000 U.S. Census, 628 people (96.1% white; 3.9% other races) live in Vienna and 817 people (98.3% white; 1.7% other races) live within a one mile radius of the site (1). See area map and demographic statistics in Appendix 1 (Figure 1A).

Vienna Public Wells

In 1954, Vienna Public Drinking Water Well #1 (Well #1) was drilled to 670 feet and cased to 356 feet. In 1985, Vienna Public Drinking Water Well #2 (Well #2) was drilled to 935 feet and cased to 375 feet. In 1994, Vienna Public Drinking Water Well #3 (Well #3) was drilled to 970 feet and cased to 321 feet. Since 1994, public drinking water has almost exclusively been drawn from Well #3. Well #1 has been used for emergency and supplemental water supply. Well #2 has not been used since 2007 because of aesthetic concerns caused by iron in the water. (2)

The Missouri Department of Natural Resources' (DNR) Public Drinking Water Program requires that public drinking water suppliers submit periodic water samples for testing to ensure that the water meets state and federal quality standards. It is required that public drinking water wells be tested for volatile organic compounds (VOCs), including PCE, every 3 years. During routine

water samplings in May 1991 and March 1993, no VOCs were detected in pre-treated water collected from Well #1 or Well #2. On June 7, 1994, 0.9 µg PCE/L was detected in Well #1. Well #3 was drilled in the fall of 1994 and designated the primary well as no VOCs were detected in Well #3 at that time. Well #1 was converted to an emergency standby well. When testing occurred 3 years later, in March of 1997, a PCE concentration of 0.5 µg/L was detected in Well #3. Since the fall of 1998, the DNR's Public Drinking Water Program has required quarterly sampling of Well #3. (2)

Concentrations of PCE in Well #3 steadily increased between March 1997 and February 2012 (2). Breakdown products of PCE, including trichloroethylene (TCE), dichloroethylene (DCE), and vinyl chloride (VC), were not detected in those samples, which indicated that environmental conditions were not supportive of natural PCE degradation. In August of 2006, the PCE concentration (5.72 µg/L) first exceeded the U.S. Environmental Protection Agency's (EPA's) maximum contaminant level (MCL) for PCE of 5.0 µg/L (3). The EPA has established MCLs to protect the public from contaminants in public drinking water. Consistent exceedance of an MCL in a public drinking water supply requires that additional actions are taken, such as public notification, increased sampling, and evaluation by health agencies. After August 2006, PCE concentrations fell below the MCL but then exceeded the MCL again in November 2008 (2). The highest concentration of PCE in water samples from Well #3 (6.25 µg/L) was detected in November 2008.

Increasing PCE concentrations in Well #3 prompted a return to routine sampling of Well #1 in 2006. PCE continued to be detected in water samples from Well #1 between February 2006 and February 2012. However, PCE concentrations in water samples collected from Well #1 did not exceed EPA's MCL. (2)

The Vienna Wells Site was placed on EPA's National Priorities List (NPL) on September 27, 2010, due to the detection of PCE in Public Drinking Water Well # 3 in concentrations that exceeded EPA's MCL for PCE. In August 2011, United States Geological Survey (USGS), in collaboration with EPA, began an investigation of VOC contamination at the Vienna Wells Site. This has included installation of groundwater monitoring wells on the hat factory property in an effort to locate and define PCE plumes.

The City of Vienna coordinated construction of a new water treatment facility and distribution system, which was completed in 2012. The treatment facility is equipped with a 24-foot air stripper that is estimated to remove 98% of VOCs from the drinking water. According to the city water system operator, the source of water for the facility will likely alternate between Well #1 and Well #3.

Langenberg Hat Company

The former Langenberg Hat Company property is a 7.89-acre parcel of land located approximately 160 yards southeast of Well #3, 200 yards northeast of Well #1, and 1,300 yards northeast of Well #2. The eastern 4 acres is heavily wooded, and the western 3.89 acres contains the remains of the hat factory building that is surrounded primarily by shrubby vegetation and

grass. Because of the proximity of the former factory property to Well #3, it has been considered a potential source of the PCE since the beginning of the investigation.

The Langenberg Hat Company began operations at Vienna in 1952. In 1990, the property was transferred to Top This, Inc., which continued producing hats until the facility closed in 1996. Top This, Inc., dissolved in 1997, and the Langenburg Hat Company dissolved in 2000. (2)

The current owner of the hat factory property purchased it in September of 1999 and has used the building for storage. When the property was toured in 2008, the roof of the building on the eastern side was failing, allowing storm water to enter. There were also many windows that had apparently been broken by vandals. Several pieces of equipment used in the production of hats still remained in the building. (2)

As of May 2012, the former hat factory building had been partly demolished. Portions of the building and the cement slab upon which the factory was built currently remain on the site.

Little information is known about the chemicals used in production processes of the hat factory. During a site visit conducted by the DNR on April 17, 2008, six empty barrels labeled Valclene were found throughout the building being used as trash receptacles (2). Valclene® was introduced as a dry-cleaning solvent by DuPont in 1964, 8 years after production operations at the hat factory began. The composition of Valclene is not known. Its primary component is believed to be Freon 113 or 1,1,2-trichloro-1,2,2-trifluoroethane, both alternate names for Valclene. It is a current assumption that Valclene was being used in the production process at one time. PCE was the most widely-used drycleaning solvent in use in the United States while the hat factory was in operation and may have also been used as such.

The city water system operator reported to DNR that the factory was connected to both city water and sewer in the 1970s (2). It is not known whether the hat factory used a septic tank or waste water lagoon as its method of waste disposal prior to that time. Plumbing to the hat factory building was disconnected during construction of the new water treatment facility and installation of a new water distribution system in 2012. This will prevent any contaminants that may be present in factory plumbing from migrating into the city water and sewer system.

Other Potential Sources of PCE

PCE is a man-made chemical often used for dry cleaning fabrics and metal degreasing. PCE can also be found in consumer products such as water repellents, silicone lubricants, fabric finisher, spot removers, adhesives and wood cleaners. If PCE is spilled or improperly released onto the soil or into surface water, the PCE that does not evaporate into air will migrate to the sub-surface soil and groundwater and can affect drinking water supplies (4).

Additional sources of environmental PCE contamination in the Vienna area have not been located at this time. However, the search for additional sources has not been completed, so the potential for the existence of additional sources cannot yet be ruled out.

Geology of the Site

Vienna is located on a ridge that runs north and south between Fly Creek and the Gasconade River. The highest line of the ridge is primarily between Main and Mill Street. Water runoff east of this divide drains into the Gasconade River (5). Water runoff west of the divide drains into Fly Creek, which flows into the Maries River (5). A map of area waterways and public and private water wells is shown in Appendix 1 (Figure 1B).

The primary soil type in the area is silt loam composed of 12 to 80 percent clay. Bedrock is typically between 10 and 25 feet below the surface. The bedrock at the highest elevations along the ridge is made up of Jefferson City Dolomite. However, the primary bedrock throughout Vienna is the Roubidoux Formation, which consists of interbedded cherty dolomite, sandy dolomite, and sandstone. The Roubidoux Formation averages 170 feet thick. Below the Roubidoux Formation is Gasconade Dolomite, which is the bedrock found in the Maries and Gasconade River Valleys. The thickness of the Gasconade Dolomite in the Vienna area is 225 to 285 feet. Below these geological units lie the Eminence Dolomite, Potosi Dolomite, and then the Saint (St.) Francois Confining Unit (Derby-Doerun and Davis Formations). (5)

The area is underlain by the unconfined Ozark Aquifer, which extends from near the ground surface to the St. Francois Confining Unit approximately 1,000 feet below the surface. The Ozark Aquifer is the water source for the public wells and private wells in the area. Below the Ozark Aquifer, the St. Francois Confining Unit is an effective barrier preventing downward groundwater movement into the St. Francois Aquifer. (2)

SITE INVESTIGATION

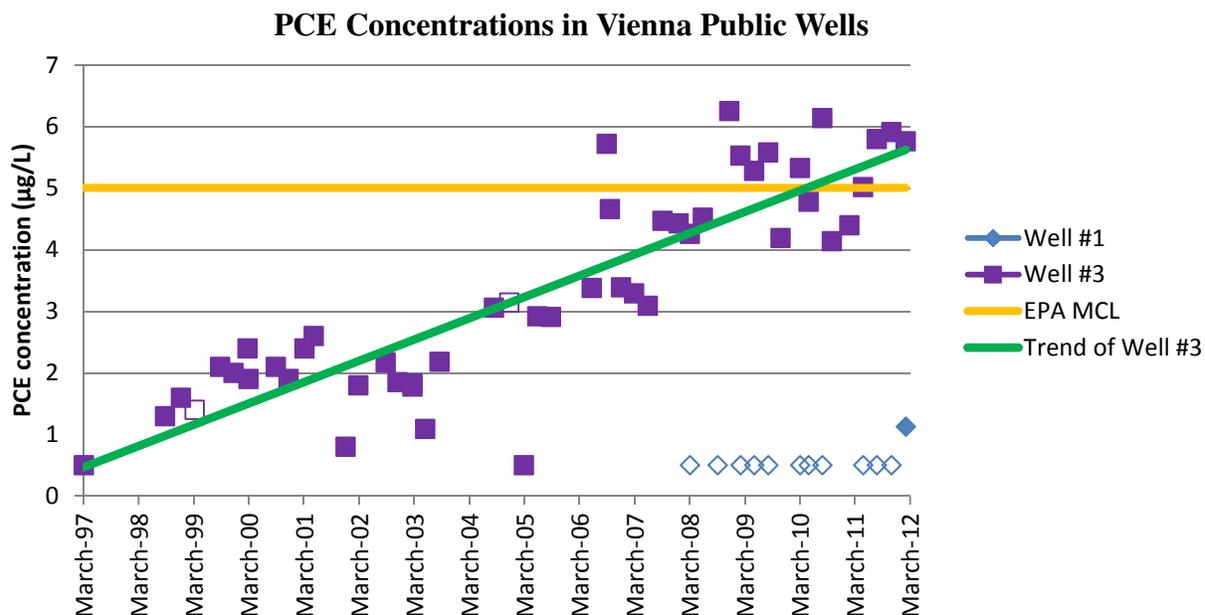
In August of 2006, pre-treated water collected from Well #3 contained 5.72 µg PCE/L, which exceeded EPA's MCL for PCE of 5.0 µg/L. Since that time, groundwater, soil, tree core, and municipal sewer line water samples have been collected to determine the source of PCE and extent of contamination. Water samples continue to be collected from Well #1 and Well #3 every 3 months to monitor VOC concentrations. In addition, water samples have been collected from private drinking water wells located in or near Vienna to determine if PCE migration is affecting those wells at levels of health concern.

