Health Consultation

Evaluation of Indoor Air

MENDENHALL SQUARE

MEMPHIS, SHELBY COUNTY, TENNESSEE, 38115

Prepared by the Tennessee Department of Health

November 16, 2020

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

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Prepared by:

Tennessee Department of Health
Environmental Epidemiology Program
Nashville, Tennessee

Foreword

This document summarizes an environmental public health investigation performed by the State of Tennessee Department of Health's Environmental Epidemiology Program. Our work is conducted under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry. The process to answer environmental public health questions includes many steps, including the following:

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, other government agencies, businesses, and the public. We work to understand how much contamination might be present, where it is located on a site, and how people might be exposed to it. We look for evidence that people might have been, are being, or in the future could be exposed to harmful substances.

Evaluate health effects: If people could 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 routes of exposure, risk assessments, 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. Environmental Epidemiology serves as an advisor in dealing with hazardous waste sites. Often, our recommendations will be action items for other agencies. However, the Tennessee Department of Health can issue a public health advisory warning people of the danger of an urgent public health hazard 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.

Write: Environmental Epidemiology Program
Tennessee Department of Health
3rd Floor, Andrew Johnson Tower
710 James Robertson Parkway
Nashville TN 37243

Call: 615-741-7247 or 1-800-404-3006 (toll-free) during normal business hours

Email: eep.health@tn.gov

Table of Contents

Summary

The Tennessee Department of Health's (TDH) Environmental Epidemiology Program (EEP) has a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR) to protect people from exposure to chemicals in Tennessee.

Our Environmental Epidemiology Program was asked by the Tennessee Department of Environment and Conservation's (TDEC) Division of Remediation to evaluate indoor air data collected in a school. This school is located in the Mendenhall Square Shopping Center in southeast Memphis, Shelby County. The school is operated as an elementary charter school with about 780 students in kindergarten through fifth grade.

From 1971 to 1997, a drycleaner operated in the Mendenhall Square Shopping Center. TDEC's Drycleaner Environmental Response Program determined the drycleaning chemical, tetrachloroethylene (PCE), along with its breakdown chemicals, trichloroethylene (TCE), cis- and trans-1,2-dichloroethylene (1,2-DCE), and vinyl chloride (VC) have contaminated soil, soil gas, and groundwater. A portion of the school includes the area of and surrounding the former drycleaner.

Groundwater at the site contains these drycleaner-related chemicals at levels of several hundred to several thousand micrograms per liter. Significant levels of drycleaner-related chemicals were found in soil gas beneath the former cleaner and beneath adjacent areas of the shopping center. A vapor intrusion mitigation system (VIMS) was installed in 2014 beneath the floor of the former cleaner to remove drycleaner-related chemical vapors in soil gas and ultimately reduce the levels of chemical vapors in the indoor air of the former shopping center.

The proper functioning and operation of the VIMS is critical to reducing indoor air levels of drycleaner-related chemicals. Without proper operation of the VIMS system, chemical vapors could move from the soil gas and groundwater beneath the building into the indoor air of the school classrooms. Indoor air levels of chemicals would be considerably higher if the VIMS was not present or operating properly.

TDH EEP reviewed previously collected soil gas, groundwater data, and most importantly, indoor air sampling data collected by the charter school's environmental consultant. The indoor air data was collected over eight months in 2019 and 2020. TDH EEP carefully considered if the chemical vapors measured in some classrooms could be a health risk to students, teachers, or staff. Possible student exposure to drycleaner solvent vapors was considered for the 6 years a student would progress through school grades. Teacher and staff exposures were considered for 6, 10, 15, and 20 years.

TDH EEP reached two conclusions about breathing indoor air at the charter school located in the Mendenhall Square Shopping Center:

- Breathing drycleaner-related volatile organic compounds is not expected to harm the health of students learning in the school provided continued operation of the VIMS keeps concentrations of PCE and its degradation products at the same or lower

concentrations as analyzed in this assessment because measured and averaged indoor air sampling results for PCE, TCE, DCE, and VC, adjusted to represent a 10 hour per day, 5 day per week, and 6 year exposure for students, were lower than both non-cancer and cancer health comparison values.

