SITE CHARACTERIZATION/RISK ASSESMENT OF TETRACHLOROETHENE (PCE)-CONTAMINATED SITE

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ABSTRACT

A healthcare company purchased property in eastern Iowa for a facility expansion. Before the purchase, a Phase I Environmental Site Assessment (ESA) revealed that the property was the site of a former dry cleaning business. Phase II sampling and testing indicated that tetrachloroethene (PCE) and trichloroethene (TCE) had affected site soil and groundwater. Maximum concentrations of PCE and TCE in groundwater were 538 and 209 mg/L, respectively, and 105 and 1.51 mg/kg in soil. Additional sampling delineated the vertical and horizontal extent of contamination in the soil. Concentrations of the chlorinated solvents in both the soil and groundwater were below levels of regulatory concern. However, the company was concerned that the Statewide Standard for PCE in soil (780 mg/kg) might not provide adequate protection for several exposure pathways and wanted to assess the risk to the public from the contamination at the site. Results of a receptor survey were used to develop site-specific target levels (SSTLs) for contamination, using accepted human health exposure factors, models, and chemical-specific toxicity values. Recommended remedial options allowed the company to minimize the human health risks posed by contamination at the site.

Key words: *chlorinated solvents, risk, tetrachloroethene, trichloroethene*

INTRODUCTION

This paper presents the results of an Environmental Site Characterization (ESC) and the methods and results of a risk-based evaluation performed on a site impacted by tetrachloroethene (PCE) and trichloroethene (TCE).

A healthcare company purchased several parcels of property in the downtown area of an eastern Iowa city. A Phase I Environmental Site Assessment (ESA) performed on the parcels before the purchase concluded that one of the parcels was the former location of a dry cleaning operation. The dry cleaners used a 3000-gallon underground storage tank (UST) for storage of dry cleaning chemicals. A previous owner removed the tank in the early 1980's but did not collect soil samples to evaluate whether the tank leaked.

An Environmental Site Characterization (ESC), conducted to evaluate the extent of contamination from PCE and its degradation compounds, indicated that PCE was present at the site in soil gas, soil, and in the groundwater below the site. Field personnel collected a total of 66 soil gas samples, 36 soil samples, and three groundwater samples from 35 locations across the one-half-acre site. The suspected location of the former UST and the dry cleaning chemical piping had the highest levels of contamination.

Groundwater at the site is about 55 feet below ground surface (bgs). An area approximately 120 feet southwest of the site contains a shallower groundwater unit at a depth of 15 to 20 feet, which is suspected to be a perched water table.

The Iowa Department of Natural Resources (IDNR) stated that contamination in groundwater at the site was not at a level of concern and that they would not require additional characterization of groundwater. The IDNR also said that although the site is not enrolled in Iowa's Land Recycling Program (LRP), a voluntary cleanup program, the Statewide Standard of 780 mg/kg from the LRP would apply for PCE in the soil. Since concentrations of PCE in soil at the site were below the Statewide Standards, the IDNR required no soil remediation.

However, to ensure the safety of patients, employees, and their neighbors, the company proceeded to evaluate the potential health risks posed by contamination at the site.

OBJECTIVES

The objective of this paper is to provide data from an ESC and demonstrate how those data were used to evaluate human health risks from contaminants in soil and groundwater. Three different sets of criteria were used to evaluate health risks at the site. The first set of criteria used the equations, model, and exposure factors from Iowa's Underground Storage Tank (UST) regulations (IAC 567 Chapter 135). The second set of criteria also used the equations and model from Iowa's UST regulations but used exposure factors from IDNR's LRP (IAC 567 Chapter 137). These first two sets of criteria are site-specific. The third set of criteria, the most conservative of the three, was the Statewide Standards from the LRP regulations and is not site-specific. The exposure factors for the UST and LRP regulations are in Table 1.

ENVIRONMENTAL SITE CHARACTERIZATION

Previous Investigations

Historical review of the site indicated that the lots were exclusively in residential single and multi-family housing through 1913. By the 1940s, the site contained one residence and a dry cleaning operation. Between 1970 and 1982, the residence was demolished for the rerouting of a street, and between 1982 and 1987 the dry cleaners was demolished and the site paved for use as an automobile sales lot. During paving of the lot, a UST containing dry cleaning chemicals was discovered, emptied, and removed. No evidence existed of soil or groundwater sampling after the removal of the tank.