Vienna Public Well Water Samples

Figure 1 shows PCE concentration trends in water samples collected from Well #1 and Well #3. PCE concentration values are shown in Appendix 2, Table 2A. Since August 2006, PCE concentrations in samples from Well #3 have exceeded the MCL on several occasions, as follows: 6.25 µg/L in November 2008; 5.53 µg/L in February 2009; 5.28 µg/L in May 2009;

5.58 µg/L in August 2009; 5.33 µg/L in March 2010; 6.14 µg/L in July 2010; 5.02 µg/L in April 2011; 5.8 µg/L in July 2011; 5.91 µg/L in October 2011; and 5.76 µg/L in February 2012. Between August 2006 and February 2012, the average concentration of PCE in samples from Well #3 was 4.86 µg/L, with a range of 0.5 µg/L to 6.25 µg/L. After the PCE concentration in Well #3 first exceeded the EPA MCL, quarterly water samples have also been collected from Wells #1. PCE concentrations in samples collected from Well #1 have not exceeded the EPA's MCL.

Figure 1. Tetrachloroethylene (PCE) concentrations (µg/L) in water samples collected from Vienna Public Drinking Water Wells #1 and #3.



PCE concentrations in Vienna public wells have not exceeded ATSDR's reference dose media evaluation guides (RMEGs) for PCE in drinking water. RMEG values for PCE are 210 µg/L for adults and 60 µg/L for children. RMEGs are contaminant concentrations unlikely to pose a non-carcinogenic health risk. Concentrations that exceed RMEGs do not necessarily indicate a health risk is present but that further investigation of exposure risks is warranted. PCE concentrations in public wells have also not exceeded ATSDR's cancer risk evaluation guide (CREG) of 17 µg/L, which is the lowest drinking water comparison value established by ATSDR for PCE. CREGs are contaminant concentrations unlikely to result in increased rates of cancer in adults exposed to those concentrations over a lifetime.

VOCs that are degradation products of PCE (i.e., TCE, DCE, and VC) were not detected in water samples. The VOC dichlorodifluoromethane was periodically detected in concentrations ranging from 1.02 µg/L to 4.2 µg/L in Well #1 and Well #3. These concentrations were well below the RMEGs for dichlorodifluoromethane of 7,000 µg/L for adults and 2,000 µg/L for children. A CREG for dichlorofluoromethane has not been established.

Water Distribution System Samples

On February 23, 2007, water samples were collected by DNR at the Vienna City Hall and WOW Pizza. The intent of this sampling event was to determine if the PCE found in the public drinking water wells was reaching the taps of users. Vienna City Hall was chosen to represent the middle of the distribution system, and WOW Pizza was chosen to represent the end of the distribution system. The water sample collected at Vienna City Hall contained 3.85 µg PCE/L, and the sample collected at WOW Pizza contained 1.40 µg PCE/L. Four days later, on February 27, 2007, PCE concentrations in pre-treated water from Wells 1 and 3 (considered to be the start points of the distribution system) were 3.14 and 3.29 µg/L, respectively. According to comparison of these start and end points, PCE in public water was found to be reaching the taps of users, although possibly in lower concentrations at locations toward the end of the distribution system.

Private Well Water Samples

DNR offered to sample private drinking water wells of interested residents living within a 4-mile radius of the hat factory property. Twenty-three households agreed to have their water tested for VOCs. In April 2007, water samples were collected from these 23 of the 86 private wells in the targeted area. Neither PCE nor its degradation products were detected in any of these samples.

(2)

In November 2011, USGS visited approximately 150 homes and sampled 54 private wells located within a 2-mile radius of the site. Neither PCE nor its breakdown products were detected in water samples collected from 53 of the wells. PCE was detected in water samples collected from one well (MK01), located approximately 200 yards southeast of the former hat factory property, which was drilled to 148 feet and cased to 80 feet below the ground surface (bgs). On the public and private well map included Appendix 1 (Figure 1B), MK01 is located within the inner-most circle which designates a radial distance of 0.25 miles from the factory property.

The initial PCE concentration in well MK01 was 10 µg/L. In December 2011, the well was resampled at various depths, and PCE concentration ranged from 5.68 µg/L at 143 feet bgs to 11.08 µg/L at 84 feet bgs. All PCE concentrations detected in the well exceeded the EPA's MCL for PCE of 5 µg/L. PCE concentrations did not exceed ATSDR's drinking water RMEGs for PCE of 210 µg/L for adults and 60 µg/L for children or ATSDR's drinking water CREG of 17 µg/L. The sample collected at 84 feet also contained a TCE concentration of 0.32 µg/L. This TCE concentration did not exceed ATSDR's drinking water RMEGs for TCE of 18 µg/L for adults and 5 µg/L for children. This TCE concentration also did not exceed ATSDR's CREG of 0.76 µg/L, which is the lowest drinking water comparison value established by ATSDR for TCE. The owner of the well stated that the well water was being used for gardening and that municipal water was being used as a source of drinking water. (6) If fruits and vegetables are grown using the water, these PCE and TCE concentrations in the well water are not cause of concern, as most of the PCE and TCE would be expected to evaporate to air after watering.

Soil Samples

DNR conducted soil sampling in 2007 and 2008 in an attempt to determine PCE source zone(s) on the former hat factory property. Sampling locations were targeted as possible factory waste spill/release points. Samples were collected on April 12, 2007, April 1, 2008, and August 26, 2008, at surface level and at depths up to 18 feet bgs by drilling borings with a track-mounted Geoprobe until there was resistance (assumed to be bedrock) (2). Surface and subsurface soils from 25 total boring locations were screened and/or sampled for VOCs.

As shown below, the maximum PCE concentration in near-surface soil, collected from 0 to 0.5 feet bgs, was 0.00719 mg/kg. Public exposure to soil contaminants occurs primarily as a result of surface soil exposure. This concentration is far below ATSDR's RMEGs for PCE in soil of 300 mg/kg for children and 4,200 mg/kg for adults. This concentration is also well below ATSDR's CREG of 330 mg/kg for PCE in soil.

April 2007

During the April 2007 sampling event, 8 borings were drilled on the former hat company property in locations identified as possible points of PCE release into the ground surface. The full depths of the borings were screened for VOCs with a soil gas probe. Because no VOCs were detected with the probe, soil samples were taken from only two of the borings for laboratory testing for VOCs. Also collected for laboratory analysis was a "background" soil sample from a boring made at the city ball park, located on the western side of Vienna within one-half mile of the factory site. The absence of PCE in the background sample provided additional evidence that the former hat company property is a likely source of PCE detected in the Vienna public drinking water wells. (2)

The soil sample collected just north of the hat factory building in front of the former loading dock (Boring 01; from 10 to 11 feet bgs) was found in laboratory analysis to contain 0.198 mg PCE per kg soil (mg/kg; see Table 1). The sample collected from the former hat factory property northeast of the building (Boring 07; from 11 to 11.5 feet bgs) had no detectable levels of VOCs. (2)

April 2008

On April 1, 2008, a second soil sampling event was conducted on the former hat factory property. Soil samples were collected from 9 borings located primarily on the north side of the building, where PCE was detected in soil during the 2007 soil sampling event. All 9 samples were sent to the laboratory for testing. Of the 9 samples, 6 contained no detectable concentrations of VOCs. The three soil samples found to contain detectable concentrations of PCE were from Boring 11 (6.5 to 7.0 feet bgs), collected near Boring 01 outside the loading dock; Boring 16 (7.5 to 8.0 feet bgs) collected in a grassy field approximately 41 yards northeast of the building; and Boring 17 (12.5 to 13.0 feet bgs) collected immediately west of the building. Estimated concentrations of PCE were 0.00323 mg/kg (Boring 11), 16.3 mg/kg (Boring 16), and

0.0991 mg/kg (Boring 17) (Table 1). Boring 16 was also found to contain an estimated concentration of 0.00454 mg cis-DCE per kg soil collected from 7.5 to 8.0 feet bgs (Table 1). (2)

Boring 16 was drilled at the request of the Vienna water system operator, who believed that this was the location of a waste-water lagoon; however, this was not able to be verified by a 1955 aerial photograph. (2)

**Table 1. Volatile Organic Compound Concentrations in Soil Samples
Former Langenberg Hat Company Property, Vienna, Missouri
April 2007- April 2008**

Boring Number	Boring Depth (feet)	VOC Concentrations (mg/kg)		
		PCE	TCE	DCE
1	10-11	0.198	ND	ND
11	6.5-7.0	0.00323	ND	ND
16	7.5-8.0	16.3	ND	0.00454
17	7.5-8.5	0.0991	ND	ND

ND = not detected

August 2008

Due to the significant concentration of PCE found in Boring 16, additional soil samples were collected on August 26, 2008, from nearby borings. As in 2007, borings were tested at the site for VOCs off-gassing from soil, and samples with the highest VOC detections were selected for laboratory analysis. A total of 10 samples were collected from 8 borings (Borings 19 to 26) from various depths. These included soil samples collected near the surface: between 0 and 0.5 feet from Boring 19 and between 0.5 and 1.0 feet from Boring 20 (2).

Table 2 shows the laboratory results of VOC concentrations in these soil samples. Laboratory results confirmed that there were low concentrations of PCE in samples collected between 0 and 1 foot bgs from Boring 19 and 20. In addition, 4 of the 8 subsurface soil samples (i.e., Boring 19, Boring 22, Boring 23, and Boring 24) contained PCE. Most notably, the soil sample collected from 9.0 to 9.5 feet bgs from Boring 23 contained 65.4 mg PCE per kg soil. TCE and cis-DCE were also present at approximately 9 feet bgs in concentrations up to 1.21 mg/kg (Boring 23) and 0.027 mg/kg (Boring 22), respectively.

