

Health Consultation

Vapor Intrusion Investigation of Residential and Commercial Buildings
Surrounding the Former Gardner Manufacturing Site
City of Horicon, Dodge County, Wisconsin

**Prepared by the
Wisconsin Department of Health Services**

May 20, 2013

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

Health Consultation: A Note of Explanation

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

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

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HEALTH CONSULTATION

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Summary and Statement of Issues

The results of a 2011 investigation of trichloroethylene (TCE) concentrations in the air beneath and inside buildings surrounding the former Gardner Manufacturing site in Horicon, WI was used to develop the following conclusions and recommendations:

Conclusion #1. The Wisconsin Department of Health Services (WDHS) concludes that seven homes in the vicinity of the former Gardner Manufacturing site have sub-slab concentrations of TCE that could pose long-term health concerns to their residents.

Basis for decision. TCE is prominently listed on ATSDR's "Hazardous Substance Priority List" and has been designated a "Contaminant of Concern" by the US Environmental Protection Agency (US EPA). Sub-slab air samples taken from homes surrounding the former Gardner Manufacturing site have revealed seven homes with sufficient potential for indoor air exceedances of the ATSDR Comparison Value (CV) and EPA Regional Screening Level (RSL) (*US EPA 2012a*) for TCE in indoor air.

Next steps. In order to protect community health and well-being, WDHS has recommended the installation of sub-slab depressurization systems (SSDSs) in all homes that exceed or have the potential to exceed the US EPA RSL for TCE in residential air, as SSDSs have proven effective in reducing health risks related to organic vapor intrusion. A contractor hired by the Wisconsin Department of Natural Resources (WDNR) is currently installing SSDSs in all homes with TCE exceedances in sub-slab air.

Conclusion #2. WDHS concludes that TCE discharged from the former Gardner Manufacturing site does pose a low-level health risk to the City of Horicon municipal water supply.

Basis for decision. WDHS concurs with the hydrogeological assessment of environmental contractors (under the direction of WDNR) that the potential risk of future impact to the municipal water supply is low. The City of Horicon Municipal Well #3 (MW#3) is located approximately 500 feet downgradient from the source property and is cased to a depth of 385 feet below ground surface (bgs). TCE has never been detected during routine testing of the municipal water system for volatile organic compounds (VOCs), nor is it expected to impact this well in the future. However, there will always be some risk of TCE contamination to the municipal water supply until removal and/or remediation is complete.

Next steps. Because the potential for TCE contamination of MW#3 will persist until the source is removed or sufficiently degraded, WDHS recommends continued VOC testing (i.e., TCE and other related chlorinated solvents) of the municipal water supply as long as the threat exists. Under standard WDNR requirements, VOC testing of water samples from MW#3 is conducted every three years. WDHS recommends annual VOC testing until the source is removed or adequately reduced, at the discretion of WDHS and WDNR staff.

Background and Public Health Concerns

Site History

In March 2011, WDNR requested assistance from WDHS and the Dodge County Health Department (DCHD) to evaluate health concerns associated with groundwater contamination beneath the former Gardner Manufacturing site at 263 Kansas Street in Horicon, WI. Gardner Manufacturing purchased the property in 1928 and began producing barn equipment and various sheet metal products, including radiator covers and metal cabinets. The outside area north of the factory building was used for cleaning and painting parts in the 1950s. Reportedly, paints and solvents were discharged to the outdoor ground surface during this period of time. Gardner Manufacturing ceased activities at this property in the 1980s. The facility was then used by Uni-Screen from 1985 to 1992, to manufacture projection screens. It was later occupied by a furniture/woodworking manufacturer. The facility has been vacant since approximately 2003.

The property is currently being considered for redevelopment by the City of Horicon. Phase I and II Environmental Site Assessments (ESAs) conducted in 2009 revealed soil and groundwater contamination with trichloroethylene (TCE) and other related chlorinated solvents, such as 1,2-dichloroethene (1,2-DCE), 1,2-dichloroethane (1,2-DCA), 1,1-dichloroethane (1,1-DCA), 1,2,3-trichloropropane (1,2,3-TCP) and vinyl chloride (VC) (*MSA 2010*). Based on the ESA findings, a more detailed Site Investigation (SI) was required by WDNR to determine the extent and degree of chlorinated solvent release from the former facility (*MSA 2011*). This investigation is still ongoing. In the spring and summer of 2010, initial samples from a number of soil borings and monitoring wells around the property were analyzed. Plume maps extrapolated from this data indicated that levels of chlorinated solvents exceeding state groundwater standards (*WI Administrative Code: Chapter NR 140*) extended beneath homes to the east and northeast of the Gardner Site, in the direction of the Rock River. WDNR, WDHS and DCHD conducted a joint investigation to determine: (1) whether chlorinated solvent vapors were accumulating, via the vapor intrusion pathway, beneath and inside of homes surrounding the former Gardner Manufacturing site, and (2) whether chlorinated solvents will impact the municipal water supply.