A Phase I ESA first indicated the potential for contamination. The existence of a former dry cleaning facility and the discovery of the former UST that contained dry cleaning chemicals constituted a "recognized environmental condition" and an area of risk. The ESA found that dry cleaning activities had occurred at the site as early as 1940 to as late as 1987. Limited soil gas sampling and on-site analysis conducted in the area believed to be the site of the former tank confirmed the presence of PCE in the soil at the site.

Physical Setting

Continuous sampling, performed at several borehole locations, documented the geological setting of the site. The site still contained the buried remnants of the basement and foundation of the former dry cleaning facility and possibly other foundations or basements from the former residences. Sand filled some of the former basements. In other areas, the surface of the site consisted of a layer of fill material containing pulverized limestone road material and native soils. Below the fill material a light brown, highly permeable sand existed with intermittent clay lenses. Refer to Figure 1 for locations of soil borings.

The bedrock at the site is Devonian Wapsipinicon Formation. This formation consists of limestone on the top; then dolomite, shale and clayey limestone, followed by dolomite limestone with dolomite at the base. The Wapsipinicon Formation is part of the Silurian-Devonian aquifer. According to bedrock topography maps, bedrock in the area lies between 650 and 700 feet mean sea level (msl), which is approximately 60 to 120 feet bgs. Well logs from the Iowa Geological Survey Bureau (GSB) in Iowa City indicate bedrock in the area varies from 3 feet to 310 feet bgs.

A two-foot thick silty clay layer at about 10 to 12 feet bgs decreased permeability at that depth. Water was not present above this clay unit on the site; however, in a monitoring well (MW-14) installed during a petroleum investigation on an adjacent property and located southwest of the site, groundwater was perched above the clay. Groundwater at the site was at 55 feet bgs within the sand unit. (Soil borings advanced for the nearby petroleum contamination investigation on an adjacent property encountered bedrock at a range of 15 to 36 feet bgs and groundwater at about 55 feet bgs.) The predominant groundwater flow direction, as determined by the petroleum site investigation, was generally to the south. At the site, however, there was no bedrock found within 105 feet of the ground surface.

Soil Gas and Soil Sampling

GeoProbe™ technology was used to draw soil gas samples from various depths at sampling locations most likely to contain PCE. Sampling locations were determined based on the approximate location of the removed tank at the former dry cleaning establishment and the results of soil gas samples. Analysis of soil gas samples took place on site using a gas chromatograph.

To confirm and correlate data obtained from soil gas sampling and to gather data on the underlying stratigraphy, field personnel collected 36 soil samples from 24 GeoProbe™ and soil boring locations as indicated in Figure 1. Areas both above and below the clay were sampled, as well as deeper areas at several locations, to determine the level of impact in the soil immediately above and within the water table.

Groundwater Sampling

Two groundwater samples were collected during the GeoProbe™ investigation from GeoProbe™ location P-6. In addition, three monitor wells placed at two boring locations were

used to investigate groundwater conditions at the site. Two wells (MW-6A and MW-31A) screened at a shallow depth monitored water potentially located above the clay layer. A third well (MW-6B), placed near well MW-6A, monitored water at a depth of 92.5 to 102.5 feet bgs. Additionally, field personnel collected a groundwater sample from the existing monitoring well (MW-14) located on the southwest side of the block. Groundwater samples from MW-6B and MW-14 were analyzed for volatile organic compounds (VOCs) by EPA Method SW 8260B. MW-6A and MW-31A failed to produce water.

Sampling Results

The PCE results of the 66 soil gas samples collected ranged from non-detect to 19,485 mg/L. Table 2 presents a summary of results for soil and soil gas between 10 and 25 feet bgs. The highest concentrations of PCE detected in soil gas were in the 12 to 25 bgs interval in the area of P-6. Actual soil sampling and testing in this area confirmed that it contained the highest concentrations of PCE in soil. Soil gas analyses also indicated elevated concentrations in the area of B-28 (2480 mg/L) and B-31 (2361 mg/L) at depths of 40 and 50 feet, respectively.