**Table 2. Volatile Organic Compound Concentrations in Soil Samples
Former Langenberg Hat Company Property, Vienna, Missouri
August 26, 2008**

Boring Number	Boring Depth (feet)	VOC Concentrations (mg/kg)		
		PCE	TCE	DCE
19 ^a	0.0-0.5	0.00719	ND	ND
	6.5-7.5	2.39	0.588	ND
20	0.5-1.0	0.0141	ND	ND
22	8.5-9.0	0.412	0.598	0.027
23	9.0-9.5	65.4	1.21	0.018
24	12-12.5	0.00574	ND	ND

^aOther VOCs detected in sample 19 at 6.5-7.5 feet below ground surface: 33.1 mg/kg 2-butanone, 53.2 mg/kg acetone, and 3.17 mg/kg tetrahydrofuran
ND = not detected

In January 2012, USGS collected soil samples from a newly-dug, 335-foot-long water line trench on the west side of the hat factory property. Thirty-seven samples were collected from either 1 foot or 3.5 feet below the surface. Neither PCE nor TCE were detected. (6)

Tree Core Samples

Tree core samples were analyzed in an attempt to locate PCE in shallow groundwater and soil (i.e., within approximately 30 feet bgs) on the former hat factory property. DNR collected 19 tree core samples in October 2007 (2) and USGS collected 74 tree core samples in August/September 2011 from on-site trees and shrubs (6).

PCE was not detected in the 2007 samples. However, 3 weeks of heavy rainfall prior to sampling may have allowed the trees and shrubs to take up recent rainwater instead of contaminated groundwater. Additional tree core samples were not collected to confirm these results. (2)

In 2011, PCE was detected in 50 core samples, and TCE was detected in 10 core samples (6). Core samples containing the highest PCE concentrations were collected approximately 30 feet south of the factory building, in an area that previously served as the factory employee parking lot. In 2012, USGS installed monitoring wells on the property, including near the PCE-contaminated trees, to further investigate the extent of contamination in soil and groundwater at the site. That investigation is on-going.

Sewer Samples

In January 2012, USGS collected 26 sewer effluent samples from 21 manholes throughout the city of Vienna to investigate the possibility of other sources of PCE in Vienna (6). Several samples were collected in the vicinity of the hat factory and other establishments identified by Vienna city utilities personnel as possible producers or users of VOCs. PCE was detected in 3 samples from manholes located in southeast Vienna, some distance from the former factory property, in concentrations ranging from 0.5 µg/L to 1.3 µg/L. USGS plans to further investigate the possibility of PCE contamination at those additional locations.

Physical Hazards

Physical hazards were found during the April 2008 hat factory site visit (2). The roof on the eastern portion of the building was failing and allowing water to enter the building. Glass from broken windows was observed in and around the building. Several barrels and old factory equipment remained in the building. During a June 2012 site visit, it was found that much of the building had been demolished, and debris from the demolition had been removed from the property. The remaining portion of the building is dilapidated and continues to store factory materials and antique cars belonging to the current owner of the property. Access to the building site has not been limited and continues to pose potential physical hazards.

DISCUSSION

Pathways Analysis

This section addresses the pathways by which people may be exposed to PCE. Exposure occurs when a potentially toxic substance comes into contact with and enters the body. For the substance to pose a health risk, a completed exposure pathway must exist. ATSDR has determined that an exposure pathway consists of five elements: a source of contamination, transport through an environmental medium, a point of exposure, a route of human exposure, and a receptor population. Completed exposure pathways require that all five elements of exposure exist. An exposure pathway can be eliminated if at least one of the five elements is missing and will never be present. Potential exposure pathways have at least one of the five elements missing or uncertain but that could exist. Completed and potential exposure pathways could have occurred in the past, could be occurring presently, or could occur in the future.

Exposure Pathways

The five elements of an exposure pathway at Vienna are:

1. **Contaminant source** – former hat factory spills

2. **Environmental medium and transport** – water, soil, soil gas, and air
3. **Point of exposure** – drinking water, former hat company property soil, and indoor air
4. **Route of exposure** - ingestion, inhalation, and dermal contact
5. **Receptor population** – local residents, on-site workers, and former factory property trespassers

Completed Exposure Pathways

Completed exposure pathways at the Vienna Wells site are ingestion, inhalation, and dermal (skin) exposure to PCE in public drinking water. Prior to installation of a new water treatment and distribution system in 2012, pre-treated drinking water collected from Well #3 was found to contain PCE concentrations that exceeded EPA's MCL on several occasions. Individuals can be exposed to PCE in the water through the ingestion exposure route by drinking the well water or eating food prepared with the water. Individuals can be exposed to PCE through the inhalation exposure route by breathing in PCE that has volatilized into the air from the water when showering, bathing, washing clothes, running a dishwasher, or other household activities. Individuals can also be exposed to PCE through dermal exposure routes during bathing or showering with the public well water, although ingestion and inhalation are the primary routes of exposure.

Ideally, PCE concentrations in tap water (i.e., water at the point-of-use) should be used to determine the health risks of exposure to PCE in public drinking water. However, only 2 water samples were collected in the Vienna public water service area from a point-of-use faucet for PCE analysis. PCE was detected in both of these water samples, collected at the Vienna City Hall and WOW Pizza. The results of only 2 samples do not provide enough information to estimate the average concentration of PCE in Vienna drinking water following its distribution.

Because point-of-use data are limited, health risks from past exposures were assessed using the average PCE concentration detected in the water collected at Well # 3 following the first exceedance of the MCL. There is no known source of PCE within the public water system; therefore, it is unlikely that the PCE concentrations are increasing as the water travels through the water system.

Installation of a new water treatment and distribution system, designed to remove 98% of VOCs, was completed in 2012. Current and future exposures are, therefore, expected to be significantly lower than past exposures, even if PCE concentrations in the extracted groundwater continue to slowly increase. Even if the PCE concentration in Well #3 rises to 10 µg/L, only 0.2 µg/L (2%) would be expected to remain in the treated municipal water.

Potential Exposure Pathways

Potential exposure pathways at the Vienna Wells site are ingestion, inhalation, and/or dermal (skin) exposure to PCE in private well water, soil on the former hat factory property, and vapors that could intrude into homes and buildings located in close proximity to contaminated groundwater and/or soil gas.

Private Well Water

In November 2011, PCE was detected in a water sample that USGS collected from private well MK01, located approximately 200 yards southeast of the former hat factory. The concentration of PCE in the initial well water sample was 10 µg/L, exceeding EPA's MCL of 5 µg/L. The owner of the well stated that the well water is used for gardening and that municipal water is used as drinking water. A PCE concentration of 10 µg/L is not a high enough to cause concern for eating fruits and vegetables grown using the water, considering that most of the PCE would be expected to evaporate to air after watering. The other 76 private well water samples tested either by USGS in November 2011 or DNR in April 2007 did not contain detectable concentrations of PCE. However, private well water could become contaminated in the future if PCE and/or its chlorinated degradation products migrate with groundwater from the source zone(s). There also may be private wells in the area that have not yet been tested for VOCs.

Soil

When a PCE spill occurs, much of the PCE evaporates into the air (4). The portion of PCE that does not evaporate into the air will quickly migrate through the surface soil and contaminate deeper subsurface soil and groundwater (4). Typically, PCE does not reside at the surface for more than a few days following its release, due to its high volatility and medium to high mobility in soil (4).

In an effort to determine the source and extent of PCE contamination at the Vienna Wells site, a total of 25 soil borings have been completed around the former hat factory building and in the area suspected of being the site of a former waste-water lagoon. PCE was detected in some soil boring samples collected at various depths. The highest concentration of PCE from the 25 targeted locations was 65.4 mg/kg, collected 9.0-9.5 feet bgs near the wooded area east of the factory building. PCE concentrations in soil were lowest near the surface and tended to increase with depth to 9.0-9.5 feet bgs. PCE in samples collected from 0-0.5 feet bgs did not exceed 0.00719 mg/kg, in an area where vegetative cover limits potential exposure to the soil.

Exposure to contaminated soil primarily occurs by ingestion of the soil, either intentionally or unintentionally. Soil on unwashed hands or edible plants can be inadvertently ingested. Children are especially susceptible to inadvertent consumption of surface soils on hands, clinging to objects, or tracking into the home from outdoors. Considering that PCE release at the Vienna Wells site likely occurred several years ago, prior to the sale of the property in 1999, and considering the low residence time of PCE in surface soils, the potential for exposure to PCE in the surface soil is expected to be quite low. Individuals would not be exposed to the higher PCE concentrations, detected 9.0 feet to 9.5 feet bgs, unless they were digging on the property. Based on current property use for private storage, digging on the property and possible exposure to higher concentrations in deeper soils is not expected to occur. Access to the property is not currently restricted, partly because some neighboring residents use roads that cross the property to access their homes.

Vapor Intrusion

In some situations, PCE vapor intrusion into homes and buildings can be quite significant and pose a health risk. Home and buildings are at risk of vapor intrusion if located in close proximity, generally 100 feet or less, to contaminated soil and shallow groundwater (7). At the Vienna Wells site, residential properties border the former hat factory property where PCE was found in some soils. PCE was also detected in tree core samples collected from trees along the south boundary of the factory property and the north boundary of an adjacent residential property. A PCE concentration of 10 µg/L was detected in a 148-foot private well on 1 residential property, located approximately 200 yards southeast of the hat factory.

There is also not enough information to evaluate potential past exposure to PCE vapors inside the hat factory building. PCE concentrations inside the hat factory while it was in operation, either due to the use of PCE as a solvent or due to vapor intrusion, are not known. Since closure of the factory in 1996, the factory building has been vacant and used for storage, and PCE concentrations in indoor air have not been investigated. Currently, much of the building is dilapidated, and it is expected that vapors might accumulate in indoor air in small sections of the building only. It is unlikely that individuals (e.g., workers or trespassers) would remain in those areas for extended periods of time.

In July 2014, EPA performed a vapor intrusion investigation at 17 residences located near the former hat factory property. DHSS is currently evaluating the data from that investigation and preparing a separate public health consultation on vapor intrusion at residences near the Vienna Wells Site.

TOXICOLOGICAL EVALUATION

Tetrachloroethylene (PCE) Comparison Values

The health risks of PCE exposure are evaluated, in part, by comparison to health-based guidelines. Guideline values (or comparison values) are media-specific concentrations developed for evaluating the health risks of exposure to contaminants of concern. Environmental contaminant concentrations above these values do not necessarily indicate that a health risk is present but that further evaluation is warranted.

Comparison values established for exposure to PCE in drinking water and soil include RMEGs. For chronic ingestion exposure to PCE in water, RMEGs are 60 µg/L for children and 210 µg/L for adults. For exposure to PCE in soil, RMEGs are 300 mg/kg for children and 4,200 mg/kg for adults. These values were developed from EPA's oral reference dose (RfD) for lifetime exposure to PCE and are concentrations in drinking water or soil that are unlikely to have a non-carcinogenic, adverse effect on health.

