Health Consultation

EVALUATION OF THE VAPOR INTRUSION INVESTIGATION FOR THE

JOHNSON CONTROLS FACILITY

LEXINGTON, HENDERSON COUNTY, TENNESSEE

MAY 2, 2011

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Foreword

This document summarizes an environmental public health investigation performed by the Environmental Epidemiology Program of the State of Tennessee Department of Health. Our work is conducted under a Cooperative Agreement with the federal Agency for Toxic Substances and Disease Registry. In order for the Health Department to answer an environmental public health question, several actions are performed:

Evaluate Exposure: Tennessee health assessors begin by reviewing available information about environmental conditions at a site. We interpret environmental data, review site reports, and talk with environmental officials. Usually, we do not collect our own environmental sampling data. We rely on information provided by the Tennessee Department of Environment and Conservation, U.S. Environmental Protection Agency, and other government agencies, businesses, or the general public. We work to understand how much contamination may be present, where it is located on a site, and how people might be exposed to it. We look for evidence that people may have been exposed to, are being exposed to, or in the future could be exposed to harmful substances.

Evaluate Health Effects: If people have the potential to be exposed to contamination, then health assessors take steps to determine if it could be harmful to human health. We base our health conclusions on exposure pathways, risk assessment, toxicology, cleanup actions, and the scientific literature.

Make Recommendations: Based on our conclusions, we will recommend that any potential health hazard posed by a site be reduced or eliminated. These actions will prevent possible harmful health effects. The role of Environmental Epidemiology in dealing with hazardous waste sites is to be an advisor. Often, our recommendations will be actions items for other agencies. However, if there is an urgent public health hazard, the Tennessee Department of Health can issue a public health advisory warning people of the danger, and will work with other agencies to resolve the problem.

If you have questions or comments about this report, we encourage you to contact us.

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Glossary of Terms

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].

Additive effect: A biologic response to exposure to multiple substances that equals the sum of responses of all the individual substances added together.

Adverse health effect: A change in body function or cell structure that might lead to disease or health problems

Ambient: Surrounding (for example, *ambient* air).

Background level: An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

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.

Chronic exposure: Contact with a substance that occurs over a long time (more than 1 year).

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.

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.

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

EPA: United States Environmental Protection Agency.

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.

Health consultation: A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical.

Inhalation: The act of breathing. A hazardous substance can enter the body this way.

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.

Intermediate duration exposure: Contact with a substance that occurs for more than 14 days and less than a year.

Migration: Moving from one location to another.

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.

No-observed-adverse-effect level (NOAEL): The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

Plume: A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.

Point of exposure: The place where someone can come into contact with a substance present in the environment.

ppb: Parts per billion.

Remediation: 1. Cleanup or other methods used to remove or contain a toxic spill or hazardous materials from a Superfund site; or 2. for the Asbestos Hazard Emergency Response program, abatement methods including evaluation, repair, enclosure, encapsulation, or removal of greater than 3 linear feet or square feet of asbestos-containing materials from a building.

Remedial investigation: The CERCLA process of determining the type and extent of hazardous material contamination at a site.

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.

Soil-Gas: Gaseous elements and compounds in the small spaces between particles of the earth and soil. Such gases can be moved or driven out under pressure.

Solvent: A liquid capable of dissolving or dispersing another substance (for example, acetone or mineral spirits).

Source Area: The location of or the zone of highest soil or groundwater concentrations, or both, of the chemical of concern. The source of contamination is the first part of an exposure pathway.

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.

Volatile organic compounds (VOCs): Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, dichloroethylene, toluene, trichloroethylene, methylene chloride, methyl chloroform, and vinyl chloride.

SUMMARY

INTRODUCTION

The Tennessee Department of Health's (TDH) Environmental Epidemiology Program (EEP) wrote this health consultation at the request of the Tennessee Department of Environment and Conservation (TDEC), Division of Solid and Hazardous Waste Management's (DSWM) State Remediation Program (SRP) in Nashville. This health consultation was prepared to evaluate the results of indoor air and sub-slab soil-gas sampling. Some of the sampling points were located in and beneath the former Johnson Controls facility located at 659 Natchez Trace Drive in Lexington, Henderson County, Tennessee. Manufacturers Industrial Group (MIG) now has operations in the building. Other air sampling points were located in and around homes downgradient from Johnson Controls.

Site investigations have been ongoing for many years. The Johnson Controls plant had releases of degreasing solvents over time. The solvents migrated through soil and into groundwater at the site. Several chemicals documented to have been used at the site were identified in groundwater investigations. The most abundant chemical found was trichloroethylene (TCE). TCE has been indentified in groundwater beneath the site and beneath commercial and residential properties south and southeast of the site. Concentrations of many of the site-related chemicals exceed the U.S. Environmental Protection Agency's tap water screening levels. Because of the potential for TCE vapors to migrate from groundwater into the indoor air of overlying buildings, indoor air testing was completed in the site building itself and 7 private residences downgradient from the site, in the direction of groundwater movement.

All data supplied for this health consultation were compared to residential health comparison values provided by the Agency for Toxic Substances and Disease Registry (ATSDR) and the U.S. Environmental Protection Agency (EPA). Comparison values are chemical concentrations based on toxicology below which no adverse health effects are predicted to occur.

CONCLUSIONS

The EEP reached two conclusions in this health consultation:

Conclusion 1

EEP concludes that the chemical trichloroethylene (TCE), and TCE's breakdown products cis-1,2-dichloroethylene, trans-1,2-dichloroethylene, 1,1-dichloroethylene, and vinyl chloride are not expected to harm the health of the workers of the Manufacturer's Industrial Group (MIG) facility.

Basis for Conclusion

PCE was measured in very small amounts, 0.26 ppb, in the background soil-gas sample. Very small amounts of both PCE and TCE were identified in one soil-gas sample that was collected from the downgradient residential area. The PCE and TCE concentrations were 1.0 and 1.1 ppb, respectively. PCE and TCE were not found above test reporting limits in indoor air.

Next Steps

None recommended.

Conclusion 2

EEP concludes that the chemicals PCE and TCE and TCE's breakdown chemicals will not harm the health of residents in homes downgradient from the MIG facility.

Basis for Conclusion

PCE was measured in very small amounts, 0.26 ppb, in the background soil-gas sample. Very small amounts of PCE and TCE were each identified in one soil-gas sample that was collected from the downgradient residential area. The PCE and TCE concentrations were 1.0 and 1.1 ppb, respectively. PCE and TCE were not found above test reporting limits in indoor air.

Next Steps

It is understood that further investigations are continuing in the residential areas downgradient from the former Johnson Controls site. These investigations are continuing to define the edge of the groundwater contamination. Further indoor air investigations would be prudent in these areas if the groundwater is found to be contaminated.

FOR MORE INFORMATION

If you have any questions or concerns about your health, you should contact your healthcare provider. For more information on this site, call TDEC DSWM at 615-532-0780. For health information, call TDH EEP at 615-741-7247 or toll-free at 1-800-404-3006 during normal business hours. You may also e-mail the TDH EEP at eep.health@tn.gov.

Introduction

Tennessee's Department of Environment and Conservation (TDEC), Division of Solid and Hazardous Waste Management's (DSWM), State Remediation Program (SRP) requested that the Tennessee Department of Health's (TDH), Environmental Epidemiology Program (EEP), review the results of soil-gas, sub-slab soil-gas, indoor air, and ambient (outdoor) air samples collected from and in the vicinity downgradient of the former Johnson Controls Site. All air samples were collected as part of a vapor intrusion investigation.

Through previous environmental investigations, soil and groundwater beneath the site were found to be contaminated by various chemicals, many of which are chlorinated volatile organic compounds (VOCs). Tetrachloroethylene (PCE), trichloroethylene (TCE), and TCE breakdown product chemicals cis-1,2-dichloroethylene (cis-1,2-DCE), trans-1,2-dichloroethylene (trans-1,2-DCE), 1,1-dichloroethylene (1,1-DCE), and vinyl chloride have been found in groundwater beneath the site and beneath a residential area south and southwest (downgradient) from the site. TCE has been the dominant chemical in groundwater both at the site and downgradient from the site. TDEC SRP was concerned about intrusion of TCE vapors coming from the contaminated groundwater beneath the main site building into its indoor air and about TCE vapors migrating into nearby homes coming from the offsite groundwater contaminant plume. The TCE groundwater plume is migrating south and southeast of the former Johnson Controls property. All air samples collected as part of the vapor intrusion investigation (VII) were sampled by the environmental consultant for the responsible party.

This review will specifically evaluate the soil-gas, sub-slab soil-gas, indoor air, and outside air sampling results of the VII. Because the major chemicals found in groundwater were TCE, and TCE's breakdown chemicals, this public health consultation will focus on worker and residential exposure to TCE, and its break down chemicals cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and vinyl chloride, present in soil-gas, indoor air, and outdoor air. The review of the data collected was done to protect the health of those who currently work in the former Johnson Controls building and those who live in residences downgradient from the site.

Background

The former Johnson Controls facility is located at 659 Natchez Trace Drive, Lexington, Tennessee. The site is an approximately 10-acre parcel located in a mixed residential and industrial area in the City of Lexington, Henderson County, Tennessee. The investigated area is comprised of two primary areas; the facility itself (the site) and the residential areas located above the migrating groundwater plume. The former Johnson Controls Site was historically used for the manufacture of automotive parts and components. It continues to be used for this purpose by Manufactures Industrial Group (MIG). Specifically, MIG manufactures powered automobile seat adjustment mechanisms and other components (WESTON 2010). The site (Figure 1) is bordered to the east by a residential area on Natchez Trace Drive; to the south by residential areas on Hamlett Street; to the west by residential properties and vacant wooded lots on Jack Hay Drive; and to the north by an industrial area of Leroy-Somer.