- Breathing drycleaner solvent vapors is not expected to harm the health of teachers or staff working in the school for many years provided continued operation of the VIMS keeps concentrations of PCE and its degradation products at the same or lower concentrations as analyzed in this assessment. Measured and averaged indoor air sampling results for PCE, TCE, DCE, and VC adjusted to represent a 10 hour per day, 5 day per week, and 6, 10, 15 & 20 year exposures were lower than both non-cancer and cancer health comparison values for all exposure scenarios.

TDH recommends the school and their environmental consultant continue to perform indoor air testing. The indoor air testing should be done quarterly for a minimum of one year. Thereafter, testing should be conducted semi-annually or annually as needed for a period of time to show if drycleaner chemicals are absent or only present in very low levels in the indoor air of the school, and the VIMS should continue to function as intended to protect the health of students, teachers, and staff of the school. The frequency of future indoor air testing will be reviewed by both TDEC and TDH.

In addition to continuing to operate the VIMS, TDH recommends operate and monitor the HVAC system, perform monthly pressure field tests, and continue work to decrease chemical levels in the indoor air of the school to preferably non-detect levels.

Overview

The Tennessee Department of Health's Environmental Epidemiology Program reached two conclusions about breathing indoor air in the charter school located in the Mendenhall Square Shopping Center.

Conclusions

Conclusion 1

Breathing drycleaner solvent vapors is not expected to harm the health of students learning in the school provided continued operation of the vapor intrusion mitigation system (VIMS) keeps concentrations of PCE and its degradation products at the same or lower concentrations as tested in this assessment.

Basis for Decision

Measured and averaged indoor air sampling results for PCE, TCE, DCE, and VC were adjusted to represent a 10 hour per day, 5 day per week, and 6 year exposure for students. Chemical vapor levels were lower than both non-cancer and cancer health comparison values.

Next Steps

TDH recommends indoor testing to be done for a minimum of one year on a quarterly basis. Thereafter, testing should be conducted semi-annually, and annually as needed for a period of time to show if drycleaner-related chemicals are absent or only present in very low levels in the indoor air of the school, and the mitigation system should continue to function as intended to protect the health of students, teachers, and staff of the school. The frequency of future indoor air testing will be reviewed by both TDEC and TDH.

Along with continuing to operate the VIMS, TDH recommends continuing to operate and monitor the HVAC system, perform monthly pressure field tests, and continue work to decrease chemical levels in the indoor air of the school to preferably non-detect levels.

Conclusion 2

Breathing drycleaner solvent vapors is not expected to harm the health of teachers or staff working in the school for many years provided continued operation of the VIMS keeps concentrations of PCE and its degradation products at the same or lower concentrations as tested in this consultation.

Basis for Decision

Measured and averaged indoor air sampling results for PCE, TCE, DCE, and VC were adjusted to represent a 10 hour per day, 5 day per week, and 6, 10, 15, and 20 year exposures for teachers and staff. Chemical vapor levels were lower than both non-cancer and cancer health comparison values for all exposure scenarios.

Next Steps	TDH recommends indoor testing to be done for a minimum of one year on a quarterly basis. Thereafter, testing should be conducted semi-annually, and annually as needed for a period of time to show if drycleaner-related chemicals are absent or only present in very low levels in the indoor air of the school and the mitigation system should continue to function as intended to protect the health of the students, teachers, and staff of the school. The frequency of future indoor air testing will be reviewed by both TDEC and TDH. Along with continuing to operate the VIMS, TDH recommends continuing to operate and monitor the HVAC system, perform monthly pressure field tests, and continue work to decrease chemical levels in the indoor air of the school to preferably non-detect levels. We recommend all the above even though our analysis shows there should not be health effects to the children, teachers, or staff. The continued indoor air testing will ensure the charter school and the TDEC Division of Remediation know the remedial system is operating properly and protecting the health of students, teachers, and staff in the school.
For More Information	If you have any questions or concerns about your health, contact your healthcare provider. For more information on the Mendenhall Square Shopping Center Site, call the Tennessee Department of Environment and Conservation toll-free at 1-888-891-8332. For more information about this health consultation, call the Tennessee Department of Health's Environmental Epidemiology Program at 615-741-7247 or 1-800-404-3006 during normal business hours. You can also email TDH EEP at eep.health@tn.gov.