Site Description and Investigation

The Gardner Manufacturing site is surrounded by a number of homes, a building used for recreational purposes and a few commercial businesses (***Appendix A***). The subsurface geology of the site consists of glacial outwash and glacial till deposits, which are mostly stratified sand, silty sand, silt and clay deposits (*MSA 2011*). The depth to groundwater ranges from 9-15 feet bgs. Groundwater flow direction is to the northeast toward the Rock River, which is located about 800 feet northeast of the property. A TCE plume model developed during the 2010 SI was based on the hydrogeology of the area and groundwater samples collected from various monitoring wells around the property and the nearby Clausen Bowling Green Park (***Appendix B***). The plume model predicted potentially hazardous levels of TCE beneath six homes, one business and one recreational use building. Sub-slab and indoor air results from samples collected from homes and businesses surrounding the site will be discussed in more detail in the next section of this health consultation.

To date, the City of Horicon municipal water supply has not been impacted by TCE or other related chlorinated solvents, despite the presence of a nearby municipal well. The City of Horicon MW#3 (WI Well #BF608) is located approximately 500 feet east (downgradient) of the source property. MW#3 is one of four wells that contribute to the City of Horicon municipal water supply, which is currently subject to VOC testing every three years. MW#3 is cased to 385 feet bgs and drilled to 715 feet bgs, with an open borehole from 385 to 715 feet bgs.

Public Health Concerns and Outreach

Chlorinated VOCs are particularly troubling because of their widespread past use, relative resistance to degradation in soil and water, high volatility and toxicity (*WDNR 2011*). The discharge of TCE on the property formerly owned by Gardner Manufacturing created a groundwater contaminant plume beneath this site. The horizontal migration of the resulting contaminant plume has the potential to generate a number of public health concerns via two possible points of human exposure and multiple exposure pathways:

- 1) the inhalation of contaminated indoor air via the vertical migration, intrusion and accumulation of chlorinated solvent vapors within surrounding homes and businesses, and
- 2) the ingestion of, or dermal contact with contaminated tap water from a nearby municipal well, as well as the inhalation of chlorinated solvent vapors from showering with water from this source.

The main public health concern associated with this contaminant plume is the inhalation of TCE vapors that migrate indoors from the groundwater and soil beneath buildings surrounding the former Gardner Manufacturing site. Vapor intrusion of VOCs and their accumulation in indoor air constitutes a well-established exposure pathway for a number of volatile industrial compounds that were improperly discarded in the past (*US EPA 2002*). The potential risk of the chlorinated solvent plume impacting MW#3 has been deemed low by WDNR and their environmental contractors, based on the over 300 feet of bedrock separating the plume in the shallow (upper 50 feet) unconsolidated aquifer from the bedrock aquifer that supplies this well (*MSA 2011*). Nonetheless, the potential for chlorinated solvents to seep down to the aquifer that feeds MW#3 will exist until the source is eliminated, requiring continued VOC testing.

There has been an ongoing effort to educate the potentially affected residents of Horicon about the risks of chronic exposure to chlorinated solvents, such as TCE. WDHS has collaborated with WDNR, DCHD and the City of Horicon to provide information on the potential routes of exposure, the associated human health hazards, and the methods of mitigation at public meetings and via phone calls, emails and letters to individual home or business owners. WDHS will continue to provide updates and public health education to affected residents until all known or potential public health risks have been removed or mitigated.

Discussion

Summary of Sub-slab and Indoor Air Data

The TCE groundwater plume model generated during the 2010 SI of the former Gardner property predicted an east-northeasterly flow toward the Rock River that bisects the City of Horicon from north to south. The initial selection of buildings for vapor intrusion testing was limited to those that are located completely or partially above the proposed TCE groundwater plume (*Appendix B*). Sub-slab and indoor air samples were collected and analyzed according to US EPA Method TO-15 (*US EPA 1999*). Sub-slab and indoor air concentrations were compared to the ATSDR Cancer Risk Evaluation Guide (CREG) (*ATSDR 2012*) and US EPA RSL for TCE in residential indoor air (0.045 and 0.37 ppbV, respectively). The first round of sampling and analysis revealed that three homes to the east of the former Gardner Manufacturing site had sub-slab TCE levels more than 10-fold above the US EPA RSL for TCE in residential indoor air (*Table 1*). The highest concentration of TCE (709 ppbV) detected in sub-slab soil gas was from the northernmost home (Home D) in our initial sampling plan. Although this result was somewhat surprising based on the estimated iso-concentrations of TCE that comprised the initial plume model, the offsite northern boundary of this plume model was not based on empirical data, but was instead inferred from the available onsite data. Degradation products of TCE (e.g., 1,2-DCE and VC) were not detected in any of the sub-slab samples above levels of potential concern to public health.