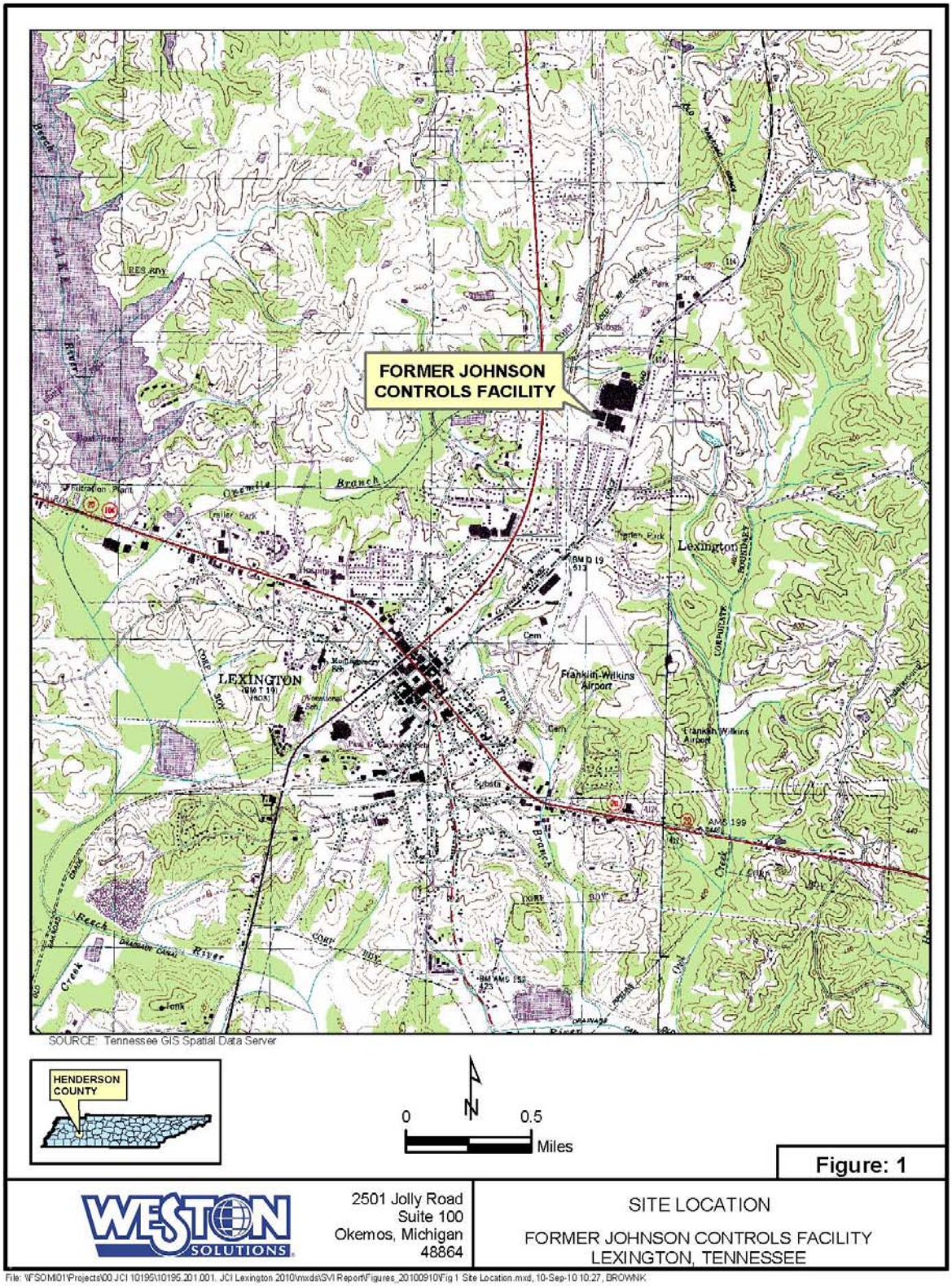


Figure 1. Former Johnson Controls (current MIG) Site location in Lexington, Henderson County, Tennessee. Note locations of residential areas south of the site. (Source: WESTON 2010).

Site History

Manufacturing operations have occurred at the site since at least 1959. The site was built on vacant agricultural land between 1957 and 1959 by Lexington Metal Products. Later the site was operated by Ferro Manufacturing for the manufacture of automotive hardware. Stamping, electro-plating, forming, and assembly were the main operations carried out during this time. Johnson Controls purchased the site in 1985 and sold it in December 2006 (WESTON 2010). Johnson Controls historically used the site for the manufacture of automotive parts and components and MIG continues to use the site for the same purpose. Solvents are no longer used at the site to clean manufactured parts.

Findings of Previous Investigations

Many previous environmental investigations have been conducted. Several investigations have also been carried out downgradient (mainly south) from the site. A groundwater contaminant plume has been found to extend approximately 0.6 miles downgradient from one of the site's buildings (Figure 2).

Background concentrations of TCE in the environment are usually less than 1 ppb. TCE is used mainly as a solvent to remove grease from metal parts, but it is also an ingredient in adhesives, paint removers, and spot removers (ATSDR 1997). At this site, TCE was used as a solvent to remove grease from metal parts. Through releases at the former Johnson Controls facility, TCE migrated into the soil, and eventually groundwater beneath the site. The southerly flow of groundwater carries the dissolved TCE into offsite areas. According to TDEC (Christoper Lagan, personal communication, 2011) the source of the contamination has not been identified. As part of a facility expansion project, a large area of soil was removed but no source for the contamination was identified during the project. An air sparging system is currently in operation in the parking lot of the site.

Groundwater occurs near the site at approximately 45 feet (ft) below the ground surface (bgs), based on water level measurements. Topography near the site slopes to the southeast with elevation changes ranging from approximately 530 ft above mean sea level (MSL) at the site to approximately 485 ft MSL near the southern limits of the plume and 455 ft MSL along the southeastern leading edge of the groundwater contamination. Consequently, the measured depth to water near the southern limits of the contaminant plume is approximately 20 ft bgs and less than 5 ft bgs near the southeastern leading edge of the contaminant plume (WESTON 2010).

Groundwater contaminants of concern at the site include VOCs and petroleum hydrocarbons. Historical groundwater contamination includes the following compounds: 1,1,1-trichloroethane (1,1,1-TCA), 1,1-dichloroethane (1,1-DCA), 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE, PCE, TCE, ethylbenzene, methyl tertiary butyl ether (MTBE), n-propylbenzene, and total xylenes (WESTON 2010).

Remaining soil and groundwater contamination beneath industrial sites can lead to vapor intrusion. Vapor intrusion is the movement of volatile chemicals from the subsurface into overlying buildings. Volatile chemicals in buried wastes and/or contaminated groundwater can emit vapors that migrate through subsurface soils and into the indoor air of overlying buildings.

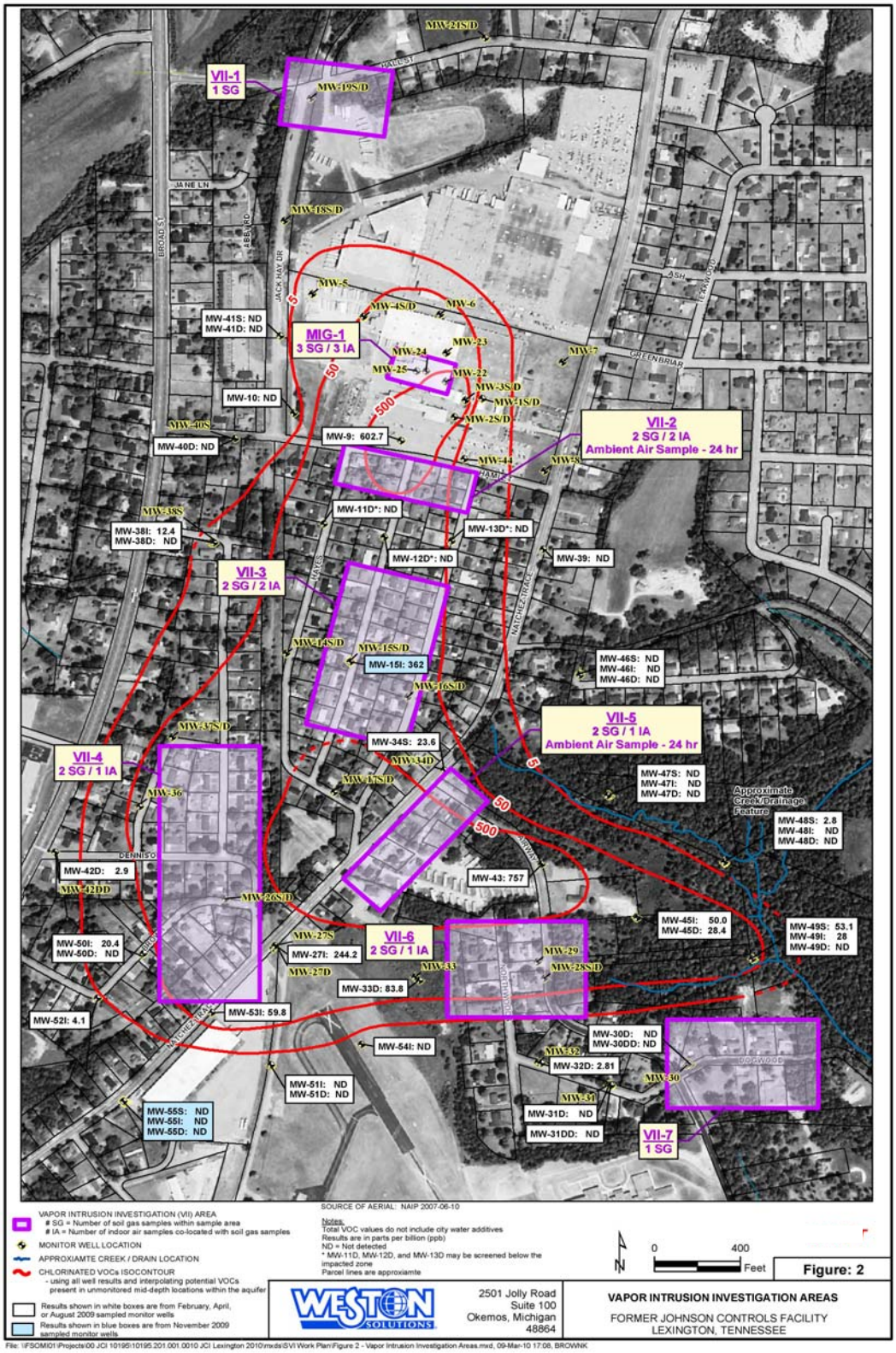


Figure 2. Mapped TCE concentrations in groundwater and groundwater plume extent at site and downgradient from site. Figure also shows the areas where soil-gas and indoor air samples were collected in 2010. (Source: WESTON 2010).