Statement of Issues and Background

The Tennessee Department of Environment and Conservation's (TDEC) Division of Remediation asked the Tennessee Department of Health's (TDH) Environmental Epidemiology Program (EEP) to evaluate indoor air data from a charter elementary school. This evaluation was requested to determine if students, teachers, and school staff were at risk of experiencing negative health effects due to exposure to drycleaning-related chemicals.

A drycleaner operated in the Mendenhall Square Shopping Center in Memphis, Shelby County, 37115, under two separate names, Bunny Cleaners and Progressive Cleaners, for about 25 years, from about 1971 to 1997 [Ensafe 2003]. Portions of the school were redeveloped from commercial spaces that were a furniture store, pizza restaurant, and discount store. Another portion of the school was built over the former drycleaner space.

The Bunny-Progressive drycleaner was enrolled as an abandoned facility in TDEC's Drycleaner Environmental Response Program (DCERP) by the Mendenhall Square Shopping Center owner in 2002. Several environmental investigations and interim remedial actions were done between 2002 and 2018.

The drycleaner solvent, tetrachloroethylene (PCE), and its breakdown chemicals, trichloroethylene (TCE), cis- and trans-1,2-dichloroethylene (1,2-DCE), and vinyl chloride (VC) were discovered in soil, soil gas, and groundwater beneath the shopping center.

Significant levels of drycleaner-related chemicals were found in soil gas beneath the former cleaner and beneath adjacent areas of the former shopping center. Levels of the drycleaner-related chemicals in groundwater ranged from several hundred to several thousand micrograms per liter.

Remedial actions included removal of contaminated soil to reduce the amount of drycleaner solvent beneath the former drycleaner area; injection of a slow release substrate medium to break down chemicals in the soil and shallow groundwater beneath the former drycleaner; and installation of engineering controls including a sub slab vapor intrusion mitigation system (VIMS) beneath a portion of the former drycleaner. These activities were performed by an environmental contractor working for the shopping center owner and by another environmental contractor working for the school. TDEC Division of Remediation provided project oversight throughout all remediation phases [Ensafe 2017, TDEC 2019].

Much of the Mendenhall Square Shopping Center was repurposed into the charter school building beginning in mid-2018. TDEC requested the school take additional mitigation actions to prevent PCE, TCE, 1,2-DCE and VC soil vapors associated with the former drycleaner from moving up into school classrooms. The school decided to apply a commercial floor coating vapor barrier product directly onto the concrete building slab [TDEC personal communication August 2019]. It was hoped the floor coating, in conjunction with the existing VIMS, would sufficiently address the vapor intrusion issues at the school.

The school opened in August 2019 with classrooms for kindergarten through fifth grade children. Approximately 780 student scholars and about 85 school staff are present in the building up to 10 hours per day, 5 days per week. As the school got underway, the air in several classrooms was tested due to the concentrations of PCE, in particular. PCE and TCE were found in the indoor air of several classrooms [Fisher Arnold 2020].

Even though there were past remedial actions, a sub slab VIMS and a liquid vapor barrier installed, there were PCE, TCE, and 1,2-DCE vapors lingering in some parts of the school. Only one detection of VC vapors was noted. The presence of chemical vapors led to more indoor air testing and various other actions to reduce levels of former drycleaning solvent vapors in the school.

Obviously, the VIMS was not functioning and operating properly as levels of drycleaner-related chemicals continued to be found in the school. Proper functioning and operation of the VIMS is critical to reducing indoor air levels of drycleaner-related chemicals. If the VIMS is not operating properly chemical vapors could continue to move from soil gas and groundwater beneath the building into the indoor air of the school. Indoor air levels of chemicals would be considerably higher if the VIMS was not present or operating properly.