Comparison values established for PCE inhalation exposure include ATSDR's environmental media evaluation guides/minimal risk levels (EMEGs/MRLs) and EPA's reference concentration (RfC). For exposure to PCE in air, EMEGs / MRLs are 1,400 $\mu\text{g}/\text{m}^3$ for acute exposure and 270 $\mu\text{g}/\text{m}^3$ for chronic exposure. The RfC is 40 $\mu\text{g}/\text{m}^3$. These values are PCE concentrations in air unlikely to cause noncarcinogenic, adverse health effects in individuals, including children and other sensitive individuals, exposed over a lifetime.

Comparison values for PCE ingestion exposure also include cancer risk evaluation guides (CREGS). CREGs for PCE exposure by ingestion are 17 $\mu\text{g}/\text{L}$ for drinking water and 300 mg/kg for soil. The CREG for PCE inhalation exposure is 3.8 $\mu\text{g}/\text{m}^3$ in air. These values are PCE concentrations in water or soil unlikely to result in increased cancer rates in adults exposed over a lifetime.

ATSDR has not established guideline values for dermal contact exposure to PCE in water. EPA's regional screening level (RSL) for non-cancer risk of dermal exposure to PCE in tap water is 160 $\mu\text{g}/\text{L}$. The RSL for carcinogenic risk is 56 $\mu\text{g}/\text{L}$.

Non-Carcinogenic Health Risks of Exposure to PCE in Vienna

Ingestion of Public Drinking Water

PCE concentrations in Vienna public well water were compared to drinking water RMEGs to determine if ingestion of the public drinking water poses a non-cancer health risk. The average well water PCE concentration (4.86 $\mu\text{g}/\text{L}$) was below RMEGs developed for adult exposure to PCE (210 $\mu\text{g}/\text{L}$) and child exposure to PCE (60 $\mu\text{g}/\text{L}$). These comparison values represent PCE concentrations unlikely to cause adverse, non-carcinogenic health effects in the general population, including sensitive individuals (8). Therefore, ingestion of the public drinking water in Vienna is not expected to have harmful, non-carcinogenic effects on health.

Inhalation of Evaporated PCE from Public Drinking Water

Calculation of the concentration of PCE in indoor air as a result of the evaporation of PCE during cooking, bathing, and showering with public water is shown in Appendix 4. The average indoor air concentration in Vienna, based on the average PCE concentration in water of 4.86 $\mu\text{g}/\text{L}$, is estimated to be 2.43 $\mu\text{g}/\text{m}^3$. This concentration is well below ATSDR's EMEG/MRL (270 $\mu\text{g}/\text{m}^3$) and EPA's RfC (40 $\mu\text{g}/\text{m}^3$) for chronic inhalation exposure. Exposure to PCE in municipal water by the inhalation pathway is, therefore, not expected to pose adverse, non-carcinogenic risks to health, including the health of children and other sensitive individuals.

Ingestion of Soil

Unless individuals are digging or excavating soil at the former hat factory property, exposure to PCE in soil is expected to occur only as a result of exposure to contaminated surface soil. Potential exposure to surface soil at the former hat factory property is only expected to be

intermittent, if landowners are visiting the property or if individuals are trespassing on the property. Vegetative cover of contaminated surface soil is also expected to limit exposure.

PCE concentrations detected in near-surface soils were well below RMEGs for PCE in soil (300 mg/kg for children and 4,200 mg/kg for adults). RMEGs are concentrations of PCE unlikely to have adverse, non-carcinogenic health effects during a lifetime of daily exposure. Therefore, it is not expected that inadvertent ingestion of surface soil at the former hat factory property will cause adverse health effects.

Potential Total Exposure Risk

To determine if combined exposures to PCE in public water from all complete exposure pathways may pose non-carcinogenic, adverse health risks, total PCE exposure doses were calculated from estimated doses from individual pathways. Pathways included ingestion of public well water, inhalation of PCE vapors as the result of evaporation of PCE from public water into indoor air, and dermal contact exposure to PCE in public water during bathing or showering. Exposure doses are estimates of the amount of contaminant an individual takes in over time. Calculations are shown in Appendix 4.

Table 3. Estimated Vienna Resident Exposure Doses

Exposure Pathway	Vienna Resident Exposure Dose to PCE^a (mg/kg-day)	Comparison Value^b (mg/kg-day)
Water Ingestion (adult)	1.39×10^{-4}	6.0×10^{-3}
Water Ingestion (child)	4.86×10^{-4}	6.0×10^{-3}
Inhalation (adult)	5.21×10^{-4}	5.79×10^{-2}
Inhalation (child)	1.94×10^{-3}	2.16×10^{-1}
Dermal Contact (adult)	1.03×10^{-5}	ND ^c
Dermal Contact (child)	3.49×10^{-5}	ND
Total Exposure (adult)	6.70×10^{-4}	ND
Total Exposure (child)	2.46×10^{-3}	ND

^a Site exposure doses are based on the average PCE concentration in water collected from Well #3 between August 2006 and February 2012 (see calculations in Appendix 4). Dose exposure factors were assigned a value of 1, meaning individuals were assumed to be continuously exposed.

^b Comparison values are exposure doses unlikely to result in non-carcinogenic harm to human health. Inhalation exposure doses are chronic minimal risk levels (MRLs; Appendix 3). Ingestion exposure dose is a chronic oral reference dose for the general population, including children and other sensitive individuals (RfD) (8).

^c ND = not determined

Table 3 (above) shows estimated adult and child exposure doses from PCE ingestion, inhalation, and dermal contact pathways. These calculations were based on the average PCE concentration in samples collected between August 2006 and February 2012, when PCE concentrations were first detected in water at levels above the EPA's MCL. Water ingestion, vapor inhalation, and dermal contact doses were based on the average PCE concentration in drinking water of 4.86 µg/L, which appears to be representative of the concentration to which people may have been exposed during this time period. Estimated exposure doses do not exceed comparison values, which are doses unlikely to result in non-carcinogenic harm to human health.

Table 3 also shows total exposure doses (i.e., the sum of exposure doses from ingestion, inhalation, and dermal pathways). Total exposure dose estimates do not exceed media-specific comparison values. Therefore, exposure to PCE by all suspected pathways is not expected to cause non-carcinogenic, adverse health effects. However, it should be noted that comparison values have not been determined for all pathways. Also, comparison values are media-specific. Contaminant exposures by separate pathways do not necessarily have the same health effects.

Estimated Cancer Risks from Exposure to PCE in Vienna

There have been no definitive studies showing that PCE causes cancer in humans. However, the National Toxicology Program lists PCE as a chemical reasonably anticipated to be a human carcinogen (9). EPA has determined that PCE is likely carcinogenic to humans by all exposure pathways, based on studies that have shown chronic inhalation and ingestion of PCE can cause tumor growth in rats and mice (8).

EPA used the results of animal studies to develop cancer unit risk factors to estimate cancer risk for individuals exposed to PCE. Unit risk factors are typically developed by exposing laboratory animals to very high contaminant doses and assuming that there is a reduction in cancer rate as the dose decreases. Cancer unit risk factors are developed assuming that even the smallest exposure to the chemical will cause a slight increase in the American Cancer Society's estimate of risk. For example, it may be estimated from cancer unit risk factors that contaminant exposure may cause 1 additional cancer case in 1 million people exposed to the contaminant. The true or actual cancer risk posed by exposure to PCE at these low concentrations is not known. Note that the American Cancer Society estimates that slightly less than half of men and slightly more than a third of women in the United States will develop some form of cancer in their lifetime (10).

Cancer risk estimations are typically expressed as a single number. For example, the estimate that 1 additional cancer case may occur in 10,000 people exposed is shown as 1×10^{-4} , and an estimate of 1 additional cancer case in a million people exposed is shown as 1×10^{-6} .

For screening purposes, ATSDR has developed CREGs for drinking water ingestion, soil ingestion, and inhalation that are based on EPA's cancer unit risk factors and a target risk level of 1×10^{-6} . The average PCE concentration of 4.86 µg/L and the maximum concentration of 6.25 µg/L in Vienna's public drinking water are less than the drinking water CREG (17 µg/L). The maximum PCE concentration of 0.00719 mg/kg in surface soil at the hat factory property is less

than the soil CREG (330 mg/kg). The estimated concentration of PCE of 2.43 $\mu\text{g}/\text{m}^3$ in indoor air as a result of PCE evaporation during bathing, showering, and dishwashing is less than the air CREG (3.8 $\mu\text{g}/\text{m}^3$). Increased risks of cancer as a result of drinking water ingestion, inhalation of evaporated PCE, or soil ingestion at the Vienna Wells site are, therefore, not expected to exceed 1 in 1,000,000 people.

Estimated cancer risks associated with exposure to PCE at the Vienna Wells site through water ingestion, dermal absorption, and inhalation pathways are shown in Table 4. Calculations of cancer risks (shown in Appendix 5) demonstrate that a population of 100 million people would have to be exposed to the concentrations of PCE detected in Vienna’s public drinking water for the number of cancer cases to increase. Therefore, PCE exposure among Vienna’s population of less than 700 people is not expected to pose an increased cancer risk.

Table 4. Estimated Cancer Risk from Tetrachloroethylene (PCE) Exposure

Exposure Pathway	Cancer Risk Value^a	Estimated Increase in Cancer Cases
Ingestion (adult)	2.1×10^{-8}	2 per 100 million people
Ingestion (child)	7.3×10^{-8}	7 per 100 million people
Dermal contact (adult)	1.6×10^{-9}	1-2 per 1 billion people
Dermal contact (child)	5.2×10^{-9}	5 per 1 billion people
Inhalation	4.5×10^{-8}	4 – 5 per 100 million people

^a Risk values were determined assuming 5 years of daily ingestion or dermal exposure to 4.86 μg PCE/L water or 5 years of continuous inhalation exposure to PCE volatilized into a closed, unventilated area from water containing 4.86 PCE / L. Five years is the estimated length of time that PCE was present in Well #3 prior to installation of the public drinking water treatment system. Risk values are determined assuming the average lifespan of an exposed population is 70 years.

Children’s and Other Sensitive Populations’ Health Considerations

Children

Because children’s bodies are still developing and because their behaviors are different than adult behaviors, children’s susceptibility and exposure to chemicals in the environment may be different than those of adults. The possible effects of PCE exposure on children’s health are determined by extrapolation of what is observed in adults as a result of occupational exposure. An understanding of the possible effects of PCE exposure on fetal and children’s health has also been acquired from toxicological studies on animals. PCE has been shown in animal studies to be temporarily stored in body fat and to pass through the placenta and contaminate breast milk (4).