Vapors may accumulate in buildings to levels that pose safety hazards, health risks, or odor problems. Vapor intrusion has been documented in buildings with basement, crawlspace, or slab-on-grade foundation types. Vapor intrusion can be an acute health hazard. Usually, indoor vapor levels are low. Low levels of vapors, breathed over a long period of time, may or may not be a chronic health concern.

TCE is classified as "*reasonably anticipated to be a human carcinogen*" (IARC 1995, NTP 2001). Groundwater concentrations beneath the downgradient residential area were found to range from under 50 to over 500 micrograms per liter (µg/L) as shown in Figure 2. Because of these relatively high groundwater concentrations, both TDEC SRP and TDH EEP were concerned about vapors off-gassing from the groundwater plume. With the large number of homes over the plume, TDEC SRP and TDH EEP agreed that the next logical step in TDEC's site evaluation process should be to investigate if vapor intrusion was occurring in the residential area downgradient of the site.

The community located downgradient of the site and on top of the groundwater contamination is composed mainly of single family homes. Home construction varies; most are wood framed homes sided with aluminum, transite, or brick. There is a small trailer park located south of the site. Lot sizes are typical of a small city. At least one community gathering place, a church, is located in the residential area. There are only a few retail and commercial businesses in the area affected by the groundwater plume.

TDEC requested a vapor intrusion work plan from WESTON for investigation of potential vapor intrusion at the former Johnson Controls site. TDEC DSWM SRP asked TDH EEP to assess the work plan to better understand the sampling approach and to ensure that the proposed plan would provide enough data for TDH EEP to make public health conclusions.

The details of the plan and subsequent sampling activities are discussed in the following paragraphs.

Indoor Air Investigation Work Plan

WESTON submitted a vapor intrusion investigation work plan to both the TDEC SRP and TDH EEP for review. The work plan was very complete and proposed collecting 28 separate samples, including samples of soil-gas from below the MIG building floor, of indoor air inside the MIG building, of soil-gas near homes above the groundwater contaminant plume, of indoor air in homes, and of outside air in the nearby neighborhood.

TDEC SRP and TDH EEP worked together to evaluate the proposed investigation activities. TDH EEP submitted a Technical Assist to ATSDR on March 3, 2010 for the assistance provided to TDEC. Based on comments and feedback from TDEC SRP and TDH EEP, WESTON resubmitted the work plan incorporating proposed changes suggested by the reviewers. The plan as proposed by WESTON was valid as it allowed various types of samples to be collected from several different locations above the groundwater contamination. Samples were collected from areas close to the MIG building, as well as at the known downgradient limit of the groundwater contamination. Sampling locations represented the various areas around the site affected by the site-related groundwater contaminant plume. The work plan was re-evaluated and accepted.

After the work plan was accepted, WESTON obtained access agreements from the MIG facility and downgradient homeowners to collect samples. WESTON also presented the work plan to the Mayor of Lexington, Henderson County, Tennessee and to selected City staff before beginning field activities.

The intent of the vapor intrusion investigation conducted by WESTON was to provide a screening evaluation as to whether or not the inhalation exposure pathway for TCE was complete at the site and in the mainly residential area downgradient from the site. If the inhalation exposure pathway was found to be complete, further evaluation would be done to identify whether it posed a risk to human health.

WESTON collected sub-slab soil-gas, soil-gas, indoor air, and ambient (outdoor) air samples from July 28 to 29. Samples of the indoor air were collected at various locations in a portion of the onsite building and in homes downgradient from the site. A total of three sub-slab soil-gas samples were collected from beneath a portion of the floor in the MIG building in the vicinity of the release. These sub-slab samples were co-located with three indoor air samples collected in the MIG building. Soil-gas samples were collected from one upgradient location and at twelve residential locations downgradient from the site. Indoor air was sampled in seven downgradient residential locations. Ambient air samples were collected at two locations within the residential area.

TDEC DSWM SRP requested that TDH EEP review the air data to determine whether the health of the employees who work in the MIG building or the health of the residents who live in homes above the TCE solvent plume could be affected by chemicals that could be in the indoor air from off-gassing from the groundwater. Current or future workers may not know that there were potential exposure issues at the site from previous TCE solvent use. The residents who live downgradient from the site would likely be unaware of a potential TCE exposure issue.

Discussion

Introduction to Chemical Exposure

To determine whether persons have been or are likely to be exposed to chemicals, TDH EEP evaluates mechanisms that could lead to human exposure. Chemicals released into the environment have the potential to cause harmful health effects. Nevertheless, a release does not always result in exposure. People can only be exposed to a contaminant if they come into contact with it. If no one comes into contact with a contaminant, then no exposure occurs, and thus, no health effects could occur. An exposure pathway contains five parts:

- a source of contamination,
- contaminant transport through an environmental medium,
- a point of exposure,
- a route of human exposure, and
- a receptor population.

An exposure pathway is considered complete if there is evidence that all five of these elements have been, are, or will be present at the site. An exposure pathway is considered incomplete if one of the five elements is missing.
Physical contact alone with a potentially harmful chemical in the environment by itself does not necessarily mean that a person will develop adverse health effects. A chemical's ability to affect one's health is controlled by a number of other factors, including:

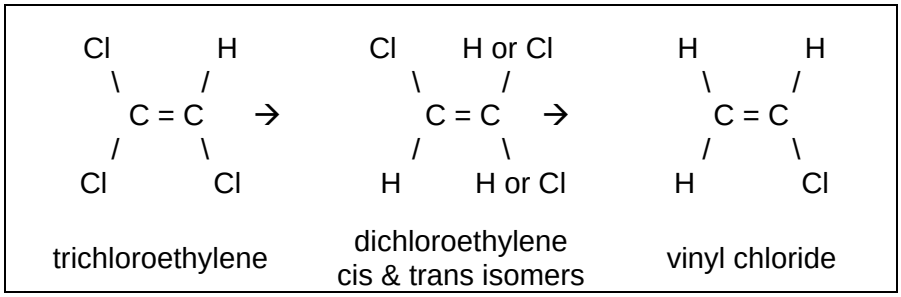
- the amount of the chemical that a person is exposed to (dose),
- the length of time that a person is exposed to the chemical (duration),
- the number of times a person is exposed to the chemical (frequency),
- the person's age and health status, and
- the person's diet and nutritional habits.

For this site, workers in the MIG building and people who live in homes nearby and above the groundwater contaminant plume are the receptor populations.

Solvent Explanation

The historic processes carried out within the former Johnson Controls plant included the use of TCE for degreasing. Minor amounts of PCE were also used but its use was limited. For the evaluation, we will concentrate on TCE. Instead of water, TCE was used as the main solvent to remove grease and other contaminants from the metal parts manufactured at the site. TCE is a colorless liquid that has a sweet smell (ATSDR 1997). TCE will quickly evaporate into a gas at room temperature.

As its name implies, trichloroethylene has three chlorine atoms on a two-carbon molecule. TCE breaks down into other chlorinated volatile organics. Each of these breakdown products has slightly different chemical properties and toxicities. The following diagram is an example of how the chemical TCE can breakdown to form another chemical.



In this example, TCE can break down to DCE, and then to VC. The only way to truly know the ratio of these breakdown products is to collect environmental samples. The TCE degradation products cis-1,2-dichloroethylene (cis-1,2-DCE), trans-1,2-dichloroethylene (trans-1,2-DCE), 1,1-dichlororethylene (1,1-DCE), and vinyl chloride have been noted in groundwater samples collected at the site. The solvent, TCE, and its breakdown products were carefully considered in developing this report.

Comparison Values

To evaluate exposure to a hazardous substance, health assessors often use comparison values. If the chemical concentrations are below the comparison value, then health assessors can be reasonably certain that no adverse health effects will occur in people who are exposed. If concentrations are above the comparison values (ATSDR 2010) for a particular chemical, then further evaluation is needed.

The Agency for Toxic Substances and Disease Registry's (ATSDR) develops minimal risk levels (MRLs) using conservative assumptions. ATSDR uses the term 'conservative' to refer to values that are protective of public health in essentially all situations. Environmental Media Evaluation Guidelines (EMEGs) are calculated by ATSDR from their MRLs. EMEGs consider non-cancer adverse health effects. Exposure durations are defined as acute (14 days or less), intermediate (15–365 days), and chronic (365 days or more) exposures. ATSDR does not use serious health effects, such as irreparable damage to the liver or kidneys, or birth defects, as a basis for establishing EMEGs. Chronic EMEGs assume exposure for 24 hours per day, 7 days per week, 52 weeks, 365 days per year, over a 70-year lifetime exposure. Exposure to a level above the EMEG does not necessarily mean that adverse health effects will occur (ATSDR 2007).

To understand if concentrations of the solvent TCE or its breakdown chemicals could lead to excess cancers, measured concentrations of these chemicals were also compared to ATSDR cancer risk evaluation guides (CREGs). Lifetime exposure to a chemical at a concentration equal to its CREG comparison value could theoretically result in a one in a million risk of developing cancer in addition to the background risk of developing cancer. EPA considers an excess cancer risk between 1 in 10,000 and 1 in 1,000,000 as acceptable (EPA 1991).