Since the highest TCE concentration detected in the initial vapor intrusion sampling plan was directly northeast of the former Gardner Manufacturing site, WDNR, WDHS and DCHD concluded that it was necessary to continue sampling in this direction. Three of the four homes that participated in the second and third rounds of sampling had sub-slab concentrations in exceedance of the sub-slab-attenuated US EPA RSL for TCE in residential indoor air (*Table 1*). The highest sub-slab TCE concentration (Home G – 12,200 ppbV) detected was also northeast of the former Gardner Manufacturing site, and just to the north of the previous high concentration (Home D – 709 ppbV). The detection of additional homes with sub-slab exceedances of TCE to the north and east of the former Gardner Manufacturing site dictated further sampling in this direction. The decision was also made to determine whether TCE had migrated west of the former Gardner Manufacturing site, to the opposite side of Kansas St. TCE was not detected beneath the six homes that participated in the final rounds of sampling, effectively ruling out TCE migration to the west and further to the north of the previous sampling areas.

Table 1. Summary of TCE concentrations in sub-slab and indoor air samples collected in structures surrounding the former Gardner Manufacturing Facility, City of Horicon, Dodge County, WI.

<i>Structure (sampling round)</i>	<i>Sub-slab</i>	<i>Basement</i>	<i>1st Floor</i>	<i>2nd Floor</i>	<i>Outdoor</i>
Building A (1)	ND	NS	NS	NS	NS
Building B (1)	NR	NR	NR	NR	NR
Home A (1)	6.8*	ND	NS	NS	ND
Home B (1)	9.4*	NS	NS	NS	NS
Home C (1)	ND	NS	NS	NS	NS
Home D (1)	709*	0.5[^]	0.3 [#]	ND	ND
Home E (1)	1.4 [‡]	NS	NS	NS	NS
Home F (1)	0.4	NS	NS	NS	NS
Home G (2)	12,200*	3.6[^]	0.3 [#]	NS	ND
Home H (2)	40*	ND	0.3 [#]	NS	ND
Home I (3)	188*	ND	ND	ND	ND
Home J (3)	2,400*	5.5[^]	0.6[^]	0.9[^]	ND
Home K (3)	ND	NS	NS	NS	NS
Home L (4)	ND	NS	NS	NS	NS
Home M (4)	ND	NS	NS	NS	NS
Home N (4)	NR	NR	NR	NR	NR
Home O (4)	ND	NS	NS	NS	NS
Home P (5)	ND	NS	NS	NS	NS
Home Q (6)	ND	NS	NS	NS	NS

All sub-slab and indoor air concentrations in parts per billion by volume (ppbV).

Sampling locations listed in chronological order of sampling round: (1) April 2011; (2) August 2011; (3) October 2011; (4) December 2011; (5) September 2012; (6) October 2012.

ND: not detected

NS: not sampled

NR: no response from owner

*: greater than 10-fold above ATSDR CREG (0.045 ppbV) and 10-fold above US EPA RSL (0.37 ppbV) for TCE (bolded)

‡: greater than 10-fold above ATSDR CREG, but less than 10-fold above US EPA RSL for TCE

[^]: above the ATSDR CREG and US EPA RSL for TCE (bolded)

[#]: above the ATSDR CREG, but less than US EPA RSL for TCE

When indicated and allowed by the residents, indoor air samples were taken from homes with elevated sub-slab concentrations of TCE. The homes with the two highest sub-slab TCE concentrations also had exceedances of the ATSDR CREG and US EPA RSL for TCE in the ambient air of their basements (Table 1), strengthening the case for mitigation in these homes. However, mitigation was recommended for all homes with sub-slab levels of TCE more than 10-fold (sub-slab dilution factor) above the US EPA RSL for TCE in residential indoor air, in accordance with vapor intrusion mitigation guidance developed jointly by WDNR and WDHS (WDNR 2011). Indoor air levels can vary seasonally and over time, based on changes in temperature, barometric pressure, wind, air exchange rates, and the presence of cracks or other

changes to the integrity of a home's foundation. Because of this variation, WDHS typically recommends mitigation based on the sub-slab levels of a contaminant and the potential for an indoor air exceedance. It is assumed that the sub-slab provides at least a 10-fold reduction in indoor TCE concentrations, which is conservative, but has been proven by EPA to provide sufficient protection in over 95% of TCE vapor intrusion cases (*US EPA 2012b*).

Adverse Health Effects and Risk Assessment

Noncancer toxicities and risk assessment. The primary health concerns of residents living near the former Gardner Manufacturing site are those associated with the chronic inhalation of TCE that has migrated into their homes via the vapor intrusion pathway. ATSDR and the US EPA have concluded that TCE poses a potential human health hazard to the central nervous system, the immune system, the kidney, the liver, the male reproductive system, and the developing fetus (*ATSDR 1997; US EPA 2011*). The immune system and the developing fetus are most sensitive to the toxic effects of TCE, as reductions in thymus weight (*Keil 2009*) and the development of fetal cardiac malformations (*Johnson 2003*) are the earliest observed adverse effects following low level exposures. Although these studies were conducted in rats and mice exposed to TCE in drinking water, physiologically based pharmacokinetic (PBPK) modeling was used to convert oral doses in animals to human equivalent concentrations (HECs) in air. The US EPA RSL for TCE in residential air (0.39 ppbV) is based on the Reference Concentration (RfC) derived from the Keil and Johnson ingestion studies, as they are below the candidate RfCs derived from the lowest concentrations associated with adverse effects from TCE inhalation studies. The US EPA TCE RSL is similar to the ATSDR TCE inhalation chronic Minimal Risk Level (0.4 ppbV)