Exposure of female rats and mice to very high concentrations of PCE in air (0.1% or approximately 6,780 mg/m³) during pregnancy has been shown to be toxic to unborn pups (4). Changes in behavior have also been seen in the offspring of rats that breathed high concentrations of PCE while they were pregnant (4). Rat pups given PCE orally (5 mg/kg-day) when their brains were still developing were hyperactive as adults (4).

Inhaled doses in animal studies were approximately 10,000,000 times higher than the dose calculated for adults who may have breathed PCE in indoor air in Vienna, based on estimated rates of PCE evaporation during use of the water at home. Ingested doses in animal studies were approximately 2,000 times higher than the multiple-exposure-route dose calculated for children who may have been exposed to PCE found in drinking water wells in Vienna. As discussed in this health assessment, the results of these studies indicate that adverse health effects are unlikely to occur with childhood exposure to the concentration of PCE found in Vienna public drinking water.

Adults

Some adults may have increased sensitivity to high concentrations of PCE. While prolonged occupational exposure to high concentrations of PCE (i.e., approximately 68 mg/m³ to 102 mg/m³ PCE in air for 10 to 20 years) has been linked to some adverse effects on the liver and kidneys, individuals with clinical or subclinical liver or kidney disease may be more sensitive to PCE (4). Alcohol use and smoking may increase an individual's susceptibility to the health effects of PCE (4). Persons with pre-existing nervous system disease may also be more sensitive to the neurological effects of PCE (4). However, as discussed in this health assessment, adverse health effects are not expected to occur in sensitive populations exposed to the concentration of PCE found in Vienna public drinking water.

COMMUNITY HEALTH CONCERNS

EPA held a public meeting in Vienna on March 11, 2010, to announce the proposal to add the Vienna Wells Site to their National Priorities List. During this meeting, citizens expressed concerns about the health risks that may be caused by drinking water that contains PCE, especially risks of cancer and risks to children. Since the public meeting, DHSS has received phone calls from individuals with similar concerns. One individual called with questions about the possibility of a mother passing PCE to a fetus, their child's exposure while breastfeeding, or using the water in baby formula. These and other similar concerns are addressed in the above sections entitled *Estimated Cancer Risks from Exposure to PCE in Vienna and Children's and Other Sensitive Populations' Health Considerations*.

From September 25 through October 27, 2014, the public was invited to review and provide comments on a draft version of this public health assessment. DHSS addresses questions and comments submitted during the public comment period in Appendix 8.

Health Outcome Data

Based on the estimated exposure doses and duration of exposure, as discussed in the Toxicological Evaluation section, adverse health effects are not likely at this site. Furthermore, due to scientific limitations of health studies, a health outcome data evaluation is unlikely to enhance the public health assessment decision-making process in this community. Therefore, analysis of site-related health outcome data is not indicated at this time.

CONCLUSIONS

CONCLUSIONS

DHSS has reached four conclusions in this health assessment:

Conclusion 1 *Public Well Water*

DHSS concludes that ingesting (swallowing), inhaling (breathing), and being in dermal (skin) contact with PCE detected in Vienna public well water between March 1997 and February 2012 is not expected to harm people's health. This conclusion applies to past exposures of one year or longer.

Basis for Decision *Public Well Water*

PCE was first detected in pre-treated water samples collected from Vienna's main public drinking water well (Well #3) in March 1997. In response to the detection of PCE in Well #3, public well water samples have been collected every 3 months (quarterly) for analysis. PCE concentrations from Well #3 exceeded EPA's MCL of 5 µg/L on several occasions between August 2006 and February 2012. Exceeding an MCL does not mean that a health risk is present; rather, exceedance of the MCL requires additional actions be taken, such as public notification, increased sampling, and evaluation by health agencies.

Between August 2006, when PCE concentrations first exceeded the MCL, and February 2012, the average concentration of PCE in Well #3 was 4.86 µg/L. This average concentration is below ATSDR's health-based guidelines for adult and child exposure to PCE in drinking water, as well as ATSDR's cancer risk evaluation guide (CREG) for PCE. These guidelines were developed by ATSDR to identify concentrations of potential human health concern.

Conclusion 2 *Soil*

DHSS concludes that inadvertently ingesting (swallowing), inhaling (breathing), and being in dermal (skin) contact with surface soil located at the hat factory property for a year or longer is not expected to harm people's health. This conclusion applies to present and future exposures.

DHSS does not know past concentrations of PCE in surface soil and, therefore, cannot draw conclusions about the health effects of potential exposure in the past, especially prior to 1997, when the hat factory was operating.

DHSS also cannot conclude whether exposure to PCE in soil below the ground surface may harm people's health. However, based on the current use of the hat factory property, exposure to subsurface soil is not expected.

*Basis for Decision
Soil*

PCE was detected in some soil samples that the Missouri Department of Natural Resources (DNR) collected from 25 borings in areas identified as possible factory waste spill/release points on the former hat factory property. PCE in surface soil that does not evaporate into air will migrate quickly to deeper soils. As expected, PCE concentrations tended to increase with depth on the property. PCE concentrations in soil near the ground surface were well below health-based screening values and, therefore, unlikely to have adverse health effects.

Additional investigation should be conducted prior to any digging or removal of soil on the hat factory property. DHSS recommends that continued efforts are made to characterize the site and locate the area(s) of concentrated (e.g., non-aqueous phase) PCE in subsurface soil.

*Conclusion 3
Private Well Water*

DHSS concludes that ingesting (swallowing), inhaling (breathing), and being in dermal (skin) contact with PCE through the use of private drinking water wells in the Vienna area for a year or longer is not expected to harm people's health. This conclusion applies to past and present exposures to water at private wells that have been tested.

PCE may continue to migrate with groundwater from the source area. As a result, DHSS cannot conclude whether future exposure to PCE in private well water may harm people's health. Continuation of efforts to characterize the extent of groundwater contamination at the site and continued private well water testing, as needed, will allow DHSS to determine the future exposure potential and possible future health effects of PCE in private well water.

*Basis for Decision
Private Well Water*

In April 2007, DNR conducted water sampling of 23 private wells located within a 3-mile radius of the site. These water samples did not contain detectable concentrations of PCE or its chlorinated breakdown products.

In November 2011, the United States Geological Survey (USGS) tested private well water at 54 residences located within a 2-mile radius of the site. Neither PCE nor its breakdown products were detected in water samples from 53 of the wells. A water sample from one private well

(MK01) that is located approximately 200 yards southeast the former hat factory contained PCE. The concentration in that well (10 µg/L) exceeded EPA's MCL for PCE (5 µg/L), but the owner of the well stated that municipal water is used in the home.

Currently, there does not appear to be widespread PCE contamination of private well water in and around Vienna. DHSS recommends that continued efforts are made to locate the source of PCE contamination. Cleanup of groundwater at the site may prevent future migration of PCE and its chlorinated breakdown products that can result in contamination of private wells in and around Vienna. Until the site is remediated, DHSS also recommends continued monitoring of private wells, particularly those located in close proximity to the contaminated area. If PCE or its chlorinated breakdown products are detected at levels of health concern, DHSS recommends that the owners of those wells use an alternative water source until the site can be remediated.

Conclusion 4
Vapor Intrusion

DHSS cannot conclude if past exposure to VOCs as a result of vapor intrusion into the hat factory building may harm people's health. DHSS does not expect that present and future VOC exposure as a result of vapor intrusion into the former factory building will harm people's health.

DHSS is currently in the process of preparing a separate public health consultation to evaluate the results of EPA's recent vapor intrusion investigation at residences located near the former hat factory property.

Basis for Decision
Vapor Intrusion

VOCs in groundwater or soil may evaporate into soil gas that can seep through the foundations of homes or other buildings and build up to levels in indoor air that may pose a health risk.

PCE concentrations inside the factory building between 1952 and 1996, while the factory was in operation, are not known. PCE concentrations in indoor air inside the currently standing sections of the former factory building have not been investigated, as the building is currently dilapidated. It is expected that vapors might only accumulate in a small sections of the building that remain intact, where individuals working or trespassing on the property would not be expected to remain for extended periods of time.

DHSS recommends testing for vapor intrusion at residences located in close proximity to VOC-contaminated areas (i.e., generally within 100 feet of a defined contaminant plume). In July 2014, EPA performed a vapor intrusion investigation at 17 residences located near the former hat factory property. DHSS is currently evaluating the data from that investigation.

<p>Conclusion 5 <i>Physical Hazards</i></p>	<hr/> <p>DHSS concludes that visiting or trespassing on the site may currently pose physical health hazards. DHSS cannot draw a conclusion about physical hazards of visiting or trespassing on the site in the past.</p>
<p>Basis for Decision <i>Physical Hazards</i></p>	<p>The former hat factory building is dilapidated, and sections of the building have been demolished. Currently, access to the site is unrestricted, and visitors or trespassers on the site could have easy access to the building. DHSS does not know when the factory building began posing physical hazards, after operations ceased in 1996. DHSS recommends removal of any physical hazards from the site.</p>

RECOMMENDATIONS

1. DHSS recommends continued quarterly monitoring of public well water, along with regular monitoring of the VOC removal efficiency of the public water treatment system. DHSS recommends that the City of Vienna continues to work with DNR and other agencies and provide well water samples for testing.
2. DHSS recommends that the City of Vienna considers coordinating expansion of the new water treatment and distribution system to meet increased demand for clean water, if the population of the city increases in the future. The City of Vienna coordinated construction of a public drinking water treatment facility designed to significantly reduce VOCs in the public drinking water. The City of Vienna also coordinated the installation of a new water distribution system. These projects were completed in 2012.
3. DHSS recommends that USGS, EPA, and other agencies continue to define currently suspected sources of PCE contamination, identify potential additional sources of PCE, and characterize contaminant plumes in anticipation of cleaning up the site.
4. DHSS recommends continued monitoring of private wells located in close proximity to contaminated areas. If VOCs are detected at levels of health concern, DHSS recommends that the owners of those wells use an alternative water source until the site can be remediated.
5. DHSS recommends that EPA and other agencies investigate potential vapor intrusion into homes or buildings that are found to be in close proximity to VOC-contaminated soil gas and/or groundwater.
6. DHSS recommends that the owner(s) of the former hat factory remove any physical hazards from the site.