Indoor Air Investigations

When the school opened in August 2019 levels of PCE, TCE, and 1,2-DCE were present in the indoor air of the school. PCE levels reached 35.6 micrograms per cubic meter ($\mu g/m^3$). It was found the exhaust for the sub slab VIMS was being pulled back into the school via roof top heating, ventilation and air conditioning (HVAC) units. The VIMS exhaust pipe was moved to a location away from roof top HVAC units in September 2019. Chemical levels in indoor air decreased. Classroom testing was adjusted accordingly. Rooms with no PCE exceedances for six consecutive weeks were moved to bi-weekly testing. Bi-weekly testing showed no increases after six consecutive tests.

From September 2019 to the Christmas holiday break, chemical levels were low or below analytical detection limits. During the Christmas holiday, TCE levels in one classroom increased to 8.41 $\mu g/m^3$ [Fisher Arnold 2020a]. This TCE level was an immediate health concern for that classroom. As a result of this increase, TDEC instructed the school to revert back to a weekly testing schedule at all testing locations. TCE continues to be detected in some classrooms.

An independent vapor mitigation contractor Clean Vapor was retained to evaluate the VIMS. On January 14, 2020, the day the vapor mitigation contractor visited the school, TDH EEP staff members Joseph George and Rebecca Gorham met with the TDEC project manager, the school’s environmental consultant, and the school’s Chief Operating Officer to emphasize it was imperative actions were needed to further reduce chemical vapors in the school as vapor intrusion was continuing to occur despite the operation of the VIMS. The VIMS was not adequately addressing the migration of vapors from the elevated levels of drycleaner-related chemicals in soil gas and groundwater beneath the building. Both TDEC and TDH were seeking to resolve this potential public health concern as soon as possible. TDEC recommended the charter school make improvements to the VIMS and HVAC systems suggested by Clean Vapor. Clean Vapor’s analysis showed the VIMS was not functioning as intended and the minimum vacuum requirements of the VIMS were not being met.

To further investigate chemical vapors in the indoor air, the school contracted with Hartman Environmental Geoscience (Hartman) to conduct continuous indoor air testing on February 27, 28, 29, and March 1, 2020. Indoor air results collected by Hartman were considered screening data as they were not subjected to thorough quality assurance or quality control considerations. Testing was first done continuously overnight in select classrooms. Indoor air grab samples were then collected from 29 different classrooms, storage rooms, utility closets, cabinets, an HVAC intake, and the influent and effluent ports of the existing VIMS. Indoor air samples were also collected continuously overnight in another set of classrooms [Fisher Arnold 2020b]. The VIMS and the HVAC systems were turned off for one day to understand the influence of these systems on the indoor air levels of the chemicals. EEP's Mr. George observed work activities on February 28 and 29, 2020.

Data collected by Clean Vapor and Hartman was subsequently evaluated and used by DocAir, another contractor hired by the school. DocAir recommended and ultimately installed a second smaller remedial system for three classrooms. DocAir determined the radius of influence of the original VIMS system was not adequately reaching the three classrooms and there was a need for an additional vapor removal point in each. The three new vapor removal points were connected to a separate vent fan arrangement, in addition to the original VIMS.

Along with installing the new vapor removal points in the three classrooms DocAir also recommended making HVAC adjustments. Each unit louver north of the play area of the school (former drycleaner location) was adjusted to allow 10% more positive air flow within the classrooms. The increased positive air flow contributed to increased vacuum readings below the floor of the school.

After improvements suggested by DocAir were made, confirmation testing in May 2020, , showed very low PCE levels, TCE levels commonly below very low testing detection limits, and non-detect levels of 1,2-DCE and VC.

TDH was provided all indoor air data collected at the school during 2019 and 2020. TDH used the eight months of weekly indoor air sampling data provided by Fisher Arnold to evaluate both the highest and highest average (or highest arithmetic mean) level of PCE, TCE, 1,2-DCE, and VC at a location over specific time frames. EEP also evaluated measured amounts of these chemicals adjusted based the number of hours each day, days per week, and number of years students or teachers and staff would be in the school.