Results from the 36 soil samples collected and analyzed for VOCs, using EPA Method 8260B, ranged from non-detect in the outer perimeter samples to 105 mg/kg near the former tank location. The highest levels found were in the area of P-6 and P-40, both located near the suspected location of the former UST and piping runs. Elevated concentrations of PCE in the soil were present at a variety of depths but generally above the clay layer in the areas of P-6, MW-31, and P-34. Elevated concentrations were also present in an area suspected to be the dry cleaning facility's basement at P-43.

Laboratory analytical results indicated VOCs other than PCE in several samples. Table 3 contains a summary of the sample locations and compounds detected. Some of these compounds, such as TCE and *cis* 1, 2-dichloroethene (DCE), are suspect breakdown products of PCE. Others, such as methylene chloride, may indicate other solvent use.

During GeoProbe™ sampling activities, analysis of a groundwater sample collected from a depth of 50 to 55 feet bgs in the area of P-6 indicated groundwater from this depth contained 538 ug/L PCE.

Two of the newly installed monitoring wells, MW-6A and MW-31A, screened from 10 to 20 feet and from 14 to 24 feet, respectively, never yielded enough water for sampling. Analysis of a sample collected from the third well, MW-6B, located near the suspected area of the tank and screened from 92.5 to 102.5 feet bgs, revealed a concentration of 90.1 mg/L of PCE. Monitoring well MW-14, screened at a depth of 15 to 20 feet bgs, indicated a PCE concentration of 5.4 mg/L.

Other contaminants found in groundwater samples in the area of P-6 included TCE, *cis* 1, 2-DCE, and chloroform.

RISK EVALUATION

Three different sets of criteria were used to evaluate the potential human health risk at the site. The first set of criteria used the equations, target risk, target hazard quotient, exposure frequency, and duration from Iowa's UST regulations (Iowa Department of Natural Resources, 1998). The second set of criteria also used the equations from these regulations but used exposure factors from Iowa's LRP regulations (Environmental Protection Commission, 1998). These first two sets of criteria are site-specific. The third set of criteria is the Statewide Standards from the LRP regulations and is not site-specific. Table 4 lists toxicity and chemical-specific human health risk factors.

Identification of Receptors

The identification of actual and potential receptors was the first step in the risk evaluation process. The receptor identification process included determining the presence of drinking and non-drinking water wells, protected groundwater source, plastic drinking water lines, enclosed spaces, and surface water bodies.

The Geological Survey Bureau provided information on wells within 1000 feet of the site. Hydraulic conductivity testing revealed that a contaminant plume could spread beyond 1000 feet so GSB provided information on wells within one-half mile of the site. The search identified eight non-drinking water wells and no drinking water wells within one-half mile (2640 feet) of the site.

Field personnel performed three bail-down tests on the deep well installed at the site, logging the results with a datalogger. The test results, when analyzed by the Bouwer and Rice Method, indicated hydraulic conductivities of 13.24 m/day, 8.75 m/day, and 84.57 m/day. The hydraulic conductivity used for the risk calculations was 13.24 m/day because it was the median result and also because the timing of the tests was close together and may have affected the results of the last two tests. This hydraulic conductivity established the aquifer underlying the site is in the IDNR category of a "protected groundwater source" since the hydraulic conductivity exceeded 0.44 m/day.

Plastic drinking water lines in contact with contaminated soil or groundwater can provide a pathway for ingestion of contamination. The city water department stated that no plastic drinking water lines were in service near the site.

Enclosed spaces where vapors can accumulate were a concern. Sanitary sewers can provide such an enclosed space as well as basements. One sanitary sewer ran along the northwest side of the site. An explosimeter survey alleviated concern that explosive levels of vapors were present in basements and other enclosed spaces near the site. Potential vapors coming from contaminated soil and groundwater and entering the basement of the future healthcare facility expansion were of concern.

No surface water bodies were located near the site or subject to impact from contamination requiring no further evaluation of this pathway.