EPA's Regional Screening Levels (RSLs) for residential air inhalation were also used in evaluating the results of the testing. Exposure to workers and residents downgradient from the site is involuntary. Workers may not know that there are potential exposure issues in the site building. Solvents are no longer used to clean manufactured parts at the site. Even so, Federal Occupational Safety and Health Administration (OSHA) work place standards were not used because current employees of MIG are not covered under a workplace safety plan. Further, residential values were used because of the involuntary exposure that would be experienced by people living in homes above the groundwater plume that has migrated downgradient from the site.

Breathing small amounts of TCE may cause a variety of short-term health effects including headaches, lung irritation, dizziness, poor coordination, and difficulty concentrating. Breathing it for long periods may cause nerve, kidney, and liver damage.

The cancer risk posed by TCE has been under evaluation for some time within EPA and the health community. Its toxicity class is also under review. ATSDR does not have a published CREG for TCE. However, EPA has a residential setting TCE inhalation regional screening level (RSL) for one excess cancer in 1,000,000 people of 0.22 ppb. The concentrations of TCE for the 10^{-4} to 10^{-6} excess cancer risk considered acceptable are 0.22 to 22 ppb (EPA 2010).

Environmental Sampling

Samples of sub-slab soil-gas, soil-gas, and indoor/outdoor air samples were collected July 28 to 29, 2010. Sampling was conducted inside the MIG building where the release occurred and in six other general locations above the downgradient groundwater plume. These locations are numbered MIG-1 and VII-1 through VII-7. Figure 3 shows the sampling sites within the investigation areas. Sample location numbers with 'SG' are soil-gas samples. Locations having 'SS' in the sample location number show where sub-slab soil-gas samples were collected. Locations with 'IA' in the sample location numbers are where indoor air samples were collected while locations having 'AA' in their identifications are where ambient or outside air samples were collected.

All air samples were shipped via overnight courier in their appropriate containers under chain-of-custody procedures to Air Toxics Ltd., an analytical laboratory specializing in air analysis located in Folsom, California.

The area investigated inside the MIG facility was identified as MIG-1. WESTON collected 3 sub-slab soil vapor samples and 3 indoor air samples from inside the MIG building where historic information and previous soil sample results indicated the possible presence of elevated concentrations of TCE solvent. The samples were collected from areas in the building to represent exposure to MIG workers.

VII-1 is located north and upgradient of the source area and was used as a background sampling location to establish measurements of VOCs in the soil-gas in an area found to be unaffected by groundwater plume migration.

The VII-2 location is in the residential neighborhood immediately south of the former Johnson Controls facility and within the central groundwater plume footprint (immediately south of the potential release areas). VII-2 overlies an area of the groundwater contaminant plume with historical VOC concentrations likely above 500 ppb. Two soil-gas samples were collected from two homes in VII-2 along with two (plus one duplicate) co-located indoor air samples.

VII-3 is also located south of the MIG facility in a residential area. VII-3 overlies the central area of the plume footprint that had TCE concentrations as high as 150 ppb, historically. TCE, cis-1,2-DCE, 1,1-dichloroethane, 1,1-DCE, and xylene were detected in this area during the 2010 groundwater sampling events. TCE concentrations were as high as 72 ppb in 2010 groundwater sampling events. WESTON collected two soil-gas samples and two co-located indoor air samples, one each from two homes in the area.

The area represented by the southwestern leading edge of the groundwater plume is area VII-4. VII-4 is located southwest (downgradient) of VII-3 in an area of residential properties. TCE and cis-1,2-DCE were detected in or adjacent to this area during the 2010 groundwater sampling events. TCE was measured at a high of 59 ppb in groundwater. WESTON collected two soil-gas samples, one each from two homes, and one co-located indoor air sample from one of the homes in area VII-4.

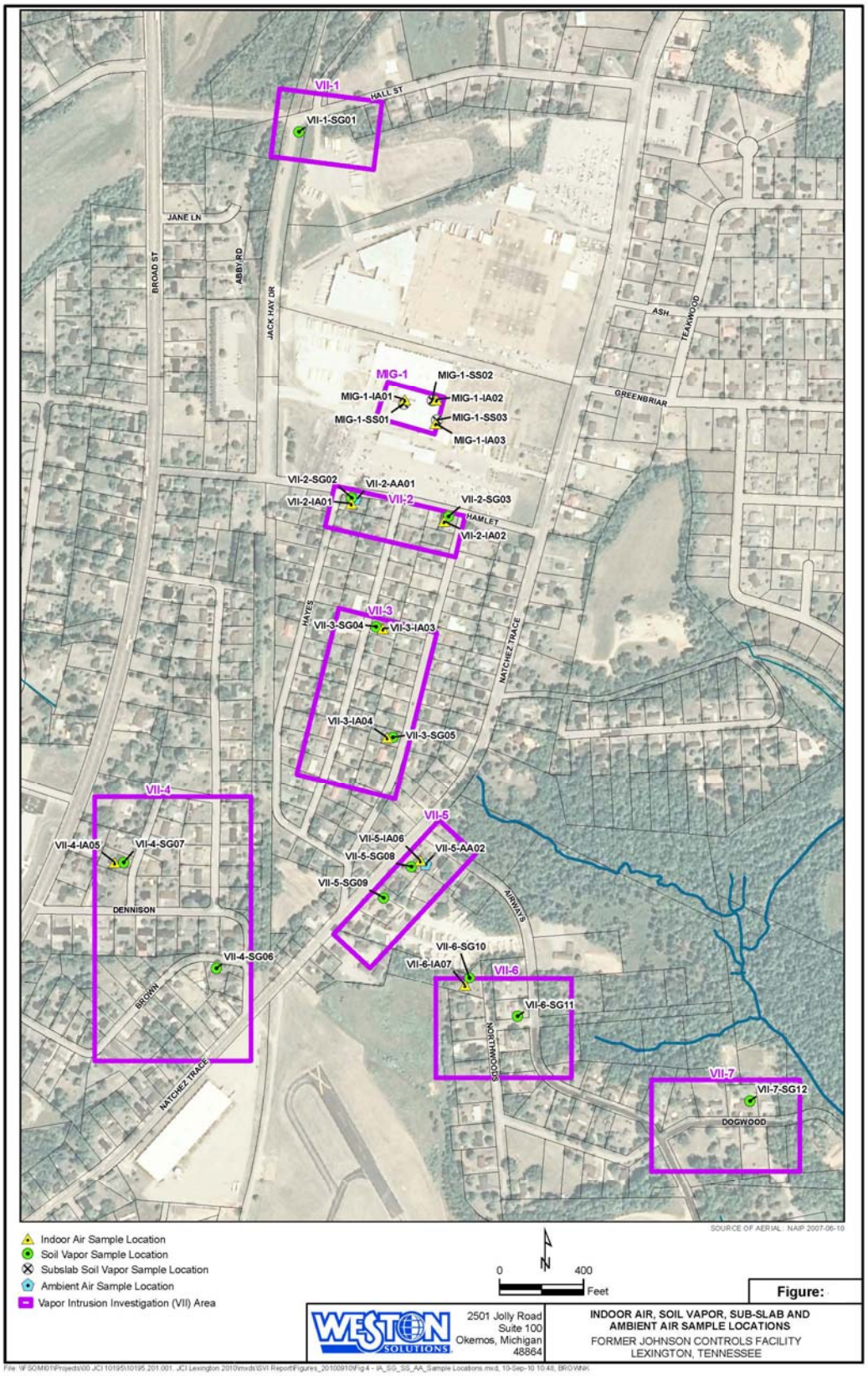


Figure 3. Sub-slab (SS), Soil-gas (SG), indoor air (IA), and outdoor air (AA) sampling locations. (WESTON 2010).

VII-5 is located southeast of VII-3 in a mixed area of residential properties and wooded non-residential properties. TCE and cis-1,2-DCE were detected in this area and in wells immediately upgradient and downgradient during the 2010 groundwater sampling events. The upgradient well to this area had a historical high TCE measurement of 480 ppb and a most recent TCE detection of 92 ppb. WESTON collected two soil-gas samples (with one duplicate sample) and one co-located indoor air sample from one home in area VII-5. WESTON also collected one ambient air sample from this area.

The VII-6 area is located southeast of VII-5 in a mixed area of residential properties and wooded non-residential properties. Based on 2010 groundwater analytical results, VII-6 overlies the downgradient groundwater plume footprint in an area with TCE detections as high as 110 ppb. VII-6 is farther downgradient than VII-5 and is located near the leading edge of the groundwater plume where depths to groundwater are less, approximately 18 ft to 25 ft bgs. This is due to changing topography. WESTON collected two soil-gas samples, one each from two homes in the area, and one co-located indoor air sample from one of the homes.

The area south of the identified leading edge of the groundwater contaminant plume was identified as VII-7. The VII-7 area is located southeast (downgradient) of VII-6 in a mixed area of residential properties and wooded non-residential properties. Similar to VII-6, the groundwater table is shallower than the upgradient VII areas (between 7.5 ft and 25 ft bgs), suggesting that vapors from the groundwater plume would require less distance to migrate to the ground surface. No detections of TCE have been found in the wells in this area (wells 30D and 30DD) in 2009. Samples collected in this area would be a worst-case demonstration of the ability for vapor intrusion to occur downgradient of the site. WESTON collected one soil-gas sample from the VII-7 area on the plume side (north side) of the selected residential property to assess the potential for vapors from the plume to migrate toward homes in this area.

All soil-gas, indoor air, and outdoor air samples collected were tested for the entire TO-15 laboratory list of chemicals. A listing of these chemicals is in the Appendix.

Results

Based on an extensive groundwater investigation, the primary chemical found was TCE. Minor amounts of PCE, and the TCE breakdown chemicals cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and vinyl chloride, were also found.

TCE was measured in very low amounts in outdoor air. No other site-related chemicals were measured in the two outdoor air samples collected. Neither TCE nor its related breakdown chemicals were identified in any of the indoor air samples collected.