Discussion

Introduction to Chemical Exposure and Evaluation

To determine whether persons have been or are likely to be exposed to chemicals, TDH EEP evaluates pathways that could lead to human exposure. Chemicals released into the environment have the potential to cause harmful health effects. Even so, a release does not always result in exposure. People can only be exposed to a contaminant if they come into contact with it. If a person does not come into contact with a contaminant, then no exposure occurs, and thus, no adverse health effects could occur.

The five questions to consider when deciding if a person could be exposed to a chemical include the following:

1) Where is the chemical coming from (source)?
2) What in a person's environment has been contaminated (environmental medium)?
3) Is there a way a person might come into contact with the chemical (exposure point)?
4) How might a person come into contact with the chemical (exposure route)?
5) Who might be exposed to the chemical (exposed population)?

The source of contamination is the place where the chemical was released. For the school, three possible sources for the contamination were found:

- Spills and leaks from the former drycleaning machine in the area of the school where the drycleaner was located
- Storage of PCE and filters associated with the former drycleaning operation
- Chemicals from other spills, leaks, and historic disposal practices that could have occurred over 26 years this and surrounding properties were used by commercial businesses

Exposure Pathway and Exposed Populations

An exposure to a chemical and the possibility of adverse (harmful) health effects requires people to come into contact with the chemical through ingestion (eating or drinking), inhalation (breathing the chemical), or absorbing the chemical through the skin (dermal absorption). Having contact with a chemical does not necessarily result in adverse health effects. A chemical's ability to result in adverse health effects is influenced by a number of factors, including the amount of a chemical that a person is exposed to (dose), how often and how long a time a person is exposed to the chemical (frequency and duration), and the amount and type of damage the chemical can cause in the body (toxicity). Knowing or estimating the number of times people have contact with hazardous substances is essential to assessing the public health implications of these contaminants.

An exposure pathway is the way a person can be exposed. An exposure pathway is considered complete if there is evidence that all five of the elements above have been, are, or will be present. An exposure pathway is considered incomplete if one of the five elements above is missing. A potentially completed exposure pathway is when all five elements might have occurred in the past or might occur in the future. A completed exposure pathway is when all five elements of the pathway are either expected to occur or are occurring. Table 1 summarizes the exposure pathways at the school.

Table 1. Exposure pathways for students, teachers, and staff at the Mendenhall Square Site.

Source	Environmental Medium	Exposure Point	Exposure Route	Exposed Population	Time Frame	Exposure
Former cleaner releases	Soil and groundwater	Indoor air from vapor intrusion of subsurface chemicals	Inhalation	Students	Past Present Future	Completed Potential Potential
				Teachers staff	Past Present Future	Completed Potential Potential

Incomplete = indicates at least one element of the exposure was or is not present
Potential = indicates all five elements of the exposure pathway might have occurred in the past or might occur in the future
Completed = indicates all five elements of the exposure pathway are either expected to occur or are occurring

Responses of people to potentially harmful substances may vary with the individual or group of individuals, such as children, the elderly, or people with weakened immune responses, or other chronic health issues. These susceptible populations may have different or heightened responses as compared to most people exposed at the same concentration to a particular chemical in the environment. Reasons for these differences include genetic makeup, age, health status, nutritional status, and exposure to other toxic substances. These factors may limit a person's ability to detoxify or eliminate the harmful chemicals from their body or may increase the effects of damage to their organs or physiological systems. In general the elderly, with declining organ function, and the young, with immature and developing organs, are more vulnerable to toxic substances than are healthy adults. Child-specific exposure situations and susceptibilities are considered in our health evaluation. Long-term daily exposures were also considered for children and adults attending and working in the school.

This health consultation focuses on the population attending and working in the school. The building has been used as a school since its opening in July 2019. As of mid-January 2020 there were 783 student scholars attending classes for grades kindergarten through 5th at the school. As mentioned previously, about 85 teachers and staff work in the school. Teachers and staff ages range from the 20s to 50s. At the time of this publication, it was reported that teachers and children were attending school virtually due to the COVID-19 pandemic. Only administrative staff are present in the school.