Groundwater Ingestion Pathway

In order to assess more accurately the potential impact of the contamination, field personnel collected groundwater samples for VOC analysis from monitoring wells located on neighboring properties, as well as collecting a second round of groundwater samples from the site. Table 5 presents groundwater sampling data summaries. The wells sampled included MW-6B, located at the site; MWs 4 and 5, installed southeast of the site during the earlier petroleum hydrocarbon investigation; and MW-8, installed west of the site during the same petroleum hydrocarbon investigation.

The high concentration of petroleum hydrocarbon in MW-5 necessitated that the laboratory make several dilutions before analysis. This resulted in an elevated reporting limit for PCE. The TCE concentration in MW-5 was higher than that at the site, potentially due to the proximity of other off-site sources of the chemical. These factors resulted in exclusion of the results from MW-5 from the risk evaluation. Investigation of potential off-site sources was outside the scope of this project.

Of the eight compounds identified in groundwater at the site, PCE, TCE, *cis* 1,2-DCE, *trans* 1,2-DCE, chloroform, vinyl chloride, 1,1-DCE, and methylene chloride, this risk evaluation addressed only PCE and TCE. *Cis* 1,2-DCE, *trans* 1,2-DCE, chloroform, vinyl chloride, and 1,1-DCE were each below the maximum contaminant level (MCL) for these chemicals in drinking water. The reporting limit for methylene chloride was 10 mg/L and the MCL was five mg/L. The evaluation for risk excluded methylene chloride since it was not only below the method detection limit, but was not found in elevated concentrations in the soil.

For all groundwater calculations, the source of PCE and TCE was assumed to be at B6-M. A GeoProbe™ groundwater sample collected at that location yielded a PCE concentration of 538 mg/L and a TCE concentration of 209 mg/L.

Drinking water wells. A search by GSB for wells within one-half mile of the site yielded no drinking water wells. Using the transport equations from IDNR's UST regulations and guidance, the concentration of PCE at one-half mile from the site was calculated to be 4.3 mg/L, based on the conservative assumption that no decay of PCE was taking place. This was below the MCL of five mg/L. Groundwater flow direction (southerly), plume range (150 degrees), and hydraulic gradient (0.00176 ft/ft) were derived from a Tier 2 Site Cleanup Report prepared on an adjacent property. Because the source concentration of TCE was less than that of PCE and the MCL for TCE was also five mg/L, it was reasoned that the TCE plume at one-half mile from the site was also less than the MCL. Based on the above assumption, risk from exposure through this pathway was found to be minimal when measured against the site-specific requirements of IDNR's UST and LRP regulations, both of which require the receptor concentration not exceed the MCL.

Statewide Standards, however, as provided by IDNR's LRP regulations, require that the source concentration not exceed the MCL; meaning that PCE and TCE would pose a health risk when compared to this standard.

Non-drinking water wells. The Geological Survey Bureau identified eight non-drinking water wells within a one-half-mile radius of the site. The well determined to be most at risk is located approximately one-third mile downgradient from the site. Site specific target levels (SSTLs) were calculated for the source well based on a maximum acceptable concentration at the receptor well of 70 mg/L PCE and 42 mg/L TCE. These receptor well targets were calculated using the UST and LRP exposure factor and the UST risk equations from the IDNR regulations. The SSTLs were 3900 mg/L PCE and 2100 mg/L TCE. These SSTLs were calculated using the exposure factors from IDNR's LRP regulations and equations from IDNR's UST regulations. The actual concentrations at the source for PCE and TCE were 538 mg/L and 209 mg/L, respectively, well below the SSTLs.

Calculations based on exposure factors in IDNR's UST regulations would permit up to 360 mg/L of PCE and 210 mg/L of TCE at the receptor well. This would result in SSTLs of 20,200 mg/L for PCE and 11,800 mg/L for TCE at the source well. Based on SSTLs calculated both ways, risk from exposure through this pathway was found to be minimal.

The site failed when compared with the Statewide Standards because the source well must not exceed the MCL of five mg/L for any protected groundwater source. Table 6 summarizes the SSTLs calculated from each set of exposure factors and the Statewide Standards.