PUBLIC HEALTH ACTION PLAN

The Public Health Action Plan (PHAP) for the Vienna Wells Site contains a description of actions to be taken by the Missouri Department of Health and Senior Services (DHSS), the Agency for Toxic Substances and Disease Registry (ATSDR), and other involved parties. The purpose of the PHAP is to ensure that this health assessment not only identifies public health hazards, but provides an action plan to mitigate and prevent adverse human health effects resulting from past, present, and future exposures to hazardous substances at or near the site. Included is a commitment from DHSS to follow up on this plan to ensure that it is implemented.

1. DHSS will coordinate with the City of Vienna, EPA, ATSDR, and USGS to address community health concerns and questions as they arise by providing health professional and community education.
2. DHSS will coordinate with the City of Vienna, EPA, ATSDR, and other agencies to implement the recommendations in this public health assessment.
3. DHSS will review and comment on any additional data from environmental samples collected by EPA, USGS, and other agencies as they become available.

REPORT PREPARATION

This Public Health Assessment for the Vienna Wells site was prepared by the Missouri Department of Health and Senior Services under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved agency methods, policies, procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. ATSDR has reviewed this document and concurs with its findings based on the information presented.

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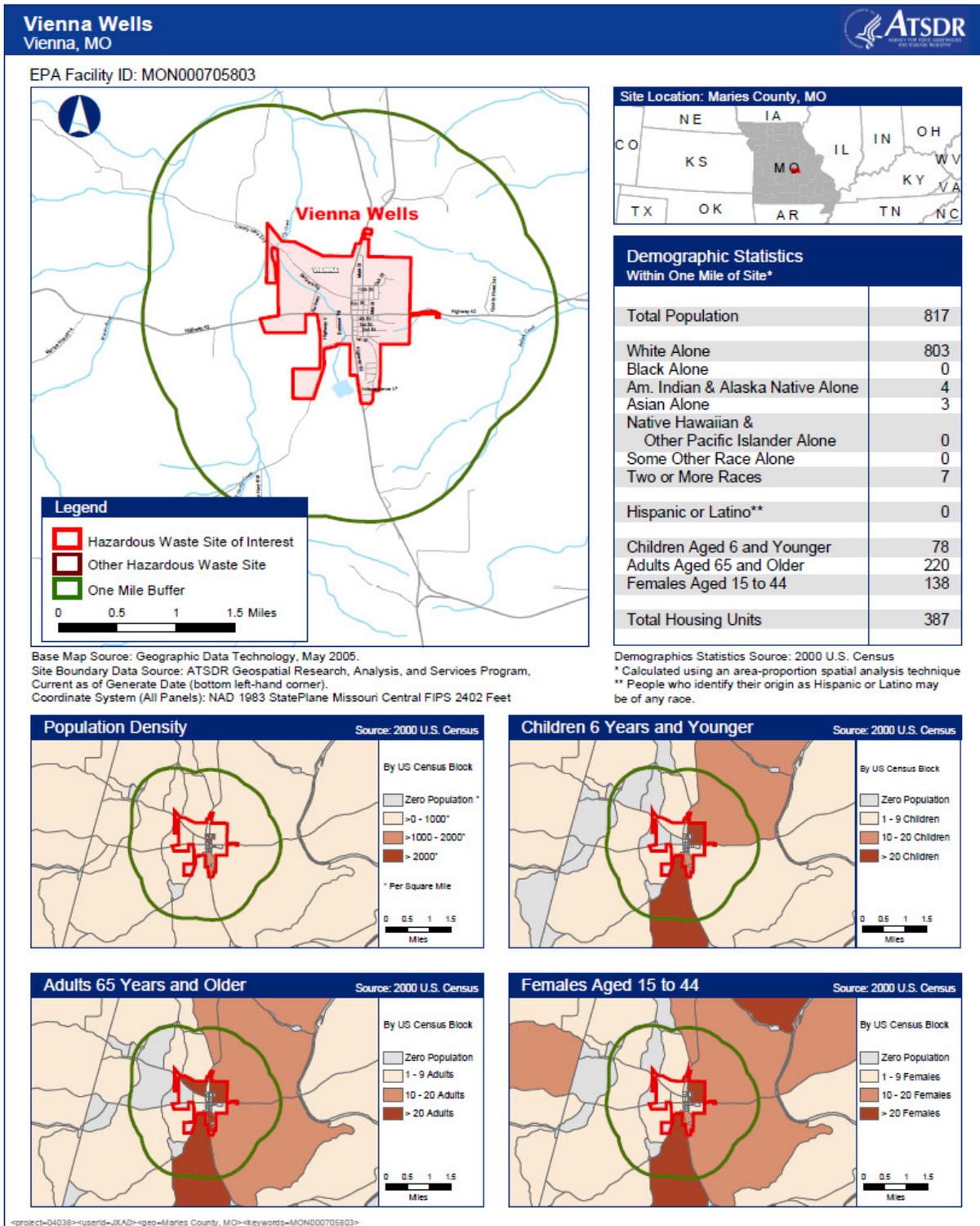
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APPENDICES

- Appendix 1: Maps
- Appendix 2: PCE Concentrations in Public Well Water
- Appendix 3: Minimal Risk Level Calculations
- Appendix 4: Vienna Exposure Calculations
- Appendix 5: Cancer Risk Calculations
- Appendix 6: Exposure Pathways Table
- Appendix 7: Glossary of Terms
- Appendix 8: Response to Comments

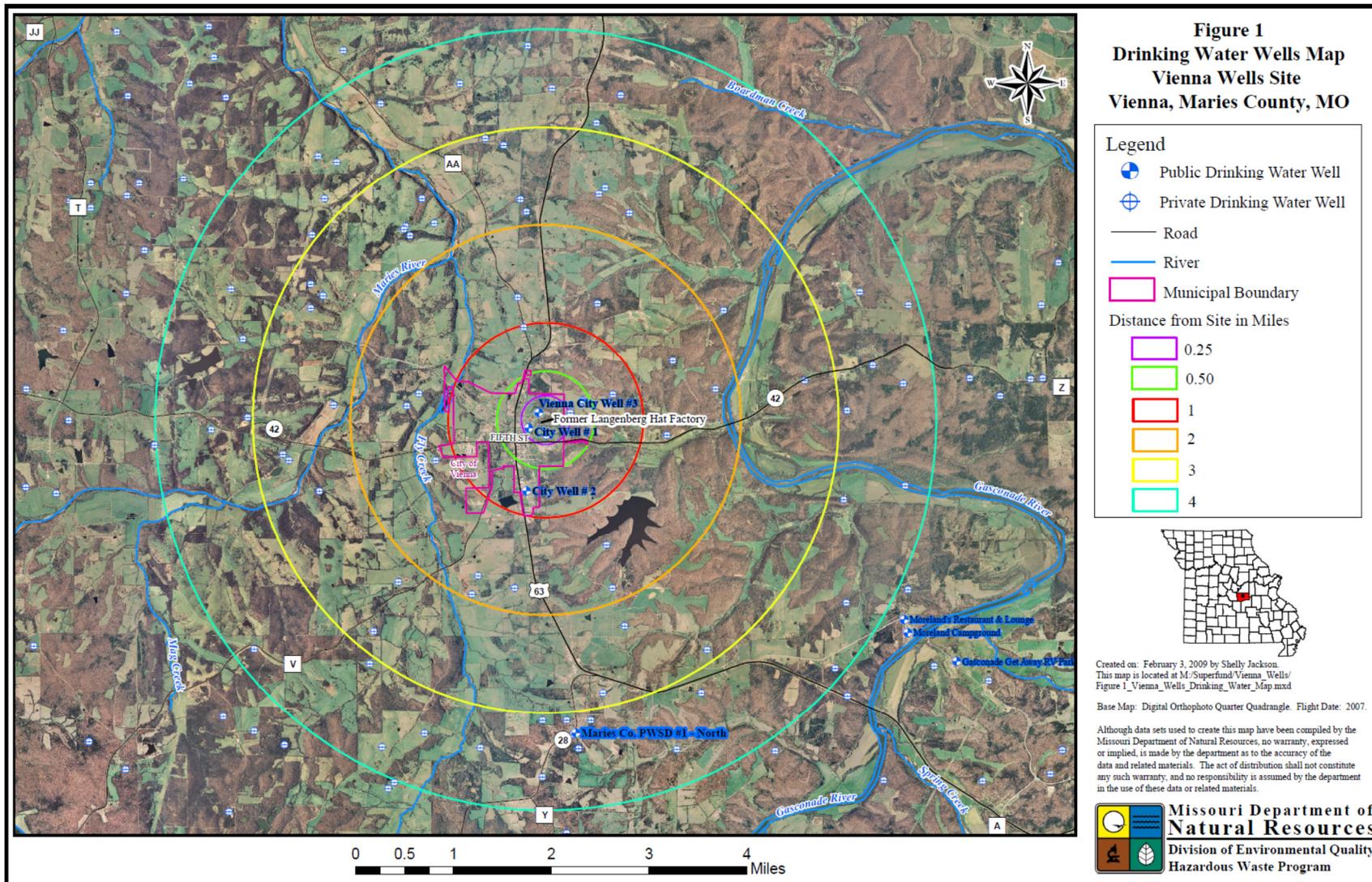
Appendix 1: Maps

Figure 1A. Demographic Statistics of Vienna Wells Site



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Figure 1B: Vienna Area Drinking Water Wells Map



**Figure 1
Drinking Water Wells Map
Vienna Wells Site
Vienna, Maries County, MO**

Legend

- Public Drinking Water Well
- Private Drinking Water Well
- Road
- River
- Municipal Boundary

Distance from Site in Miles

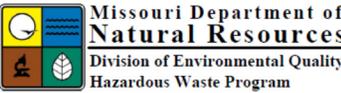
- 0.25
- 0.50
- 1
- 2
- 3
- 4



Created on: February 3, 2009 by Shelly Jackson.
This map is located at M:\Superfund\Vienna_Wells\
Figure 1_Vienna_Wells_Drinking_Water_Map.mxd

Base Map: Digital Orthophoto Quarter Quadrangle. Flight Date: 2007.

Although data sets used to create this map have been compiled by the Missouri Department of Natural Resources, no warranty, expressed or implied, is made by the department as to the accuracy of the data and related materials. The act of distribution shall not constitute any such warranty, and no responsibility is assumed by the department in the use of these data or related materials.