Child Health Considerations

For a school with contamination of the air inside it's building ATSDR and TDH recognize the unique vulnerabilities of children demand special emphasis. Due to their immature and developing organs, children are usually more susceptible to toxic substances than are adults. Children are more likely to encounter contaminated vapors close to the ground. Children are generally smaller than adults, which results in higher doses of chemical exposure because of their lower body weights relative to adults. In addition, the developing body systems of children can sustain permanent damage if toxic exposures occur during critical growth stages. Although there are no direct, definitive links between PCE, TCE, 1,2-DCE, or VC inhalation and an increased incidence of adverse health effects in children or fetuses, evidence from animal studies, together with limited information from human studies, strongly suggests that developmental effects are of concern [ATSDR 2001, EPA 2011].

While a number of health studies have examined acute PCE, TCE, 1,2-DCE, and VC exposures in adults, similar studies in children and the effects of low-level chronic exposures typically seen in vapor intrusion cases are lacking. Also, age-dependent differences in the absorption, distribution, metabolism, and excretion of xenobiotics may also alter the susceptibility of children to PCE or TCE, compared to adults.

Data on the toxicokinetics of PCE, TCE, 1,2-DCE, and VC in children are virtually nonexistent, making it difficult to predict potential differences in response between adults and children. Nonetheless, source mitigation, removal, and public education directed at parents should be used to help prevent or minimize exposure to children.

Site-Related Chemicals

Chemicals identified in indoor air at the school related to the former drycleaner are grouped in a class of chemicals called volatile organic compounds (VOCs). VOC chemicals such as PCE, TCE, 1,2-DCE, and VC are all chlorinated solvents. These chemicals are used for a wide variety of commercial and industrial purposes, but many are used as cleaning solutions. Their chemical structure helps them to efficiently remove organic materials such as fats and greases [ATSDR 2014a]. PCE was the main chemical used in the former drycleaning operation.

Spills and leaks of chlorinated solvents have caused widespread subsurface contamination in the environment. Chlorinated solvents in general can be harmful to human and ecological health if levels of these chemicals are high enough to cause harmful exposures. PCE, TCE, and VC can cause or are suspected of causing cancer. Chlorinated solvents such as PCE can also degrade into other chemicals. PCE can degrade to TCE, then 1,2-DCE, and then VC through natural processes.

Any corrective process to remove PCE from site soils will also remove other breakdown chemicals, such as TCE, 1,2-DCE, and VC. PCE is generally a clear liquid that will readily vaporize to a gas when exposed to air. PCE has a sweet odor. PCE is not flammable [ATSDR 2014a]. PCE is a suspected carcinogen. TCE is a breakdown chemical found in soil gas at the site and is classified as probably carcinogenic to humans [ATSDR 2014b]. Cis- and trans-1,2-DCE are also PCE breakdown product chemicals and are not known to cause cancer [ATSDR 1996]. VC is a known carcinogen [ATSDR 2006].

The ATSDR Health Evaluation Process

The first stage of the Agency for Toxic Substances and Disease Registry (ATSDR) health effects evaluation process involves screening indoor air data by comparing site contaminant concentrations to comparison values. Comparison values (CVs) were developed by ATSDR as chemical concentrations in environmental media (in this case indoor air). CVs were set at levels that are highly health protective, well below concentrations known or anticipated to result in adverse health effects. Contaminant concentrations at or below the CV require no additional evaluation. When chemicals are found on a site at concentrations greater than the CV, it does not mean that adverse health effects would be expected, but it does identify that a more in-depth evaluation is warranted. PCE and TCE were the site-related chemicals detected at levels above a CV during the indoor air testing period of July 2019 to February 2020.

The second stage of the process is the health guideline comparison and involves looking more closely at site specific exposure conditions, estimating exposure doses, and comparing the dose estimates to health guideline values. An exposure dose is an estimate of the amount of a substance a person may come into contact within the environment during a specific time period, expressed relative to body weight. Health guideline values represent daily human exposure levels to a substance that is likely to be without much risk of adverse (negative) health effects during a specified exposure time. Important factors in determining exposure dose estimates include the measured level of the chemical, the amount of time and frequency of exposure, the route of exposure, and the health status of the exposed person or population.