Seven homes surrounding the former Gardner manufacturing site have indoor air concentrations either above the US EPA RSL or with sufficient potential to exceed it in the future (based on sub-slab concentrations). The HEC for fetal cardiac malformations is 3.7 ppbV and the candidate RfC is 0.37 ppbV. The highest indoor air TCE concentration detected in this study (3.61 ppbV) is almost 10-fold above the US EPA candidate RfC, and approaching the HEC for fetal cardiac malformations. Exposure of pregnant women to TCE levels above the US EPA RSL, or even the HEC, does not guarantee that fetal heart development will be impaired. However, breathing air approaching or exceeding these levels of TCE begins to introduce a small amount of risk to proper fetal development and should be avoided.

Carcinogenic potential and risk assessment. In addition to noncancer toxicities associated with TCE exposure, long-term inhalation of TCE can also increase one's risk of developing certain cancers. The US EPA recently released an extensive toxicological review of TCE, in which they reclassified it as "carcinogenic to humans by all routes of exposure" (*US EPA 2011*). The National Toxicology Program has also determined that TCE is "reasonably anticipated to be a human carcinogen". The most consistent and convincing evidence of a causal association between TCE exposure in humans and cancer is that for cancer of the kidney. However, there are also compelling links between TCE exposure and cancers of the lymphoid tissues (lymphoma) and liver (*US EPA 2011*), which should also be taken into consideration in health risk assessments. Please refer to **Appendices C and D** for the theoretical excess cancer risk calculations associated with lifetime exposure to the US EPA RSL for residential indoor air and the maximum indoor air concentration of TCE detected in this investigation.

In application, WDHS adjusts the carcinogenic US EPA RSL for TCE in indoor air (0.39 ppbV or $2.1 \mu\text{g}/\text{m}^3$) to reflect the 1-in-100,000 excess lifetime cancer risk level (*Appendix C*). Thus, exposure to any indoor air concentration above this would represent an unacceptable increase in lifetime cancer risk. Six homes surrounding the former Gardner manufacturing site have indoor air concentrations either above the 1-in-100,000 excess lifetime cancer risk level or with sufficient potential to exceed it in the future (based on sub-slab concentrations). The highest indoor air concentration of TCE detected in this study was 3.61 ppbV ($19.72 \mu\text{g}/\text{m}^3$). At this maximum concentration, the theoretical excess lifetime cancer risk is 9- to 10-fold higher than the lifetime cancer risk deemed acceptable by WDHS (*Appendix D*), and exposures to 3.61 ppbV for approximately 10 years or greater will result in theoretical cancer risks above 1-in-100,000 (see Total Risk for Age Groups “21 to <30” and “30 to 70” in *Appendix D*).

Child Health Considerations

In communities faced with air and water contamination, the many physical differences between children and adults demand special emphasis. Children are often at greater risk when exposed to hazardous substances because their lower body weight and higher intake rate results in a greater dose of hazardous substance per unit of body weight. If toxic exposure levels are high enough during critical stages of development or growth, the developing body systems of children can sustain permanent damage. Finally, children are dependent on adults for access to housing, food, medical care and risk identification. Thus adults need as much information as possible to make informed decisions regarding their children’s health.

Although there are no direct, definitive links between TCE inhalation and an increased incidence of adverse health effects in children or fetuses, evidence from animal studies, together with the limited information from human studies, strongly suggests that developmental and reproductive effects are of concern (ATSDR 2001; US EPA 2011). Studies of TCE in drinking water have shown TCE is lipophilic, crosses into the placenta and has been detected in human newborns after the use of TCE as a maternal anesthetic during childbirth. TCE was discontinued as a general anesthetic in the 1980s over concerns of fetal toxicity and its carcinogenic potential (ATSDR 2001). TCE is also excreted into breast milk, providing another potential source of exposure in breastfeeding infants (Pastino, et al., 2000). While a number of studies have examined acute TCE exposures in adults, similar studies in children and the effects of low-level chronic exposures typically seen in vapor intrusions cases are lacking. Age-dependent differences in the absorption, distribution, metabolism and excretion of xenobiotics may also alter the susceptibility of children to TCE, compared to adults. Unfortunately, data on the toxicokinetics of TCE in children are virtually nonexistent, making it difficult to predict potential differences in response between adults, children and the fetus. Nonetheless, source mitigation, removal and public education directed at parents should be used to help prevent or minimize exposure to children and women of childbearing age.

Conclusions

- WDHS concludes that breathing TCE entering homes in the vicinity of the former Gardner Manufacturing site via the vapor intrusion pathway for a long time (a year or more), or during pregnancy, could harm people's health.
- WDHS concludes that drinking water from the municipal water supply in the City of Horicon is not expected to harm people's health. To date, contaminants have not been detected and the depth of the municipal well closest to the former Gardner Manufacturing site is deep enough to make contamination with TCE highly unlikely in the future. Nonetheless, a low-level of risk to the municipal water supply will exist until the contamination is sufficiently reduced or removed.