Protected groundwater source. The site is a protected groundwater source by the IDNR definition. The PCE concentration of 538 mg/L at the source exceeded the two SSTLs as well as the Statewide Standard. (The Statewide Standard does not increase from the five-mg/L limit for a protected groundwater source.) For calculations based on the IDNR's UST and LRP exposure factors, the SSTL for PCE at the source in protected groundwater was 360 and 70 mg/L, respectively, without an institutional control in place. For the Statewide Standards, the source may not exceed the MCL of five mg/L in a protected groundwater source.

The TCE concentration at the source, 209 mg/L, was less than the 210-mg/L target, based on IDNR's UST exposure factors. The TCE concentration at the source exceeded the target of 42 mg/L calculated based on IDNR's LRP exposure factors. The TCE concentration at the source also exceeded the Statewide Standard which requires a level less than five mg/L at any point in a protected groundwater source.

Soil Leaching to Groundwater Pathway

The concern with the soil leaching to groundwater pathway is that contaminants in the soil will continue to leach to the groundwater, increasing the chance of groundwater exceeding its target level

for contamination.

The soil contamination source was assumed to be P-40, which had a PCE concentration of 105 mg/kg and a TCE concentration of 1.51 mg/kg.

Non-drinking water wells. The nearest well could be at risk for soil leaching PCE to groundwater under the most restrictive criteria, which was using the exposure factors from IDNR's LRP regulations. To eliminate the risk from PCE for this pathway, the concentration in the soil would have to be less than 61.0 mg/kg. TCE in soil is already less than the 12.0 mg/kg required, minimizing risk to the nearest well from TCE at the site.

Using the less restrictive IDNR UST exposure factors, PCE cleared this pathway with the SSTL being 314 mg/kg.

The Statewide Standards for PCE and TCE in soil remain at 780 and 180 mg/kg, respectively. This pathway is clear using Statewide Standard criteria.

Protected groundwater source. Based on calculations using either the IDNR's UST or LRP exposure factors, the concentrations of PCE and TCE in the soil at the source exceeded the SSTLs calculated for the soil leaching to the protected groundwater source pathway. With an institutional control in place, the allowable PCE at the soil source was calculated at 1.9 mg/kg and the allowable TCE was 0.41 mg/kg based on IDNR's LRP exposure factors. Based on IDNR's UST exposure factors, the SSTLs were 9.9 mg/kg and 2.1 mg/kg, respectively.

The Statewide Standard for PCE in soil, as provided in IDNR's LRP, however, is 780 mg/kg and the Statewide Standard for TCE is 180 mg/kg. The site failed both of the site-specific criteria for this pathway for PCE, and TCE failed when using the LRP exposure factors.

Groundwater vapor. The pathway is an evaluation of the potential for soil to leach to groundwater to such an extent that vapors from the groundwater become a health risk by migrating into enclosed spaces. The actual receptors at risk for soil leaching to groundwater vapor were the existing basement of the truck sales building on the site, the future basement of the new healthcare facility, and the sanitary sewer running along the alley to the north of the site. The SSTL for PCE in the soil was 33.5 mg/kg in order to protect the environment of the truck sales building basement using IDNR's LRP exposure factors. Using the exposure factors from IDNR's UST regulations, the allowable PCE in the soil was 160 mg/kg. Since the actual PCE concentration was 105 mg/kg, the site cleared this pathway for PCE using the exposure factors from the UST regulations but failed when using the factors from the LRP.

In order to protect the environment of the future facility basement, the SSTL for PCE was 56.6 mg/kg (IDNR's LRP exposure factors) or 270 mg/kg (IDNR's UST exposure factors). Again, the site cleared this pathway for PCE using the exposure factors from IDNR's UST regulations but failed when using the factors from the LRP. Based on the location of the sanitary sewer, allowable concentrations of PCE in the soil were even higher still, so this was not calculated. Soil

leaching TCE to groundwater vapor did not pose an unacceptable risk based on the low concentration of TCE in site soil.

Statewide Standards were higher than the actual contaminant concentrations from PCE and TCE, thus passing the site when using non site-specific criteria.