For our evaluation we used ATSDR Environmental Media Evaluation Guides (EMEG), Cancer Risk Evaluation Guides (CREG), and Minimal Risk Levels (MRL) for the chemicals. An ATSDR MRL is equivalent to an EPA Reference Dose. ATSDR defines the MRL as an estimate of the daily human exposure to a hazardous substance likely to be without much risk of non-cancer health effects over a specified time of exposure, in this case, over several years. If a substance has the potential to cause cancer as is the case for PCE, TCE, and VC, then the cancer risk is estimated by multiplying the dose by the substance’s cancer slope factor and averaged over a lifetime. For this site we evaluated cancer risk over 6 years for children attending the school, and 6, 10, 15, and 20 years for teachers and staff.

To determine if adverse health effects are possible for the site-specific exposure doses calculated for children and adults, these values are compared to data collected in human health effect and animal laboratory studies for the chemicals of concern. The health study data are generally taken from ATSDR or EPA references that summarize human and animal studies that have undergone extensive validation review. Comparisons are made on the basis of the exposure route (ingestion/eating, inhalation/breathing, or dermal/skin contact) and length of the exposure. Preference is given to human study data and chemical doses or concentrations where no adverse health effects were observed. If no human data or no-adverse-effect data are available, animal data or the lowest chemical dose where adverse health effects were observed, called lowest observed adverse effect levels (LOAELs) may be used.

There are limitations inherent to the risk assessment process. These include the availability of analytical data collected for a site, the type and quantity of health effects information, and the risk estimation process itself. To minimize the impact of these limitations, the parameters selected for exposure estimates (amount breathed, frequency of exposure, years of exposure) were all selected to be health protective, representing a realistic maximum exposure for people to the environmental contamination that may exist on the site.

The comparison value and health guideline value used in this document were developed by ATSDR (CV and MRL) for intermediate (15 days to 364 days) and chronic (greater than 1 year) daily exposure to the five chemicals evaluated. The chronic CVs would be consistent with breathing the school's indoor air over the 6-year duration of time children and 6-, 10-, 15-, and 20-year duration for teachers and staff. See Appendix A for equations and exposure parameters used to estimate exposure the doses.

Environmental Data Exposure Evaluation

TDH evaluated the measured levels of PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, and VC the students, teachers and staff of the school would be exposed to, we evaluated the data in the following five ways:

1. TDH used the highest levels of chemicals found during the eight months of testing as a cautious, worst-case scenario to evaluate potential health risks.

2. TDH evaluated potential health risk using the highest average (or highest arithmetic mean) at any testing location for each chemical found during the period from July 2019 through September 2019 when the VIMS exhaust was found to be causing elevated levels,

3. TDH evaluated the potential health risk using the highest average value at any testing location for each chemical found during the time period from October 2019 through February 2020, after the VIMS exhaust was relocated,

4. TDH evaluated the potential health risk using the highest average value for each chemical during the eight months of testing. The levels of each chemical at each sample location were averaged over the entire 8 months to obtain the value used. This was done to simulate health effects of what the average level of each chemical may have been in the school, and,

5. TDH evaluated the potential health risk of levels of chemicals after they were adjusted for a typical length of exposure for students, teachers, and staff at the school.

When drycleaner chemicals were not found in indoor air tests above their laboratory detection limits (the level at which the laboratory can determine the presence of a chemical), the highest laboratory detection limit for the analysis was used as the measured value as the test result. These results were noted in the following tables with a DL note. This was the case for trans-1,2-DCE and VC. Using laboratory detection limits as actual measured values is a conservative approach. This approach can overestimate the potential exposure to the chemical for students, teachers, and staff. However, TDH used this method because we wanted to be cautious and conservative evaluating the indoor air results as children can be more susceptible to health effects of chemicals than adults.

Table 2 shows four ways the data was evaluated using the highest concentration of each chemical evaluated and the highest averaged concentrations. Table 2 also shows whether the highest level of a chemical used was a measured value or a laboratory method detection limit, along with comparison values for each chemical.