Recommendations

- WDHS recommends that WDNR take steps to interrupt the vapor intrusion pathway for affected homeowners, via indoor air mitigation (SSDSs) and TCE source removal and/or degradation.
- WDHS recommends that the City of Horicon Water Utility increase the frequency of VOC testing (from every three years to every year) to monitor their water supply against the minor risk of the presence of TCE and related chlorinated solvents from the former Gardner Manufacturing site.

Public Health Action Plan

WDHS will:

- Support the effort of WDNR to install SSDSs in those homes that have been identified as having sub-slab and/or indoor air concentrations of TCE with the potential to result in long-term health concerns and educate homeowners on the proper use and maintenance of these systems.
- Provide public health guidance to WDNR to determine the optimal strategy for TCE source removal of the contaminated groundwater plume surrounding the former Gardner Manufacturing site.
- Provide ongoing community outreach and education efforts in collaboration with WDNR, DCHD and the City of Horicon for work related to remediation and redevelopment of the former Gardner Manufacturing site. Work to date has included public availability sessions, information pamphlets and letters to potentially affected residents detailing the health concerns associated with TCE exposure, and the status of the investigation and mitigation efforts. Ongoing work with our partners will include community discussions to solicit and incorporate recommendations from affected residents with regard to proposed remediation efforts and continued education on exposure reduction strategies.

Report Preparation

This Health Consultation for the Former Gardner Manufacturing Site was prepared by the Wisconsin Department of Health 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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References

US EPA. 2012a. Risk-Based Concentration Tables for Human Health Risk Assessment: Regional Screening Level (RSL)_Residential Air Supporting Table_November 2012.

Available online at

http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/pdf/resair_sl_table_run_MAY2012.pdf

MSA Professional Services. 2010. Phase I and II Environmental Site Assessments: Former Gardner Manufacturing Property, Horicon, WI.

MSA Professional Services. 2011. Site Investigation: Former Gardner Manufacturing Property, Horicon, WI.

WDNR. 2011. Addressing Vapor Intrusion at Remediation and Redevelopment Sites in Wisconsin. Available online at <http://dnr.wi.gov/org/aw/rr/archives/pubs/RR800.pdf>

US EPA. 2002. OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance).

Available online at

<http://www.epa.gov/epawaste/hazard/correctiveaction/eis/vapor.htm>

US EPA. 1999. Compendium Method TO-15: Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially-Prepared Canisters and Analyzed By Gas Chromatography/Mass Spectrometry (GC/MS). Available online at

<http://www.epa.gov/ttnamtl1/files/ambient/airtox/to-15r.pdf>

ATSDR. 2012. Air Comparison Values from ATSDR's Sequoia Database. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

US EPA. 2012b. EPA's Vapor Intrusion Database: Evaluation and Characterization of Attenuation Factors for Chlorinated Volatile Organic Compounds and Residential Buildings.

Available online at

http://www.epa.gov/oswer/vaporintrusion/documents/OSWER_2010_Database_Report_03-16-2012_Final.pdf

ATSDR. 1997. Toxicological Profile for Trichloroethylene (TCE). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. Available online at

<http://www.atsdr.cdc.gov/toxprofiles/tp19.pdf>

US EPA. 2011. Toxicological Review of Trichloroethylene (CASRN 79-01-6) in Support of Summary Information on the Integrated Risk Information System (IRIS).

Available online at <http://www.epa.gov/iris/toxreviews/0199tr/0199tr.pdf>

Keil DE, Peden-Adams MM, Wallace S, Ruiz P and Gilkeson GS. 2009. *Assessment of trichloroethylene (TCE) exposure in murine strains genetically-prone to develop autoimmune disease*. Journal of Environmental Science and Health 44(5):443-453.