Groundwater Vapor to Enclosed Space Pathway

Groundwater vapor accumulation in enclosed spaces from existing groundwater contaminant levels did not pose a risk to human health when SSTLs were calculated based on IDNR's UST exposure factors. The SSTL for PCE in groundwater was 8100 mg/L and for TCE it was 2000 mg/L, well above the actual concentrations in groundwater. SSTLs for PCE and TCE in groundwater based upon the IDNR's LRP exposure factors were 1700 mg/L and 1500 mg/L, respectively. They were also well above the actual concentrations for this pathway. This pathway did not pose an unacceptable risk based upon the criteria.

Statewide Standards do not deviate from the MCL of five mg/L for PCE and TCE based on this pathway.

Soil Vapor to Enclosed Space Pathway

The existing basement of the truck sales building was at risk for vapors from the soil due to PCE concentrations in the soil. The SSTL based on exposure factors from IDNR's UST and LRP regulations were 52 mg/kg and 10.8 mg/kg, respectively. PCE concentration in site soil (105 mg/kg) was above the target level. TCE concentrations did not pose a risk for either of the site-specific criteria. Statewide Standards for soil, as mentioned earlier, are 780 mg/kg for PCE and 180 mg/kg for TCE.

Due to its location, the future basement of the new facility was not at risk for exposure to unacceptable vapor concentrations of PCE or TCE from existing contamination.

CONCLUSIONS

These conclusions were based upon models, equations, and exposure factors found in IAC 567 Chapters 135 (IDNR's UST regulations) and IAC 567 Chapter 137 (IDNR's LRP regulations). The calculations were designed to project the potential for risk and do not predict future conditions. Chemical-specific parameters used were from public sources (U.S. Department of Energy, 1999).

Groundwater

Based upon site-specific evaluations of risk and using exposure factors from IDNR's UST and LRP regulations, concentrations of PCE and TCE in groundwater did not pose an unacceptable risk of exposure to the actual receptors evaluated, which included eight non-drinking water wells located within a one-half mile radius of the site.

The aquifer underlying the site was a protected groundwater source by the IDNR definition. PCE concentrations exceeded the calculated SSTLs whether being calculated using IDNR's UST or LRP exposure factors. TCE concentrations exceeded the more stringent SSTL calculated with the exposure factors in IDNR's LRP regulations but passed using factors from IDNR's UST regulations.

The Statewide Standard for PCE or TCE in groundwater is five mg/L and not site-specific. PCE and TCE concentrations both exceed five mg/L.

Soil

Concentrations of PCE and TCE in the soil were considered a risk due to the ability of the contaminant to leach into the groundwater, potentially putting the non-drinking water wells and the protected groundwater source at risk in the future. Calculations also indicated that contaminants leaching from the soil could elevate contaminant levels in the groundwater to an extent that vapors from the groundwater could become a problem in enclosed spaces in the vicinity of the truck sales building. These conclusions are from the site-specific criteria. According to the non-site specific Statewide Standards, the level of risk is acceptable.

Vapors moving directly from the soil into enclosed spaces also presented a risk to the sales building basement according to the criteria used for this evaluation.

The Statewide Standards for PCE and TCE in soil are 780 mg/kg and 180 mg/kg, respectively. Contaminants are well below these concentrations.

RECOMMENDATIONS

Groundwater

Attaching an environmental easement to the deed to the property, and possibly on adjoining properties, that would prevent the installation of drinking and non-drinking water wells would provide protection against ingestion of contaminated groundwater.

Although the concentrations of PCE and TCE in the groundwater at the site exceeded Statewide Standards provided in IDNR's LRP regulations, the IDNR has stated that the concentrations do not warrant further investigation of the site due to the depth and complexity of the hydrogeologic system and the potential for commingled plumes from off-site sources.

Soil

Excavation of an area approximately 15 feet square by 15 feet deep centered on the location of sample P-40 would remove soil inside of the calculated 50-mg/kg soil plume. A level of 50 mg/kg would clear the soil leaching to groundwater ingestion pathway for the nearest well and for soil leaching to groundwater vapor for the basement of the new hospital facility. In actuality, the concentration of remaining PCE in the soil will probably be much lower than 50 mg/kg due to the way the model interpolated concentrations between data points. This should adequately protect the future

basement from vapors.