Appendix 2: PCE Concentrations in Public Well Water

Table 2A. PCE Concentrations (µg/L) in Vienna Public Well Water

Well #3				
Year	Winter	Spring	Summer	Fall
1997		0.5		0.7
1998	1.6	0.8	1.3	
1999	1.4	1.6	2.1	2.0
2000	2.4	1.4	2.1	1.9
2001	2.4	2.6	2.1	0.8
2002	1.8	2.0	2.17	1.85
2003	1.83	1.09	2.18	2.82
2004	2.66	2.58	3.06	3.14
2005	0.5	2.92	2.91	3.20
2006	3.46	3.38	5.72	4.66
2007	3.29	3.09	4.47	4.43
2008	4.26	4.52	4.69	6.25
2009	5.53	5.28	5.58	4.19
2010	5.33	4.78	6.14	4.14
2011	4.40	5.12	5.80	5.91
2012	5.76			
Well #1				
2006	3.82	3.76	4.64	4.80
2007	3.14	4.61	4.23	1.14
2008	0.50	0.92	0.50	0.61
2009	0.50	0.50	0.50	0.84
2010	0.50	0.50	0.50	0.83
2011	0.54	0.50	0.50	0.50
2012	1.13			

Appendix 3: Minimal Risk Level Calculations

Chronic Inhalation Minimal Risk Level (MRL)

The ATSDR MRL for chronic inhalation of PCE is currently 270 µg/m³ (0.270 mg/m³). This level is based on results of a study of women who worked in dry cleaning shops and were exposed to an average PCE concentration of 101.7 mg/m³ for approximately 10 years. Studies showed the women had significantly delayed reaction times in neurobehavioral tests. To obtain a chronic inhalation MRL, ATSDR converted this work exposure to a 24 hour per day, 7 day per week residential exposure. ATSDR also divided this exposure by an uncertainty factor of 100 to extrapolate from a lowest-observed-adverse-effects-level (LOAEL) and account for the higher susceptibilities of sensitive populations to toxic compounds.

This section shows the conversion of the MRL for chronic inhalation of PCE to an estimated exposure dose measured in mg PCE per kg body weight per day. This was done to more easily evaluate estimated inhalation exposure doses that could occur in closed, poorly ventilated areas in Vienna as a result of evaporation of PCE while bathing, showering or washing dishes.

Equation:

$$D = (MRL \times IR) / BW$$

Variables	Description	Value	Units
MRL	Inhalation MRL	0.270	mg/m ³
IR _{adult}	Inhalation Rate (adult)	15 ^a	m ³ /day
IR _{child}	Inhalation Rate (child)	8 ^a	m ³ /day
BW _{adult}	Body Weight (adult)	70 ^b	kg
BW _{child}	Body Weight (child)	10 ^b	kg
D_{adult}	Inhalation Dose (adult)	5.79 × 10⁻²	mg/kg-day
D_{child}	Inhalation Dose (child)	2.16 × 10⁻¹	mg/kg-day

^a EPA, Exposure Factor Handbook (ref. 11)

^b ATSDR, Public Health Assessment Guidance Manual, 2005 (ref. 12)

mg/m³ = milligrams per cubic meter

m³/day = cubic meters per day

kg = kilograms

mg/kg-day = milligram per kilogram per day

Adult Inhalation Dose Calculation

$$D_{\text{adult}} = (\text{MRL} \times \text{IR}_{\text{adult}}) / \text{BW}$$

$$D_{\text{adult}} = (0.270 \text{ mg/m}^3 \times 15 \text{ m}^3/\text{day}) / 70 \text{ kg}$$

$$D_{\text{adult}} = 0.0579 \text{ mg/kg-day} = \mathbf{5.79 \times 10^{-2} \text{ mg/kg-day}}$$

Child Inhalation Dose Calculation

$$D_{\text{child}} = (\text{MRL} \times \text{IR}_{\text{child}}) / \text{BW}$$

$$D_{\text{child}} = (0.270 \text{ mg/m}^3 \times 8 \text{ m}^3/\text{day}) / 10 \text{ kg}$$

$$D_{\text{child}} = 0.216 \text{ mg/kg-day} = \mathbf{2.16 \times 10^{-1} \text{ mg/kg-day}}$$

Appendix 4: Vienna Exposure Calculations

Estimated PCE Exposure Doses with Ingestion of Vienna Public Well Water

Equation:

$$D = (C_w \times IR) / BW^a$$

Variables	Description	Value	Units
C_w	Average PCE Concentration in Water	0.00486	mg/L
IR_{adult}	Ingestion Rate (adult) ^a	2	L/day
IR_{child}	Ingestion Rate (child) ^a	1	L/day
BW_{adult}	Body Weight (adult) ^a	70	kg
BW_{child}	Body Weight (child) ^a	10	kg
D_{adult}	Estimated Water Ingestion Dose (adult)	1.39×10^{-4}	mg/kg-day
D_{child}	Estimated Water Ingestion Dose (child)	4.86×10^{-4}	mg/kg-day

^a ATSDR Public Health Assessment Guidance Manual, 2005 (ref. 12)

mg/L = milligrams per Liter

L/day = Liters per day

kg = kilograms

mg/kg-day = milligrams per kilogram per day

Adult Water Ingestion Exposure Dose Calculation

$$D_{adult} = (C_w \times IR_{adult}) / BW$$

$$D_{adult} = (0.00486 \text{ mg/L} \times 2 \text{ L/day}) / 70 \text{ kg}$$

$$D_{adult} = 0.000139 \text{ mg/kg-day} = 1.39 \times 10^{-4} \text{ mg/kg-day}$$

Child Water Ingestion Exposure Dose Calculation

$$D_{child} = (C_w \times IR_{child}) / BW$$

$$D_{child} = (0.00486 \text{ mg/L} \times 1 \text{ L/day}) / 10 \text{ kg}$$

$$D_{child} = 0.000486 \text{ mg/kg-day} = 4.86 \times 10^{-4} \text{ mg/kg-day}$$

Estimated Inhalation Dose of PCE ^a

Equation:

$$D = (C_{\text{air}} \times IR) / BW^b$$

Variables	Description	Value	Units
C_w	Average PCE Concentration in Water	0.00486	mg/L
K	Volatilization constant ^c	0.5	L/m ³
C_{air}	Indoor Air Concentration ($C_w \times K$)	0.00243	mg/m ³
IR_{adult}	Inhalation Rate (adult) ^d	15	m ³ /day
IR_{child}	Inhalation Rate (child) ^d	8	m ³ /day
BW_{adult}	Body Weight (adult) ^b	70	kg
BW_{child}	Body Weight (child) ^b	10	kg
D_{adult}	Estimated Inhalation Dose (adult)	5.21×10^{-4}	mg/kg-day
D_{child}	Estimated Inhalation Dose (child)	1.94×10^{-3}	mg/kg-day

^a Estimated inhalation dose assumes that vapors are released from public water to air in an enclosed space.

^b ATSDR Public Health Assessment Guidance Manual, 2005 (ref. 12)

^c K = volatilization constant; EPA, 1991 (ref. 13)

^d EPA, Exposure Factor Handbook (ref. 11)

mg/L = milligrams per liter

L/m³ = liters per cubic meter

mg/m³ = milligrams per cubic meter

m³/day = cubic meters per day

kg = kilograms

mg/kg-day = milligrams per kilogram per day

Adult Inhalation Exposure Dose Calculation

$$D_{\text{adult}} = (C_{\text{air}} \times IR_{\text{adult}}) / BW$$

$$D_{\text{adult}} = (0.00243 \text{ mg/m}^3 \times 15 \text{ m}^3/\text{day}) / 70 \text{ kg}$$

$$D_{\text{adult}} = 0.000506 \text{ mg/kg-day} = \mathbf{5.21 \times 10^{-4} \text{ mg/kg-day}}$$

Child Inhalation Exposure Dose Calculation

$$D_{\text{child}} = (C_{\text{air}} \times IR_{\text{child}}) / BW$$

$$D_{\text{child}} = (0.00243 \text{ mg/m}^3 \times 8 \text{ m}^3/\text{day}) / 10 \text{ kg}$$

$$D_{\text{child}} = 0.00194 \text{ mg/kg-day} = \mathbf{1.94 \times 10^{-3} \text{ mg/kg-day}}$$

Estimated Dermal PCE Absorption while Bathing with Vienna Public Well Water

Equation:

$$D = (C_w \times P \times SA \times ET \times CF_w) / BW^a$$

Where:

Variables	Description	Value	Units
C_w	Average PCE Concentration in Water	0.00486	mg/L
CF	Conversion Factor	0.001	L/cm ³
P	Dermal Permeability Coefficient for PCE ^b	0.033	cm/hour
ET _{adult}	Exposure Time per Day (adult) ^b	0.25	hours/day
ET _{child}	Exposure Time per Day (child) ^b	0.33	hours/day
SA _{adult}	Body Surface Area (adult) ^b	18,000	cm ²
SA _{child}	Body Surface Area (child) ^b	6,600	cm ²
BW _{adult}	Body Weight (adult) ^a	70	kg
BW _{child}	Body Weight (child) ^a	10	kg
D_{adult}	Estimated Dermal Contact Dose (adult)	1.03 × 10⁻⁵	mg/kg-day
D_{child}	Estimated Dermal Contact Dose (child)	3.49 × 10⁻⁵	mg/kg-day

^a ATSDR Public Health Assessment Guidance Manual, 2005 (ref. 12)

^b U.S. EPA, Risk Assessment Guidance for Superfund, part E (ref. 14)

mg/L = milligrams per liter

L/cm³ = liters per cubic centimeter

cm/hour = centimeters per hour

cm² = square centimeters

kg = kilogram

mg/kg-day = milligram per kilogram per day

Adult Dermal Contact Dose Calculation

$$D_{adult} = (C_w \times P \times SA_{adult} \times ET_{adult} \times CF) / BW$$

$$D_{adult} = (0.00486 \text{ mg/L} \times 0.033 \text{ cm/hour} \times 18,000 \text{ cm}^2 \times 0.25 \text{ hours/day} \times 0.001 \text{ L/cm}^3) / 70 \text{ kg}$$

$$D_{adult} = 0.0000103 \text{ mg/kg-day} = \mathbf{1.03 \times 10^{-5} \text{ mg/kg-day}}$$

Child Dermal Contact Dose Calculation

$$D_{child} = (C_w \times P \times SA_{child} \times ET_{child} \times CF) / BW$$

$$D_{child} = (0.00486 \text{ mg/L} \times 0.033 \text{ cm/hour} \times 6,600 \text{ cm}^2 \times 0.33 \text{ hours/day} \times 0.001 \text{ L/cm}^3) / 10 \text{ kg}$$

$$D_{child} = 0.0000349 \text{ mg/kg-day} = \mathbf{3.49 \times 10^{-5} \text{ mg/kg-day}}$$

Appendix 5: Cancer Risk Calculations

Estimated Cancer Risks from Exposure to PCE at the Vienna Wells Site

Increases in cancer risk from the ingestion, dermal absorption, or inhalation of PCE from the Vienna Wells site were estimated from exposure doses calculated in Appendix 4. Exposure dose calculations were performed assuming Vienna Well water contained 4.86 µg PCE /L (i.e., the average PCE concentration detected in water samples from Vienna Well #3 between August 2006 and February 2012). Cancer risks were estimated assuming individuals were continuously exposed to a PCE concentration of 4.86 µg/L during this time period (i.e., approximately 5 years) and that the lifespan of exposed individuals is 70 years. Risk values were calculated using cancer unit risk factors specific to PCE exposure: a cancer slope factor of 2.1×10^{-3} milligrams per kilogram per day (mg/kg-day)⁻¹ for oral ingestion and an inhalation unit risk of 2.6×10^{-7} µg/m³ for inhalation exposure (10). Risk values from dermal exposure were calculated using a dermal cancer slope factor that is the same as the oral cancer slope factor, assuming that the fraction of PCE absorbed in the intestinal tract is equal to 1 (13).