TCE was detected in each of the three sub-slab samples collected from below the concrete slab floor of the MIG facility (MIG-1 area), the ambient air sample collected from area VII-2 just south of the site property line, and the soil-gas sample collected from area VII-7. All other soil-gas samples had concentrations of TCE below the laboratory reporting limit.

Outdoor Air

The ambient (outdoor) air sample collected from the VII-2 area contained 10 VOCs that were measured above laboratory detection limits. These VOCs included acetone, bromomethane, carbon disulfide, chloromethane, dichlorodifluoromethane, ethanol, 2-butanone (MEK), toluene, TCE, and trichlorofluoromethane. TCE was measured at a concentration of 0.33 ppb. Seven of the VOCs found in the VII-2 outdoor air sample were also present above laboratory detection limits in the outdoor air sample collected from the VII-5 area. These include acetone, chloromethane, dichlorodifluoromethane, ethanol, MEK, toluene, and trichlorofluoromethane. The results from the outdoor air samples were not compared to any regulatory concentrations or comparison values and were only used as reference information for background/ambient conditions.

Soil-Gas

Only one of 12 soil-gas samples collected from areas other than below the floor of the former Johnson Controls building had measureable amounts of TCE. In this investigation, TCE sub-slab soil-gas measurements from area MIG-1 ranged from 160 parts per billion (ppb) to 22,000 ppb. All other site-related compounds were not present in the three samples above their method detection limits. Reporting limits ranged from 0.48 ppb to 31 ppb. Reporting limits were elevated in two of the sub-slab samples because of the high amounts of TCE present.

The TCE measurement in the one soil-gas sample collected from area VII-7, where the depth to groundwater is the shallowest, was 1.1 ppb. All other samples collected in this investigation area were non-detect. Reporting limits for the non-detect samples ranged from 0.14 to 1.2 ppb.

A total of 38 other VOCs were detected above laboratory detection limits in soil-gas samples and four VOCs, bromodichloromethane, 1,3-butadiene, chloroform, and naphthalene, were detected above the U.S. Environmental Protection Agency (EPA) Office of Solid Waste and Emergency Response (OSWER) Vapor Intrusion Guidance document screening level of 100 times the indoor air screening level. The concentration of a compound at 100 times the EPA indoor air screening level indicates the possibility that the compound identified in soil-gas may be present in indoor air from vapor intrusion.

There were 31 VOCs present above laboratory reporting limits in the background soil-gas sample collected from the VII-1 area. Only naphthalene was detected above the OSWER screening level of 100 times the U.S. EPA indoor air screening level in this soil-gas sample.

Indoor Air

Neither TCE nor its related breakdown chemicals that were found in groundwater at the site were identified in any of the indoor air samples collected. Reporting limits for the analyses were very low and ranged from 0.16 to 0.34 ppb.

Although the site chemicals of concern were not reported in the indoor air samples, 31 other VOCs were detected above laboratory reporting limits in the indoor air of homes sampled. Ten of the VOCs were detected above their respective ATSDR or U.S. EPA screening levels for

indoor air in 6 of the 7 samples collected. These VOCs included benzene, 1,3-butadiene, chloroform, 1,4-dichlorobenzene., 1,2-dichloroethane, 1,4-dioxane, ethylbenzene, methylene chloride, naphthalene, and 1,2,4-trimethylbenzene. However, none of these VOCs were associated with the TCE groundwater plume being investigated. Instead, these 10 VOCs are attributed to sources other than the groundwater plume (WESTON 2010).

Several possible sources for the indoor air contaminants were identified and documented on the pre-sampling indoor air building survey forms prepared by WESTON. The following possible sources were identified at one or more of the residences:

- kerosene or fuel oil
- gasoline storage cans in attached garage or carport
- gas powered equipment in attached garage or carport
- paints/thinners/strippers
- cleaning solvents
- house cleaning products
- polishes/waxes
- air freshener(s)
- candles

Health Risk Evaluation

The evaluation of the health risk at the site and in homes downgradient from the site will only consider major chemicals of concern that have been confirmed to be present in groundwater. These chemicals include TCE, and the TCE breakdown chemicals cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and vinyl chloride. The evaluation is organized by locations of samples; soil-gas and indoor air samples collected at the former Johnson Controls site, and those samples collected in and around homes downgradient from the site.

Ambient Outdoor Air

Outdoor air in the area of the homes was tested to gain a better understanding of the levels of site-related and other chemicals that occur in the area of the site. Test results are shown in Table 1. One site-related chemical, TCE, was found in the outdoor air sample collected in the residential area immediately south of the Johnson Controls site. All other site-related chemicals were below their respective reporting limits. The source of the TCE in outdoor air in this area is not known. No site-related chemicals were measured in the second outdoor air sample collected, farther south, in VII-5, from the site. Outdoor air measurements were compared to background measurements collected by EPA as reference.

Soil-Gas

Sub-slab soil-gas samples were collected from three locations inside the MIG building above the source area of the contamination. Table 2 shows the results of these samples. Site-related chemicals detected below the concrete floor of the building included cis-1,2-DCE, and TCE (Table 2). Cis-1,2-DCE was measured in concentrations from 13 to 600 ppb in the three samples. TCE measurements ranged from 160 to 22,000 ppb. Health comparison values have

TABLE 1. Outdoor air sampling results for the former Johnson Controls (MIG) building, Lexington, Henderson County, TN. Samples were collected on July 29, 2010, over 8 hours with Summa canisters (S&ME 2010). Locations of samples are shown on Figure 3. Values reported in parts per billion (ppb). Background chemical measurements are from various sources and are in ppb.

Chemical / Sampling Data and Location Name	Acronym	VII-2-AA01	VII-5-AA02	Measured United States Background Levels
tetrachloroethylene	PCE	<0.17*	<0.19*	0.1[1]
trichloroethylene	TCE	0.33	<0.19	0.17[2]
1,1-dichloroethylene	1,1-DCE	<0.17	<0.19	131[2]
cis-1,2-dichloroethylene	cis-1,2-DCE	<0.17	<0.19	0.67[2]
trans-1,2-dichloroethylene	trans-1,2-DCE	<0.17	<0.19	0.93[2]
vinyl chloride	VC	0.17*	<0.19*	<0.008[3]

Notes:

Reporting Limit = Limits that can be greater than or equal to the method detection limit for the analysis.

<0.17 = Not detected in the air sample. Concentration represents the analytical reporting limit.

<0.17* = Reporting limit was greater than one or more comparison values.

0.33 = Detection of chemical in outdoor air.

[1] = EPA Region 9 Ambient Air background values (EPA 2004).

[2] = Some emission and exposure data for trichloroethylene and related chemicals EPA National Center for Environmental Assessment, Office of Research and Development, Washington, D.C. March 2001.

[3] = Background concentrations of 18 air toxics for North America, J. of Air and Waste Mgmt. Assoc. 2006. 56: 3-11

not been developed for soil-gas measurements. Target levels for indoor air based on soil-gas results have been developed, however.

One of the sub-slab TCE measurements was especially high. The measurements of TCE in the 3 sub-slab samples were 160, 3,500, and of 22,000 ppb. An evaluation using EPA's screening level Johnson & Ettinger model to simulate indoor air results was performed on the sub-slab TCE measurements. The 22,000 ppb TCE value was used as a worst case value. The model simulation was run using reference porosity, subsurface foundation area, crack ratio, and other attenuation values. Values such as depth of sampling, soil temperature, and an averaged TCE sub-slab measurement were reported values. The simulation was run for a worker who worked 250 days per year for 20 years inside the building. The model simulation resulted in an excess cancer risk of 2.8×10^{-3} or about 3 excess cancers above background in 10,000 people. This excess cancer risk is considered unacceptable by EPA. Further evaluation of the TCE measurements follows below.

EPA's *OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)* (2002) suggests all 3 TCE measurements exceed the generic target shallow soil-gas concentration corresponding to a target indoor air concentration of 0.41 ppb. This generic target concentration is for a soil-gas to indoor air attenuation factor of 0.1, for one excess cancer in 100,000 people (10^{-5} risk). Therefore, EPA

TABLE 2. Former Johnson Controls (MIG) building, Lexington, Henderson County, TN sub-slab soil-gas sampling results. Samples were collected on July 29, 2010, over approximately 1 to 3 hours with Summa canisters (WESTON 2010). Locations of samples are shown on Figure 3. Values reported in parts per billion (ppb). Regulatory comparison values are EPA shallow soil-gas target values with an attenuation factor of 0.1 and 10 times the EPA industrial indoor air values.

Chemical / Sampling Data and Location Name	Acronym	MIG-1-SS01	MIG-1-SS02	MIG-1-SS03	EPA OSWER Shallow Soil-Gas Target Levels Attenuation Factor = 0.1		EPA Industrial Indoor Air RSLs at 10^{-5} risk (ppb)
					(10^{-5} excess cancer risk) (ppb)	(10^{-4} excess cancer risk) (ppb)	
Tetrachloroethylene	PCE	<0.48	<7.4	<31	12	120	3.1
Trichloroethylene	TCE	**160**	**3,500**	**22,000**	0.41	4.1	11.4
1,1-dichloroethylene	1,1-DCE	<0.48	<7.4	<31	500	500	nc
cis-1,2-dichloroethylene	cis-1,2-DCE	13	**120**	**600**	88	88	nc
trans-1,2-dichloroethylene	trans-1,2-DCE	<0.48	<7.4	<31	180	180	nc
vinyl chloride	VC	0.48	<7.4	<31	11	110	11

Notes:

<0.48 = Reporting limit which can be greater than or equal to the method detection limit for the analysis.

EPA OSWER = Environmental Protection Agency Office of Solid Waste and Emergency Response Shallow Soil-Gas Target Levels (EPA 2002).