After excavation, the only soil pathway which would remain affected by the soil contamination according to risk calculations, would be the soil leaching to protected groundwater source and soil leaching to groundwater vapor to the existing basement of the truck sales building. With an institutional control in place to eliminate the extraction of groundwater near the site and the planned demolition of the truck sales building, this should provide adequate protection would be afforded to the public from contaminated soil at the site.

REFERENCES

Environmental Protection Commission, 1998, Chapter 137, "Iowa Land Recycling Program and Response Action Standards," Iowa Administrative Code, 137.5(4).

Iowa Department of Natural Resources, 1998, Tier 2 Site Cleanup Report Guidance, Version 2.14, Appendix A.

U.S. Department of Energy, Office of Environmental Management, Oak Ridge Operations Office and the DOE Center for Risk Excellence, 1999, Risk Assessment Tools, Toxicity Values and Chemical Specific Factors, http://risk.lsd.ornl.gov/tox/tox_values.html.

Table 1. Exposure factors for non-residential zoning in a protected groundwater source.[a]

	IOWA'S UST REGULATIONS[b]	IOWA'S LRP REGULATIONS[c]
ATc - Averaging time for carcinogens (years)	70	70
ATn - Averaging time for non-carcinogens (years)	25	70
BW - Body weight (kg)	70	70
ED - Exposure duration (years)	25	70
EF - Exposure frequency (days/year)	250	365
TR - Target risk for carcinogens (unitless)	$1x10^{-4}$ or $1x10^{-6}$ [d]	$5x10^{-6}$
THQ - Target hazard quotient (unitless)	1.0	0.02[e] or 0.20[f]

[a] A protected groundwater source is an aquifer with a hydraulic conductivity (K) of ≥ 0.44 meters/day.
[b] (Iowa Department of Natural Resources, 1998)
[c] (Environmental Protection Commission, 1998)
[d] Pathway dependent
[e] For Cancer Group C chemicals such as 1,1-DCE
[f] For Cancer Groups D and E chemicals such as PCE and *cis* 1,2-DCE

Table 2. Soil gas and soil PCE analytical results.

DEPTH (FEET)	P-2	P-4	P-5	P-6	P-7	P-9	B-20	B21	P-22	B-23	B-24	P-25	B-26	B-27
10-15	5760[a]	852[a]	2017[a]	89.3[c] 8173[a]	4034[a]	1595[b]	715[a] 13[c]	405[a]	298[a]		191[a]		109[a]	453[a]
15-20				14935[a]										
20-25				19485[a] 13000[c]			144[a]	796[a]	194[a]	233[a] ND[c]	279[a] ND[c]	380[a] ND[c]	202[a] ND[c]	49[a] ND[c]

DEPTH (FEET)	B-28	B-29	B-31	B-32	MW-14	P-34	P-35	P-37	P-38	P-39	P-40	P-42	P-44
10-15	603[a]	388[a]	51.6[c]			14.6[c] 15.1[c]	ND[c] 6.3[c]	ND[c]	ND[c]	ND[c]	ND[c]	ND[c] 10.3[c]	ND[c]
15-20					5.4[e]			13.4[c]	362[c]	41.5[c]	105,000[c]		37.8[c]
20-25	835[a] 54.5[c]	ND[a] ND[c]		459[a]									

[a]soil gas (µg/L)
[b]soil sample, field analyzed (µg/kg)
[c]soil sample, laboratory analyzed (µg/kg)
ND = not detected

Table 3. Other contaminant concentrations.