Public Drinking Water Estimated Cancer Risks:

Formula:

$$\text{Cancer Risk} = \frac{\text{Exposure dose} \times \text{slope factor} \times \text{years of exposure}}{70 \text{ years (lifetime)}}$$

Ingestion Exposure

$$\text{Adult Cancer Risk} = \frac{1.39 \times 10^{-4} \text{ mg/kg-day} \times 2.1 \times 10^{-3} \text{ (mg/kg-day)}^{-1} \times 5 \text{ years}}{70 \text{ years}}$$

$$\text{Estimated Adult Cancer Risk} = 2.1 \times 10^{-8}$$

$$\text{Child Cancer Risk} = \frac{4.86 \times 10^{-4} \text{ mg/kg-day} \times 2.1 \times 10^{-3} \text{ (mg/kg-day)}^{-1} \times 5 \text{ years}}{70 \text{ years}}$$

$$\text{Estimated Child Cancer Risk} = 7.3 \times 10^{-8}$$

Dermal Exposure

$$\text{Adult Cancer Risk} = \frac{1.03 \times 10^{-5} \text{ mg/kg-day} \times 2.1 \times 10^{-3} \text{ (mg/kg-day)}^{-1} \times 5 \text{ years}}{70 \text{ years}}$$

$$\text{Estimated Adult Cancer Risk} = 1.55 \times 10^{-9}$$

$$\text{Child Cancer Risk} = \frac{3.49 \times 10^{-5} \text{ mg/kg-day} \times 2.1 \times 10^{-3} (\text{mg/kg-day})^{-1} \times 5 \text{ years}}{70 \text{ years}}$$

$$\text{Estimated Child Cancer Risk} = 5.24 \times 10^{-9}$$

Inhalation Exposure

$$\text{Cancer Risk} = \frac{2.4 \mu\text{g/m}^3 \times 2.6 \times 10^{-7} (\mu\text{g/m}^3)^{-1} \times 5 \text{ years}}{70 \text{ years}}$$

$$\text{Estimated Cancer Risk} = 4.5 \times 10^{-8}$$

Appendix 6: Exposure Pathways Table

Vienna Wells Site, Vienna, Missouri – Exposure Pathways

Pathway Names	Exposure Pathways Elements						Type of Pathways
	Source	Environmental Media	Point of Exposure	Route of Exposure	Exposed Population	Time	
Drinking water	PCE contaminated groundwater	Municipal Well Water	Homes, businesses, and schools served by Vienna public drinking water	Ingestion, inhalation, dermal contact	Residents served by Vienna public drinking water	Past, present, and future	Completed And Potential
Drinking water	PCE contaminated groundwater	Private Well Water	Homes served with private well water	Ingestion, inhalation, dermal contact	Residents using private drinking water wells	Past, present, and future	Potential
Soil	PCE contaminated soil	Soil	Former hat factory property soil	Ingestion, inhalation, dermal contact	Landowner, trespassers, workers digging on the property	Past, present, and future	Potential
Vapor Intrusion	PCE contaminated shallow groundwater and soil	Soil gas	Indoor air at local homes and businesses	Inhalation	Occupants of buildings near contaminated shallow groundwater	Past, present, and future	Potential

Appendix 7: Glossary of Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency in Atlanta, Georgia, with 10 regional offices in the United States. ATSDR serves the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases from toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (EPA), which is the federal agency that develops and enforces laws to protect the environment and human health. This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. For additional questions or comments, call ATSDR's toll-free telephone number, 1-888-42-ATSDR (1-888-4228737).

Acute

Occurring over a short time [compare with chronic].

Acute exposure

Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with intermediate duration exposure and chronic exposure].

Adverse health effect

A change in body function or cell structure that might lead to disease or health problems.

Cancer

Any one of a group of diseases that occur when cells in the body become abnormal and grow or multiply out of control.

Cancer risk

A theoretical risk for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen

A substance that causes cancer.

Central nervous system

The part of the nervous system that consists of the brain and the spinal cord.

Chronic

Occurring over a long time [compare with acute].

Chronic exposure

Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure]

Comparison value (CV)

Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed exposure pathway

[see exposure pathway].

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)

CERCLA, also known as Superfund, is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by CERCLA, is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances. The Superfund Amendments and Reauthorization Act (SARA) later amended this law.

Concentration

The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

Contaminant

A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Dermal

Referring to the skin. For example, dermal absorption means passing through the skin.

Dermal contact

Contact with (touching) the skin [see route of exposure].

Detection limit

The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Dose

The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An “exposure dose” is how much of a substance is encountered in the environment. An “absorbed dose” is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Environmental media

Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

Epidemiology

The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Exposure

Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].

Exposure pathway

The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Groundwater

Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].

Ingestion

The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

Inhalation

The act of breathing. A hazardous substance can enter the body this way [see route of exposure].

Intermediate duration exposure

Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

Lowest-observed-adverse-effect-level (LOAEL)

The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

Metabolism

The conversion or breakdown of a substance from one form to another by a living organism.

Metabolic byproduct

Any product of metabolism.

Minimal risk level (MRL)

An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see reference dose].

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)

EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis.

Point of exposure

The place where someone can come into contact with a substance present in the environment [see exposure pathway].

Population

A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

Prevention

Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public health assessment (PHA)

An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health.

Reference dose (RfD)

An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Risk

The probability that something will cause injury or harm.

Route of exposure

The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Sample

A portion or piece of a whole. A selected subset of a population or subset of whatever is being studied. For example, in a study of people the sample is a number of people chosen from a larger population [see population]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Sample size

The number of units chosen from a population or an environment.

Source of contamination

The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

Substance

A chemical and/or metal compound or element.

Superfund

[see Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act (SARA)]

Superfund Amendments and Reauthorization Act (SARA)

In 1986, SARA amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

Toxicological profile

An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology

The study of the harmful effects of substances on humans or animals.

Transport mechanism

Environmental media include water, air, soil, and biota (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

Volatile organic compounds (VOCs)

Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Other glossaries and dictionaries:

Environmental Protection Agency (<http://www.epa.gov/OCEPAterms/>)

National Library of Medicine (NIH)
(<http://www.nlm.nih.gov/medlineplus/mplusdictionary.html>)

For more information on the work of ATSDR, please contact: Office of Policy, Planning and Evaluation Agency for Toxic Substances and Disease Registry 1600 Clifton Road, N.E. (Mail Stop F-61) Atlanta, GA 30333 Telephone: (770) 488-0680

Appendix 8: Response to Comments

In this appendix, DHSS addresses questions and comments submitted during the public comment period of the Vienna Wells Public Health Assessment. The public was invited to review the draft document and provide comments from September 25, 2014 through October 27, 2014. The public's comments are summarized below. Correction of typos and minor additions or deletions of text were incorporated in the comments. Each comment is followed by a response from DHSS.

Comment:

There are concerns regarding future contaminants in local private wells and the watershed leading into the Gasconade River. Have any fish or invertebrates from surrounding area been tested?

Response:

In this public health assessment, DHSS recommends that EPA, USGS, and other agencies continue their efforts to define the extent of contamination at the site. Those efforts are ongoing. Although there has been extensive sampling of private wells in the area, DHSS also recommends that EPA and other agencies continue to regularly monitor the water quality in private wells, due to the possibility of migration of the contaminated groundwater plume. If contaminant concentrations are found to be elevated in private wells in the future, and if residents drink the private well water or otherwise use the water indoors, DHSS recommends that those residents change to an alternate water source until the contamination is treated or cleaned up.

EPA is currently in the process of conducting a comprehensive investigation of human health and ecological risks at the Vienna Wells site. This would include potential risks to fish and invertebrates. For more information, please contact Ben Washburn at EPA Region 7 at (913) 551-7364.

Comment:

Because one finding concludes that the deeper soil tests show increases in concentrations of PCE, and because of the physical hazards of the site, I believe the entire site needs to be cleaned and soil decontaminated before the issue will be resolved.

Response:

VOCs that contaminate subsurface soil are gradually released into groundwater and soil gas plumes that may migrate off-site and potentially pose risks to human health. Because of that risk, DHSS agrees that the site needs to be cleaned up. DHSS recommends that EPA and other agencies fully define the extent of contamination at the site. After completion of that investigation, DHSS recommends that the entire site, including contaminated soil, is cleaned up so that the site does not pose any current and future health risks.

Currently, a private individual owns the former Langenberg Hat Company property. For the protection of any workers or trespassers on the property, DHSS recommend in this public health assessment that the owner(s) of the property remove any physical hazards from the premises.

Greetings,

You are receiving a document from the Agency for Toxic Substances and Disease Registry (ATSDR). We are very interested in your opinions about the document you received. We ask that you please take a moment now to complete the following ten question survey. You can access the survey by clicking on the link below.

Completing the survey should take less than 5 minutes of your time. If possible, please provide your responses within the next two weeks. All information that you provide will remain confidential.

The responses to the survey will help ATSDR determine if we are providing useful and meaningful information to you. ATSDR greatly appreciates your assistance as it is vital to our ability to provide optimal public health information.

<https://www.surveymonkey.com/r/ATSDRDocumentSatisfaction>

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