EPA Industrial Indoor Air RSLs = Environmental Protection Agency Regional Screening Level (EPA 2010). The screening levels were developed using risk assessment guidance from the EPA Superfund Program. They are risk-based concentrations derived from standardized equations combining exposure information assumptions with EPA toxicity data. RSLs are considered by EPA to be protective for humans (including sensitive groups) over a lifetime.

Modifiers:

U = Not detected in the air sample. Concentration represents the analytical reporting limit.

160 = Concentration measured exceeds one or more regulatory guidance values.

nc = Not classified as to carcinogenicity and no guidance value is available

recommends further evaluation of the target concentration. Further evaluation could include assessing groundwater or indoor air concentrations. To further assess the soil-gas results at the site, three indoor air samples were co-located with the individual sub-slab soil-gas samples. A discussion of the results of the indoor air sampling follows below.

Building Indoor Air — Non-Cancer Evaluation

To better evaluate the adverse health effects site-related chemicals may have on workers within the MIG building, indoor air was evaluated along with the sub-slab soil-gas. Indoor air results did not show detections of site-related chemicals (Table 3). The test reporting limits for the 3 samples were low, at 0.16 ppb or 0.17 ppb. The TCE, PCE, cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and vinyl chloride reporting limit concentrations were compared to their respective non-cancer indoor air health comparison values published by the ATSDR (2010) and EPA (2010). This comparison was done as a worst case scenario evaluation. Reporting limits were compared to the PCE EMEG of 40 ppb. In the case of TCE, there is not a published ATSDR EMEG. Therefore, the reporting limit for TCE was compared to its EPA provisional comparison value of 7.4 ppb (EPA 2001).

The reporting limit concentrations of 0.16 or 0.17 ppb in the 3 samples were well below ATSDR's non-cancer effects EMEG comparison value of 40 ppb for chronic (greater than 365 days) exposure for PCE. PCE was not detected in outdoor air above the reporting limit of 0.17 ppb.

The highest TCE reporting limit concentration was 0.17 ppb. This reporting limit concentration was well below the EPA provisional comparison value of 7.4 ppb (EPA 2001). Additionally, the highest TCE reporting limit was below the 0.33 ppb background outdoor air TCE measurement. There is no evidence of vapor intrusion from TCE vapors in the sub-slab materials below the building floor migrating upwards into the indoor air of the building.

The worst case evaluation using the reporting limit concentrations of both PCE and TCE in indoor air were below their non-cancer health effects EMEGs. The workers should not experience non-cancer health effects from breathing the indoor air of the MIG building.

None of the other TCE breakdown chemicals including 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride, were present above their reporting limits of 0.16 or 0.17 ppb. Because of the age of the release at the site, and the concentration in the sub-slab soil-gas, EEP expected to see higher concentrations of these chemicals in the indoor air. Those chemicals detected below the reporting limits will not create an unhealthy indoor air environment and will not lead to any non-cancer health effects from breathing indoor air possibly containing trace amounts of these chemicals.

Building Indoor Air — Cancer Evaluation

Indoor air results from inside the MIG building did not show detections of site-related chemicals (Table 3). The test reporting limits were low, at either 0.16 ppb or 0.17 ppb. The TCE, PCE, cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and vinyl chloride reporting limit concentrations were compared to their respective cancer indoor air health comparison values published by the ATSDR (ATSDR 2010) or EPA (2010).

TABLE 3. Former Johnson Controls (MIG) building, Lexington, Henderson County, TN indoor air sampling results. Samples were collected on July 29, 2010, over 8 hours with Summa canisters (S&ME 2010). Locations of samples are shown on Figure 3. Values reported in parts per billion (ppb). Where the chemical was not detected, the result is reported as being less than (<) the reporting limit Health comparison values used are non-cancer chronic environmental media evaluation guides (ATSDR 2010), ATSDR cancer risk evaluation guides (ATSDR 2010), and EPA residential indoor air Regional Screening Levels (EPA 2010).

Chemical / Sampling Data and Location Name	Acronym	MIG-1-IA01	MIG-1-IA02	MIG-1-IA03	ATSDR EMEG (non-cancer) (ppb)	ATSDR CREG (10^{-6} excess cancer risk) (ppb)	EPA RSL	
							(10^{-6} excess cancer risk) (ppb)	(10^{-4} excess cancer risk) (ppb)
tetrachloroethylene	PCE	<0.16*	<0.17*	<0.17*	40	ngv	0.06	6
trichloroethylene	TCE	<0.16	<0.17	<0.17	7.4[EPA]	ngv	0.22	22
1,1-dichloroethylene	1,1-DCE	<0.16	<0.17	<0.17	20i	nc	ngv	ngv
cis-1,2-dichloroethylene	cis-1,2-DCE	<0.16	<0.17	<0.17	ngv	nc	nc	nc
trans-1,2-dichloroethylene	trans-1,2-DCE	<0.16	<0.17	<0.17	200i	nc	nc	nc
vinyl chloride	VC	<0.16*	<0.17*	<0.17*	30i	0.04	0.06	6

Notes:

Reporting Limit = Limits that can be greater than or equal to the method detection limit for the analysis.

ATSDR EMEG = Agency for Toxic Substances and Disease Registry Environmental Media Evaluation Guide (ATSDR 2010). Chronic non-cancer exposure comparison values (exposure greater than 365 days) used to determine if chemical concentrations warrant further health-based screening.

ATSDR CREG = Agency for Toxic Substances and Disease Registry Cancer Risk Evaluation Guide (ATSDR 2010). Cancer risk comparison values for cancer risk of 1 excess cancer in 1,000,000 people used to determine if chemical concentrations warrant further health-based screening.

EPA RSL = Environmental Protection Agency Regional Screening Level (EPA 2010). The screening levels were developed using risk assessment guidance from the EPA Superfund Program. They are risk-based concentrations derived from standardized equations combining exposure information assumptions with EPA toxicity data. RSLs are considered by EPA to be protective for humans (including sensitive groups) over a lifetime.

Modifiers:

U = Not detected in the air sample. Concentration represents the analytical reporting limit.

* = Reporting limit was greater than one or more comparison values.

EPA = There is not a published EMEG for TCE. The results were compared to the EPA's most current evaluation of the potential health risks from exposure to TCE at 7.4 ppb (EPA 2001).

i = ATSDR comparison value for intermediate exposures (15-365 days); typically higher than a chronic value

nc = Not classified as to carcinogenicity and no guidance value is available

ngv = No guidance value available

The reporting limits comparison was done as a worst case scenario evaluation. Reporting limits were compared to the PCE one excess cancer in 100,000 people EPA RSL risk comparison value of 0.6 ppb (10^{-5} risk). The highest reporting limit value of 0.17 ppb was much less than 0.6 ppb, the EPA 10^{-5} cancer risk comparison value. In the case of TCE, the one excess cancer in 100,000 people comparison value is 2.2 ppb. The highest reporting limit for the test was 0.17 ppb, much lower than the TCE comparison value of 2.2 ppb, the EPA 10^{-5} risk value. PCE was not detected in outdoor air above the 0.17 ppb reporting limit. TCE was detected in outdoor air at 0.33 ppb, which was greater than the reporting limit of the indoor air samples. There would not be any health concerns from breathing indoor air containing small amounts of PCE and TCE in the building. RSLs were developed for a chronic, 24 hours per day, 7 days a week, 365 days per year, for a 70-year lifetime exposure.

The theoretical risk for this chronic exposure scenario that workers would be subjected to can be calculated using a theoretical concentration of TCE in the work space multiplied by the inhalation unit risk (IUR) derived for TCE. The reporting limit for TCE was used as a theoretical detection value as TCE was not detected in the building. Therefore, the theoretical concentration in the building was 0.17 ppb (0.91 $\mu g/m^3$) multiplied by the TCE IUR of $(2.0x10^{-6})$ $(\mu g/m^3)^{-1}$. The theoretical risk would be approximately $1.8x10^{-6}$ or about 2 extra cancers above background in 1,000,000 people. This theoretical risk is an acceptable excess cancer risk to workers, according to EPA (1991). Workers are typically allowed an excess cancer risk of 1 excess cancer in 100,000 (10^{-5}) for screening purposes.

None of the other TCE breakdown chemicals including 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride, were present above their reporting limits of 0.16 or 0.17 ppb. These reporting limits were very low. 1,1-DCE, cis-1,2-DCE, and trans-1,2-DCE do not have cancer risk comparison values because they are not considered known or potential human carcinogens (EPA 2010). The highest reporting limit of 0.17 ppb was considered as the theoretical measured concentration for vinyl chloride. A concentration of 0.17 ppb would be less than the 0.4 ppb EPA RSL for 1 excess cancer above background in 100,000 people.

Downgradient Residences Soil-Gas

Soil-gas samples were collected from 1 upgradient location and 10 locations (with one duplicate sample) downgradient from the site. The upgradient location was sampled to understand the normal background concentrations of chemicals in soil-gas that were not related to the MIG site. The 10 downgradient locations were scattered throughout the residential area south and southwest of the site. Sampling locations were in public rights-of-way and on private residential property.

Numerous chemicals were detected in the background soil-gas sample. Only the site-related chemical, PCE, was measured at a very low concentration of 0.26 ppb (Table 4). TCE was also measured at a very low level of 1.1 ppb (Table 4) in one sample. Other site-related chemicals were not measured above their reporting limits which ranged from 0.15 ppb to 1.0 ppb (Table 4).

In the 11 residential area soil-gas samples, nearly all site-related chemicals were below the reporting limit for the analysis. The PCE was detected at 1 ppb in sample VII-5-SG08, located

in the middle of the downgradient groundwater contaminant plume in the area where the highest concentrations of site-related chemicals have been measured. TCE was found at 1.1 ppb in sample VII-7-SG12, which is located at the farthest downgradient area of known groundwater contamination and where the groundwater is closest to the ground surface, at about 7.5 to 25 feet bgs. PCE and TCE vapors may be released from groundwater at these shallow depths. The vapors of PCE and TCE detected are likely migrating upwards through the soil to the outside air. No other site-related chemicals were detected in downgradient soil-gas samples collected from the residential area.