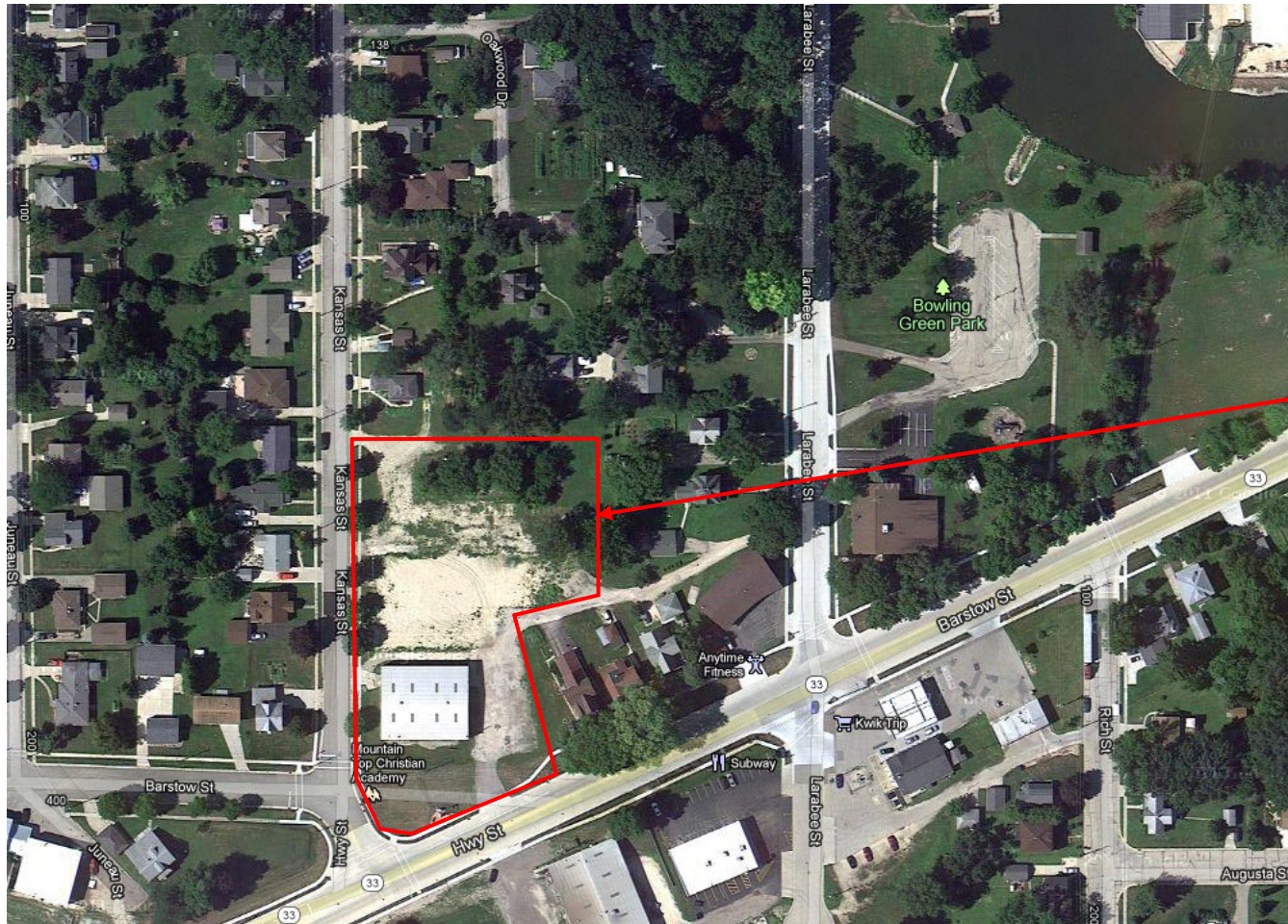
Johnson P, Goldberg S, Mays M and Dawson B. 2003. *Threshold of trichloroethylene contamination in maternal drinking waters affecting fetal heart development in the rat*. Environmental Health Perspectives 111(3):289-292.

ATSDR. 2001. Case Studies in Environmental Medicine: Trichloroethylene (TCE) Toxicity. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. Available online at <http://www.atsdr.cdc.gov/hec/csem/tce/docs/tce.pdf>

Pastino GM, Yap WY and Carroquino M. 2000. *Human variability and susceptibility to trichloroethylene*. Environmental Health Perspectives 108(suppl. 2):201-214.