CONTAMINANT	SOIL SAMPLE IDENTIFICATION AND DEPTH						
	B-6A 22'-24' (µg/kg)	B6-CA 11.75' (µg/kg)	B28-A 24'-26' (µg/kg)	P38 15' (µg/kg)	P40 12.5' (µg/kg)	P40 15' (µg/kg)	P43 9.5' (µg/kg)
n-butylbenzene	3,670	17.2		57.6		10,300	
sec-butylbenzene	2,350			44.5		7,260	
isopropylbenzene	207					1,060	
p-isopropyltoluene	1,690	12.6		79.6			
n-propylbenzene	1,180					4,360	
1,2,4-trimethylbenzene	2,900			20.7		5,710	
1,3,5-trimethylbenzene	204					2,110	
TEH as Diesel	1,000	530	12				
methylene chloride		56.2			55.4		
trichloroethene		214		30.5		1,510	
chlorotoluene				5.3			
tert-butylbenzene						4,730	
2-chlorotoluene						394	
ethylbenzene						398	
xylenes, total						927	
cis 1,2-dichloroethene							9.6
	GROUNDWATER SAMPLE IDENTIFICATION AND DEPTH						
	B6-M 51' (µg/L)	B6-W 91' (µg/L)	MW-6B 92'-102' (µg/L)				
trichloroethene	209	13.7	18.5				
cis 1,2-dichloroethene	5.5						
chloroform	3.3						

Table 4. Toxicity and chemical-specific human health risk factors[a].

		Carcinogen Class	SF_o[b]	R_fD_o[c]	SF_i[d]	R_fD_i[e]
CARCIN-OGENS	chloroform	B2	6.1e-3	1.0e-2	8.1e-2	none
	vinyl chloride	A	1.90	none	3.0e-1	none
	methylene chloride	B3	7.50e-3	6.0e-2	1.65e-3	8.57e-1
NON-CARCIN-OGENS	tetrachloroethene	none	5.2e-2	1e-2	2.0e-3	1.70e-1
	trichloroethene	none	1.1e-2	6.0e-3	6.0e-3	none
	cis 1,2-dichloroethene	D	none	1.0e-2	none	none
	trans 1,2-dichloroethene	none	none	2.0e-2	none	none
	1,1-dichloroethene	C	6.0e-1	9.0e-3	1.2	none

[a]U.S. Department of Energy, 1999
[b]oral slope factor
[c]oral reference dose
[d]inhalation slope factor
[e]inhalation reference dose

Table 5. Groundwater sampling summary for PCE and TCE.

BORING/WELL NUMBER	DATE	PCE(µg/L)	TCE(µg/L)
B6-W	8/4/98	50.3	13.7
B6-M	8/7/98	538	209
MW-14	8/11/98	5.4	<1.0
MW-6B	8/21/98	90.1	18.5
MW-6B	12/8/98	33.1	5.3
MW-5	12/8/98	<200	575
MW-4	12/8/98	<1.0	<1.0
MW-8	12/8/98	17.9	

Table 6. Summary of source target levels.

MEDIA	PATHWAY	RECEPTOR	PCE	TCE	PCE	TCE	PCE	TCE
			Chap. 135 Exp. Factors (UST)	Chap. 135 Exp. Factors (UST)	Chap. 137 Exp. Factors (LRP)	Chap. 137 Exp. Factors (LRP)	Statewide Standards	Statewide Standards
Groundwater (mg/L) Actual PCE =538 Actual TCE =209	Groundwater Ingestion	Receptor Well	20200	11800	3900	2100	**5**	**5**
		Protected GW-No IC[a]	**360**	210	**70**	**42**	**5**	**5**
		Protected GW-w/IC All	950	550	**180**	**110**	**5**	**5**
Soil (mg/kg) Actual PCE =105 Actual TCE =1.51	Soil Leaching to Groundwater	Receptor Well	314	65.0	**61.0**	12.0	780	180
		Protected GW-No IC[a]	**5.6**	1.2	**1.08**	**0.23**	780	180
		Protected GW-w/IC All	**9.9**	2.1	**1.9**	**0.41**	780	180
		GW Vapor-Truck Sales Basement	160	14.0	**33.5**	10.5	780	180
		GW Vapor-New Facility	270	23.8	56.6	17.8	780	180
	Soil Vapor to Enclosed Space	All	**52**	4	**10.9**	3.4	780	180

Figure 1. Sampling locations.
B = Soil boring
P = GeoProbe™ location
MW = Monitoring well