Comparison values have not been developed for soil-gas measurements. EPA's *OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)* (2002) suggests the PCE and TCE detections in the soil-gas samples were equal to or exceed generic target shallow soil-gas concentration for one excess cancer in 1,000,000 people (10^{-6}) risk. This risk value would be equivalent to 1.2 ppb for PCE and 0.041 ppb for TCE.

According to the EPA guidance, further evaluation of the target concentration was warranted. Further evaluation could have included assessing groundwater or indoor air concentrations. A choice was made to include companion indoor air samples that were co-located with many of the individual soil-gas samples. A discussion of the results of the indoor air sampling follows below.

Downgradient Residences Indoor Air — Non-Cancer Evaluation

Indoor air was evaluated to better understand potential health effects site-related chemicals may have on residents living in homes located downgradient and over the groundwater contaminant plume migrating from the MIG building. At 7 homes, indoor air samples were co-located with the soil-gas sample. Homes were picked in each of the investigation areas. The homes of each area were representative of homes in that specific investigation area. The soil-gas sample for each home was collected near the home outside of the drip line of the structure.

Indoor air results did not show detections of site-related chemicals (Table 4). The TCE, PCE, cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and vinyl chloride reporting limit concentrations were compared to their respective non-cancer indoor air health comparison values published by the ATSDR (2010) or EPA (2001, 2010). This comparison was done as a worst case scenario evaluation. In the case of TCE, there is not a published ATSDR EMEG. Therefore, the reporting limit for TCE was compared to its EPA provisional comparison value of 7.4 ppb (EPA 2001).

The PCE reporting limits ranged from 0.16 ppb to 0.47 ppb in the samples. These detection limit concentrations were well below ATSDR's non-cancer effects EMEG comparison value of 40 ppb for chronic (greater than 365 days) exposure for PCE.

TABLE 4. Downgradient residences soil-gas sampling results. Samples were collected on July 29, 2010, over 8 hours with Summa canisters (WESTON 2010). Locations of samples are shown on Figure 3. Values reported in parts per billion (ppb). Regulatory comparison values are EPA shallow soil-gas target values with an attenuation factor of 0.1 and EPA residential indoor air values times 10.

Chemical / Sampling Data and Location Name	Acronym	VII-1-SG01 Background	VII-2-SG02	VII-2-SG03	VII-3-SG04	VII-3-SG05	VII-4-SG06	VII-4-SG07	VII-5-SG08	VII-5-SG09 / (duplicate)	VII-6-SG10	VII-6-SG11	VII-7-SG12	EPA OSWER Shallow Soil-Gas Target Levels (Attenuation Factor = 0.1)		EPA Residential Cancer Effects Indoor Air Levels x10 (ppb)
														(10^{-6} excess cancer risk) (ppb)	(10^{-5} excess cancer risk) (ppb)	
tetra-chloroethylene	PCE	*0.26*	<0.15	<0.14	<0.95	<0.15	<0.18	<1.2	*1.0*	<0.29/ <0.14	<0.14	<0.3	<1.0	1.2	12	0.6
trichloroethylene	TCE	<0.15	<0.15	<0.14	<0.95	<0.15	<0.18	<1.2	<1.0	<0.29/ <0.14	<0.14	<0.3	***1.1***	0.041	0.41	22
1,1-dichloroethylene	1,1-DCE	<0.15	<0.15	<0.14	<0.95	<0.15	<0.18	<1.2	<1.0	<0.29/ <0.14	<0.14	<0.3	<1.0	500	500	nc / ngv
cis-1,2-dichloroethylene	cis-1,2-DCE	<0.15	<0.15	<0.14	<0.95	<0.15	<0.18	<1.2	<1.0	<0.29/ <0.14	<0.14	<0.3	<1.0	88	88	nc / ngv
trans-1,2-dichloroethylene	trans-1,2-DCE	<0.15	<0.15	<0.14	<0.95	<0.15	<0.18	<1.2	<1.0	<0.29/ <0.14	<0.14	<0.3	<1.0	180	180	nc / ngv
vinyl chloride	VC	<0.15	<0.15	<0.14	<0.95	<0.15	<0.18	<1.2	<1.0	<0.29/ <0.14	<0.14	<0.3	<1.0	1.1	11	0.6

Notes:

Italics = Detection of chemical in soil-gas sample at this location.

<0.15 = Not detected in the air sample. Concentration represents the analytical reporting limit for the analysis.

Bold Italics = Detection above one or more comparison value concentrations.

EPA OSWER = Environmental Protection Agency Office of Solid Waste and Emergency Response Shallow Soil-Gas Target Levels (EPA 2002).

nc = Not classified as to carcinogenicity and no guidance value (ngv) is available

TCE reporting limits ranged from 0.16 to 0.48 ppb. The TCE reporting limit concentrations were well below the EPA provisional comparison value of 7.4 ppb for non-cancer health effects. The TCE reporting limit concentrations were also below the concentration of TCE measured in the background air sample, 0.33 ppb.

Other chemical reporting limits were also well below their comparison values, where available, for non-cancer health effects.

Downgradient Residences Indoor Air — Cancer Evaluation

No site-related chemical vapors were found in the 7 houses tested (Table 5). The test reporting limits were low, ranging from 0.16 ppb to 0.48 ppb, depending on the sample location and chemical tested. The TCE, PCE, cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and vinyl chloride reporting limit concentrations were compared to their respective cancer indoor air health comparison values published by the ATSDR (ATSDR 2010) or EPA (2010).

This comparison was done as a worst case scenario evaluation to evaluate theoretical small concentrations in indoor air. The comparison value for one additional cancer in one million people for TCE is 0.22 ppb. The highest reporting limit for the test was 0.48 ppb, higher than the 10^{-6} risk but lower than the 10^{-5} risk comparison value for TCE of 2.2 ppb. Again, taking the evaluation one step further, the highest reporting limit of 0.48 ppb (2.3 $\mu g/m^3$) was multiplied by EPA's inhalation unit risk for TCE of $2.0x10^{-6}$. The result is a theoretical calculated cancer risk of $5.2x10^{-6}$, a very low excess cancer risk. Therefore, the evaluations, using the reporting limit concentrations for TCE in indoor air when there were no detections of these chemicals, were within EPA's acceptable range of excess cancer risk above background.

TCE was detected in outdoor air at 0.33 ppb, for comparison. The outside air concentration is similar to the reporting limit of the test. No TCE was found inside the 7 homes. Homeowners living in homes downgradient from the plant and above the area where the contaminated groundwater is closer to the surface should not experience excess cancer health effects from breathing indoor air.

Reporting limits were compared to the PCE one excess cancer in one million people (10^{-6}) risk comparison value of 0.06 ppb (EPA 2010). The highest reporting limit value of 0.48 ppb theoretically could result in less than one excess cancer in 100,000 people. Taking the evaluation one step further, the highest reporting limit of 0.48 ppb (3.3 micrograms per cubic meter [$\mu g/m^3$]) was multiplied by EPA's inhalation unit risk for PCE of $5.9x10^{-6}$ $\mu g/m^3$. The result is a theoretical calculated cancer risk of $2x10^{-5}$, a low excess risk.

The 10^{-5} excess cancer risk is within the risk range that EPA considers acceptable for residential exposure (EPA 1991). For comparison, PCE was not detected in outdoor air above a 0.17 ppb reporting limit.

TABLE 5. Downgradient residences indoor air sampling results. Samples were collected on July 29, 2010, over 8 hours with Summa canisters (S&ME 2010). Locations of samples are shown on Figure 3. Values reported in parts per billion (ppb). Health comparison values used are non-cancer chronic exposure duration greater than 365 days (ATSDR 2010), ATSDR cancer risk evaluation guides (ATSDR 2010), and EPA residential indoor air Regional Screening Levels (EPA 2010).

Chemical / Sampling Data and Location Name	Acronym	VII-2-IA01/ Duplicate	VII-2-IA02	VII-3-IA03	VII-3-IA04	VII-4-IA05	VII-5-IA06	VII-6-IA07	ATSDR EMEG (non-cancer) (ppb)	ATSDR CREG (10^{-6} excess cancer risk) (ppb)	EPA RSL	
											(10^{-6} excess cancer risk) (ppb)	(10^{-4} excess cancer risk) (ppb)
tetra-chloroethylene	PCE	<0.47/ <0.44	<0.34	<0.31	<0.16	<0.17	<0.17	<0.16	40	ngv	0.06	6
tri-chloroethylene	TCE	<0.48/ <0.45	<0.34	<0.31	<0.16	<0.17	<0.17	<0.16	7.4[EPA]	ngv	0.22	22
1,1-dichloroethylene	1,1-DCE	<0.48/ <0.45	<0.34	<0.31	<0.16	<0.17	<0.17	<0.16	20i	nc	ngv	ngv
cis-1,2-dichloroethylene	cis-1,2-DCE	<0.48/ <0.45	<0.34	<0.31	<0.16	<0.17	<0.17	<0.16	ngv	nc	nc	nc
trans-1,2-dichloroethylene	trans-1,2-DCE	<0.48/ <0.45	<0.34	<0.31	<0.16	<0.17	<0.17	<0.16	200i	nc	nc	nc
vinyl chloride	VC	<0.47/ <0.43	<0.34	<0.31	<0.16	<0.17	<0.17	<0.16	30i	0.04	0.06	6

Notes:

ATSDR EMEG = Agency for Toxic Substances and Disease Registry Environmental Media Evaluation Guide (ATSDR 2010). Chronic non-cancer exposure comparison values (exposure greater than 365 days) used to determine if chemical concentrations warrant further health-based screening.

ATSDR CREG = Agency for Toxic Substances and Disease Registry Cancer Risk Evaluation Guide (ATSDR 2010). Cancer risk comparison values for cancer risk of 1 excess cancer in 1,000,000 people used to determine if chemical concentrations warrant further health-based screening.