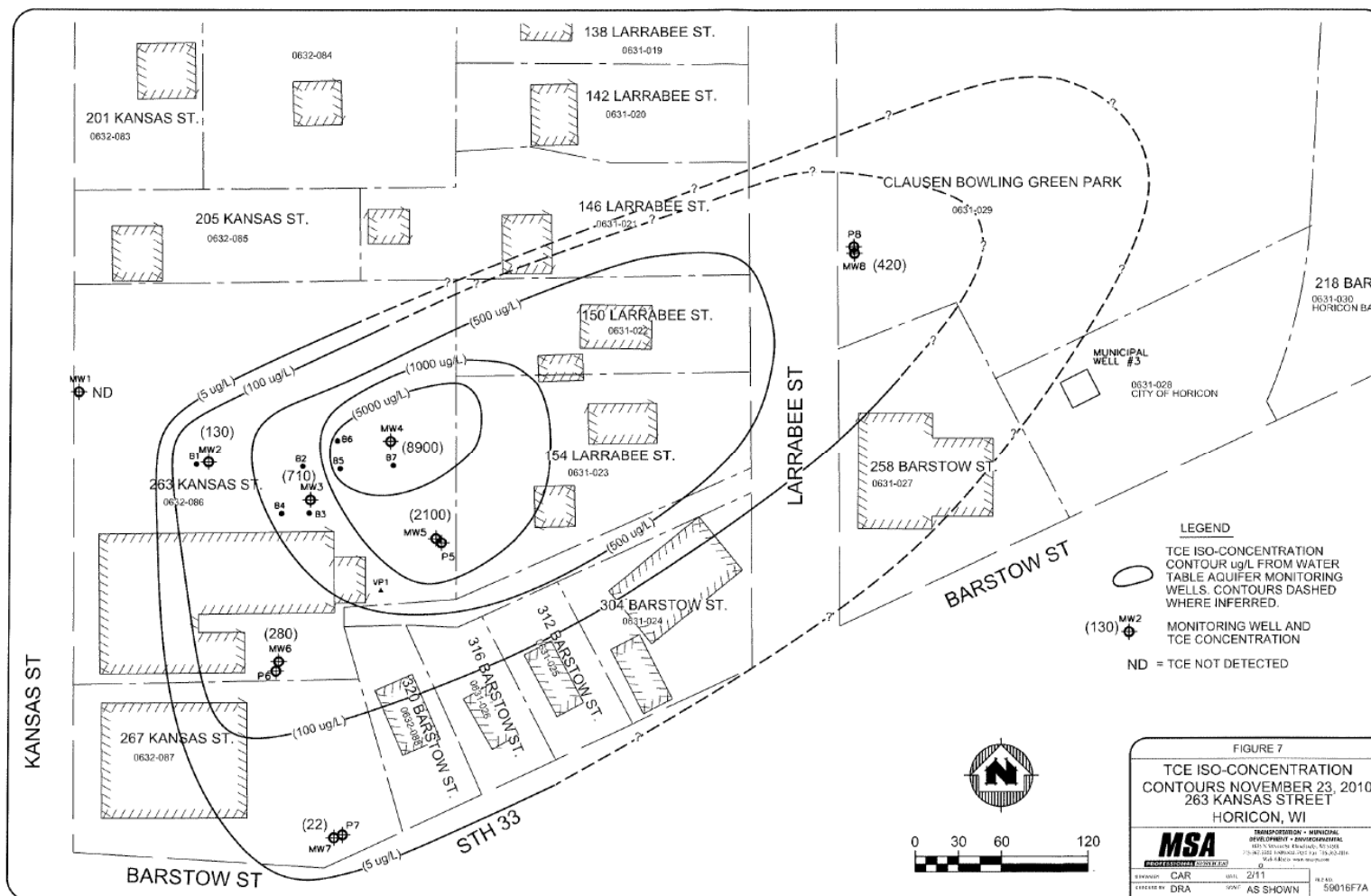
Appendix

Appendix A. Map of the former Gardner Manufacturing site and surrounding area. City of Horicon, Dodge County, Wisconsin.



**Former Gardner
Manufacturing Site**

**Appendix B. Groundwater plume model of TCE discharged from the former Gardner Manufacturing site.
City of Horicon, Dodge County, WI.**



Appendix C. Calculation of 1-in-100,000 Lifetime Theoretical Cancer Risk for Residential TCE Inhalation (US EPA 2011).

US EPA and WDNR 1-in-100,000 Residential Indoor Air Screening Level for TCE: $0.39 \text{ ppbV} = 2.10 \text{ } \mu\text{g}/\text{m}^3$

TCE Inhalation (concentration-equivalence across age groups)

Col A	Col B	Col C	Col D	Col E	Col F	Col G	Col H	Col I	Col J	Col K	Col L
Units:	Exposure scenario parameters				Dose-response assessment calculations						-
		($\mu\text{g}/\text{m}^3 \text{ air}$)	yr	-	($\mu\text{g}/\text{m}^3 \text{ air}$) ⁻¹	-	-	($\mu\text{g}/\text{m}^3 \text{ air}$) ⁻¹	($\mu\text{g}/\text{m}^3 \text{ air}$) ⁻¹	-	
Age group	risk per $\mu\text{g}/\text{m}^3 \text{ air}$ equivalence	Exposure concentration	Age group duration	Duration adjustment (Col D / 70 yr)	Kidney unadjusted lifetime unit risk (p 5-137 [5.2.2.1.4])	Kidney cancer default ADAAF	Kidney ADAAF-adjusted partial risk (Col B x Col C x Col E x Col F x Col G)	Kidney+NHL+ liver unadjusted lifetime unit risk (p 5-139 [5.2.2.2])	NHL+ liver lifetime unit risk (Col I – Col F)	NHL and liver partial risk (Col B x Col C x Col E x Col J)	Total partial risk (Col H + Col K)
Birth to <1 month	1	2.10	0.083	0.0012	1.0E-06	10	2.5E-08	4.1E-06	3.1E-06	7.8E-09	3.3E-08
1 to <3 months	1	2.10	0.167	0.0024	1.0E-06	10	5.0E-08	4.1E-06	3.1E-06	1.6E-08	6.6E-08
3 to <6 months	1	2.10	0.250	0.0036	1.0E-06	10	7.5E-08	4.1E-06	3.1E-06	2.3E-08	9.8E-08
6 to <12 months	1	2.10	0.500	0.0071	1.0E-06	10	1.5E-07	4.1E-06	3.1E-06	4.7E-08	2.0E-07
1 to <2 years	1	2.10	1.000	0.0143	1.0E-06	10	3.0E-07	4.1E-06	3.1E-06	9.3E-08	3.9E-07
2 to <3 years	1	2.10	1.000	0.0143	1.0E-06	3	9.0E-08	4.1E-06	3.1E-06	9.3E-08	1.8E-07
3 to <6 years	1	2.10	3.000	0.0429	1.0E-06	3	2.7E-07	4.1E-06	3.1E-06	2.8E-07	5.5E-07
6 to <11 years	1	2.10	5.000	0.0714	1.0E-06	3	4.5E-07	4.1E-06	3.1E-06	4.7E-07	9.2E-07
11 to <16 years	1	2.10	5.000	0.0714	1.0E-06	3	4.5E-07	4.1E-06	3.1E-06	4.7E-07	9.2E-07
16 to <18	1	2.10	2.000	0.0286	1.0E-06	1	6.0E-08	4.1E-06	3.1E-06	1.9E-07	2.5E-07
18 to <21	1	2.10	3.000	0.0429	1.0E-06	1	9.0E-08	4.1E-06	3.1E-06	2.8E-07	3.7E-07
21 to <30	1	2.10	9.000	0.1286	1.0E-06	1	2.7E-07	4.1E-06	3.1E-06	8.4E-07	1.1E-06
30 to 70	1	2.10	40.000	0.5714	1.0E-06	1	1.2E-06	4.1E-06	3.1E-06	3.7E-06	4.9E-06
Total unit risk:											1.0E-05

ADAF: Age-Dependent Adjustment Factor

NHL: Non-Hodgkins Lymphoma

Appendix D. Calculation of Maximum Lifetime Theoretical Excess Cancer Risk Associated with the Former Gardner Manufacturing Site (*US EPA 2011*).

Maximum Indoor Air TCE Concentration Detected (*Home G*) = 3.61 ppbV = 19.72 µg/m³

TCE Inhalation (concentration-equivalence across age groups)

Col A	Col B	Col C	Col D	Col E	Col F	Col G	Col H	Col I	Col J	Col K	Col L
Units:	Exposure scenario parameters				Dose-response assessment calculations						-
		(µg/m ³ air)	yr	-	(µg/m ³ air) ⁻¹	-	-	(µg/m ³ air) ⁻¹	(µg/m ³ air) ⁻¹	-	
Age group	risk per µg/m ³ air equivalence	Exposure concentration	Age group duration	Duration adjustment (Col D / 70 yr)	Kidney unadjusted lifetime unit risk (p 5-137 [5.2.2.1.4])	Kidney cancer default ADAAF	Kidney ADAAF-adjusted partial risk (Col B x Col C x Col E x Col F x Col G)	Kidney+NHL+ liver unadjusted lifetime unit risk (p 5-139 [5.2.2.2])	NHL+ liver lifetime unit risk (Col I – Col F)	NHL and liver partial risk (Col B x Col C x Col E x Col J)	Total partial risk (Col H + Col K)
Birth to <1 month	1	19.72	0.083	0.0012	1.0E-06	10	2.3E-07	4.1E-06	3.1E-06	7.3E-08	3.1E-07
1 to <3 months	1	19.72	0.167	0.0024	1.0E-06	10	4.7E-07	4.1E-06	3.1E-06	1.5E-07	6.2E-07
3 to <6 months	1	19.72	0.250	0.0036	1.0E-06	10	7.0E-07	4.1E-06	3.1E-06	2.2E-07	9.2E-07
6 to <12 months	1	19.72	0.500	0.0071	1.0E-06	10	1.4E-06	4.1E-06	3.1E-06	4.4E-07	1.8E-06
1 to <2 years	1	19.72	1.000	0.0143	1.0E-06	10	2.8E-06	4.1E-06	3.1E-06	8.7E-07	3.7E-06
2 to <3 years	1	19.72	1.000	0.0143	1.0E-06	3	8.5E-07	4.1E-06	3.1E-06	8.7E-07	1.7E-06
3 to <6 years	1	19.72	3.000	0.0429	1.0E-06	3	2.5E-06	4.1E-06	3.1E-06	2.6E-06	5.2E-06
6 to <11 years	1	19.72	5.000	0.0714	1.0E-06	3	4.2E-06	4.1E-06	3.1E-06	4.4E-06	8.6E-06
11 to <16 years	1	19.72	5.000	0.0714	1.0E-06	3	4.2E-06	4.1E-06	3.1E-06	4.4E-06	8.6E-06
16 to <18	1	19.72	2.000	0.0286	1.0E-06	1	5.6E-07	4.1E-06	3.1E-06	1.7E-06	2.3E-06
18 to <21	1	19.72	3.000	0.0429	1.0E-06	1	8.5E-07	4.1E-06	3.1E-06	2.6E-06	3.5E-06
21 to <30	1	19.72	9.000	0.1286	1.0E-06	1	2.5E-06	4.1E-06	3.1E-06	7.9E-06	1.0E-05
30 to 70	1	19.72	40.000	0.5714	1.0E-06	1	1.1E-05	4.1E-06	3.1E-06	3.5E-05	4.6E-05
Total unit risk:											9.4E-05

ADAAF: Age-Dependent Adjustment Factor

NHL: Non-Hodgkins Lymphoma