EPA RSL = Environmental Protection Agency Regional Screening Level (EPA 2010). The screening levels were developed using risk assessment guidance from the EPA Superfund Program. They are risk-based concentrations derived from standardized equations combining exposure information assumptions with EPA toxicity data. RSLs are considered by EPA to be protective for humans (including sensitive groups) over a lifetime.

Modifiers:

<0.45 = Not detected in the air sample. Concentration represents the analytical reporting limit.

* = Reporting limit was greater than one or more comparison values.

EPA = There is not a published EMEG for TCE. The results were compared to the EPA's most current evaluation of the potential health risks from exposure to TCE at 7.4 ppb (EPA 2001).

i = ATSDR comparison value for intermediate exposures (15-365 days); typically higher than a chronic value

nc = Not classified as to carcinogenicity and no guidance value is available

ngv = No guidance value available

None of the other breakdown chemicals, including 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride, were present. The range of reporting limits was from 0.16 to 0.48 ppb. These reporting limits were very low. The presence of these chemicals in amounts below the detection limits will not create an unhealthy indoor air environment and will not likely lead to excess cancer health effects from breathing indoor air possibly containing trace amounts of these chemicals.

Chemical Mixture

When you have more than one chemical at a location, there are potential additive health effects from a mixture of chemicals to an exposed population (ATSDR 2004). There is no evidence to indicate that greater-than-additive interactions among TCE or PCE health effects occur. This includes interactions for the most common liver and kidney or nervous system effects observed from PCE or TCE exposure. PCE and TCE were not measured in the indoor air samples from the MIG building or in the samples from the residential properties located downgradient from the MIG building.

Adding together the approximate site-specific theoretical risks of PCE of $2.0x10^{-5}$ and approximately $5.2x10^{-6}$ for TCE, the total excess cancer risk above background was still about 3 in 100,000, within EPAs acceptable range of risk (EPA 1991). Again, there were no measured amounts of PCE or TCE found in the indoor air of the homes.

Other Considerations

Site-related chemicals were reported in groundwater at concentrations above their respective EPA maximum contaminant levels in groundwater both at the site and throughout the downgradient residential area. There is an active groundwater remediation system in place at the former Johnson Controls Site. Continued monitoring of the groundwater plume would be prudent. TDEC recently stated that there will be more investigation activities to find out the limit of the downgradient groundwater contaminant plume by WESTON for Johnson Controls (TDEC 2010).

If not already in place, a facility inspection and maintenance plan should be started to evaluate the condition of the floor of the MIG building. The inspection plan would ensure that the building floor does not develop cracks. There are relatively high concentrations of site-related chemicals beneath the building floor. Inspecting the floor would alert plant personnel of any potential pathway for the migration of site-related chemicals from beneath the building slab into the indoor air. Any cracks developed in the floor could then be filled and sealed as part of a maintenance plan to prevent vapor migration.

If further groundwater assessment activities are conducted, it would be prudent to expand the vapor intrusion investigation to other areas that may overlie an expanded groundwater contaminant plume. If the site-specific depth-to-groundwater trend continues, groundwater would likely be shallower farther downgradient from the site. Therefore, if the groundwater is found to be impacted in these newly investigated areas, groundwater plume contaminant vapors

would be even closer to the ground surface. The shallowness of the groundwater could provide a greater potential for vapor intrusion into residences.

Child Health Considerations

The workers at the MIG building are adults. Children would only have a limited exposure to the indoor air at the MIG facility, if at all. TCE was not found in the indoor air samples collected in the MIG building. As children would only be occasional visitors to the facility, breathing the air inside the MIG building should not have any adverse health effects.

As children may be living in the homes that were tested as part of this vapor intrusion investigation, the health of children was considered as part of this health consultation. The many physical differences between children and adults demand special emphasis. Children could be at greater risk than adults from certain kinds of exposure to hazardous substances (ATSDR 1997, 1998). Children have lower body weights than adults. Although children's lungs are usually smaller than adults, children breathe a greater relative volume of air compared to adults. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children can sustain permanent damage.

The former Johnson Controls / current MIG Site no longer utilizes solvents in their manufacturing activities. There is a groundwater remediation system in place at the site that is reducing the amount of site-related chemicals leaching into the groundwater. No detections of site-related chemicals were found in the indoor air testing in downgradient homes. The sampling plan was strong overall as both soil-gas and indoor air samples were collected from numerous homes. As part of a very cautious approach, an evaluation was done of TCE and TCE breakdown chemicals using indoor air test reporting limits as theoretical detections. The reporting limit measurements for these chemicals would be an extreme and worst-case situation. Using these reporting limit amounts, there should be no excess cancer health risks from site-related chemicals.

Conclusions

EEP concludes that the chemical trichloroethylene (TCE), and TCE's breakdown products cis-1,2-dichloroethylene, trans-1,2-dichloroethylene, 1,1-dichloroethylene, and vinyl chloride are not expected to harm the health of the workers of the Manufacturer's Industrial Group facility. Sub-slab soil-gas contained measurable amounts of the site-related chemicals TCE and cis-1,2-DCE. Even with abundant TCE pollution remaining beneath the floor of the building, indoor air samples taken inside the former Johnson Controls/current MIG building did not contain TCE nor its breakdown chemicals. Therefore, it does not appear that vapors are migrating upwards from below the building slab into the indoor air of the building.

EEP concludes that the chemicals PCE and TCE and TCE's breakdown chemicals will not harm the health of residents in homes downgradient from the MIG facility. PCE was measured in very small amounts, 0.26 ppb, in the background soil-gas sample. Very small amounts of PCE and TCE were each identified in one soil-gas sample that was collected from the downgradient

residential area. The PCE and TCE concentrations were 1.0 and 1.1 ppb, respectively. PCE and TCE were not found above test reporting limits in indoor air.

Recommendations

The focus of this health consultation is to make sure the indoor air breathed by workers and residents will not lead to harmful health effects. TDH EEP and TDEC were concerned about indoor air breathed by workers in the former Johnson Controls, current MIG building and indoor air breathed by residents who live above the facility-related groundwater contaminant plume south of the MIG building. With that in mind, the following recommendation is believed to be appropriate based on EEP's review of the indoor air sampling data.

- EEP recommends facility inspection and maintenance plan should be started to evaluate the condition of the floor of the MIG building. The inspection plan would ensure that the building floor does not develop cracks. Any cracks developed in the floor could then be filled and sealed as part of a maintenance plan to prevent vapor migration.

- EEP also recommends that if the groundwater investigation is expanded and contaminated groundwater is found under other residential areas, indoor air in additional homes should be sampled. Select homes previously sampled and whose results were used as the basis for this health consultation ideally should be resampled when the outside temperatures are colder.

Public Health Action Plan

The public health action plan for the former Johnson Controls Site contains a list of actions that have been or will be taken by TDH EEP and other agencies. The purpose of the public health action plan is to ensure that this health consultation identifies public health concerns and offers a plan of action designed to mitigate and prevent harmful health effects that result from breathing, eating, drinking, or touching hazardous substances in the environment. Included is a commitment on the part of EEP to follow up on this plan to ensure that it is implemented.

Public health actions that have been taken by TDH's EEP include:

- Reviewing the sub-slab soil-gas and indoor air data from the former Johnson Controls building and the soil-gas and indoor air data from the various residential properties south of the building.

- Preparing this health consultation.

Public health actions that will be taken include:

- TDH EEP will provide copies of this health consultation to state and federal government groups interested in the former Johnson Controls Site.

- TDH EEP will maintain dialogue with ATSDR, TDEC, EPA, and other interested stakeholders to safeguard public health.

- TDH EEP staff are available to answer questions regarding the interpretation of the indoor air and soil-gas results should homeowners be interested in speaking with us.

- TDH EEP will be available to review newly collected and additional environmental data, and provide interpretation of the data, as requested by TDEC.

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Appendix

Listing of Tested Chemicals

Freon
Freon 114
Chloromethane
Vinyl Chloride
1,3-Butadiene
Bromomethane
Chloroethane
Freon 11
Ethanol
Freon 113
1,1-Dichloroethene
Acetone
2-Propanol
Carbon Disulfide
3-Chloropropene
Methylene Chloride
Methyl tert-butyl ether
trans-1,2-Dichloroethene
Hexane
1,1-Dichloroethane
2-Butanone (Methyl Ethyl Ketone)
cis-1,2-Dichloroethene
Tetrahydrofuran
Chloroform
1,1,1-Trichloroethane
Cyclohexane
Carbon Tetrachloride
2,2,4-Trimethylpentane
Benzene
1,2-Dichloroethane
Heptane
Trichloroethene
1,2-Dichloropropane
1,4-Dioxane
Bromodichloromethane
cis-1,3-Dichloropropene
4-Methyl-2-pentanone
Toluene
trans-1,3-Dichloropropene
1,1,2-Trichloroethane
Tetrachloroethene
2-Hexanone
Dibromochloromethane
1,2-Dibromoethane (EDB)
Chlorobenzene
Ethyl Benzene
m,p-Xylene
o-Xylene
Styrene
Bromoform
Cumene
1,1,2,2-Tetrachloroethane
4-Ethyltoluene
1,3,5-Trimethylbenzene
1,2,4-Trimethylbenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
alpha-Chlorotoluene
1,2-Dichlorobenzene
1,2,4-Trichlorobenzene
Hexachlorobutadiene
tert-Butyl alcohol
Naphthalene
Vinyl Bromide
Vinyl Acetate
2-Chlorotoluene
Propylene

Certification

This Public Health Consultation: *Evaluation of the Vapor Intrusion Investigation for the Johnson Controls Facility, Lexington, Henderson County, Tennessee*, was prepared by the Tennessee Department of Health's Environmental Epidemiology Program. It was prepared in accordance with the approved methodology and procedures that existed at the time the health consultation was begun.

Director of EEP, CEDS, TDH