Table 2. Measured maximum and average 8-hour indoor air sampling results for PCE, TCE, 1,2,-DCE, and VC at various monitoring locations in the school. U.S. EPA and ATSDR health comparison values shown. Weekly sampling results from July 21, 2019, to February 24, 2020 were reported in micrograms per cubic meter (µg/m^3) [Fisher Arnold 2020].

Measurement Time Frame / Comparison Values	tetrachloroethylene (µg/m^3)	trichloroethylene (µg/m^3)	cis-1,2-dichloroethylene (µg/m^3)	trans-1,2-dichloroethylene (µg/m^3)	vinyl chloride (µg/m^3)
Maximum (Jul 2019 - Feb 2020)	**35.6**	**8.41**	3.31	1.84 DL	**1.17 DL**
Maximum Average (Jul 2019 - Feb 2020)	**7.58**	**0.58**	0.49	0.44	**0.14**
Maximum Average (Jul 2019 - Sep 2019)	**17.52**	**0.51**	1.02	0.21	**0.15**
Maximum Average (Oct 2019 - Feb 2020)	3.06	**0.73**	0.59	0.61	**0.16**
EPA residential air screening level (RSL) for cancer risk 10^{-6}	11	0.48	N/A	N/A	0.17
EPA residential air screening level (RSL) for non-cancer health risk Hazard Index =1	42	2.1	N/A	N/A	100
ATSDR Cancer Risk Evaluation Guide (CREG)	3.8	0.21	N/A	N/A	0.11
ATSDR Environmental Media Evaluation Guide (EMEG)	41	2.1	N/A	790	100

Notes:
35.6 µg/m^3 = Measured result of chemical in indoor air in micrograms per cubic meter (µg/m^3)
DL = value shown is the highest test detection limit which was used in further calculations.
BOLD result = measured level of chemical exceeds ATSDR or EPA Hazard Index of 1 or cancer effects screening value for one additional cancer in 1 million people
N/A = Not Applicable. EPA RSLs or ATSDR screening levels not developed
EPA RSL = U.S. Environmental Protection Agency Residential Screening Level
ATSDR CREG = Agency for Toxic Substances and Disease Registry Cancer Risk Evaluation Guide
ATSDR EMEG = Agency for Toxic Substances and Disease Registry Environmental Media Evaluation Guide

Indoor Air Levels of PCE, TCE, cis- and trans-1,2-DCE, and VC

Contaminants of concern at the school include PCE, TCE, 1,2-DCE, and VC. Indoor air levels from July 2019 through February 2020 for these chemicals were reviewed. We evaluated the highest measured levels of PCE, TCE, and cis-1,2-DCE, and the highest detection limit values for trans-1,2-DCE, and VC as well as highest average (arithmetic mean) levels for a chemical over specific time periods.

The highest PCE level was measured in a classroom on August 12, 2019. The measured PCE level was 35.6 micrograms per cubic meter (µg/m^3). The highest TCE level measured was 8.41µg/m^3 in a classroom on December 23, 2019. Very low levels of 1,2-DCE were found in the weekly indoor air samples. The highest measured level of cis-1,2-DCE was 3.31 µg/m^3 in a classroom also on December 23, 2019. An elevated detection limit value of 1.84 µg/m^3 for trans-1,2-DCE was noted on October 11, 2019. This was the highest level used for the evaluation of trans-1,2-DCE. Another breakdown chemical, VC, was found in at an extremely low level in only one of 31 weekly indoor air samples. An elevated detection limit value of 1.17 µg/m^3 for VC was also found on October 7, 2019. As with trans-1,2-DCE, this was the highest value used for the evaluation of VC.

The highest average PCE level at a testing location was 7.58 µg/m^3 for the eight month period, as shown in Table 2. The highest average TCE level at a testing location was 0.58 µg/m^3. The highest average cis-1,2-DCE level at a testing location was 0.49 µg/m^3. The highest average detection limit trans-1,2-DCE level was 0.44 µg/m^3. The highest average detection limit VC level was 0.14 µg/m^3.

The maximum average chemical concentrations or detection limit values at a testing location for the time period from July 2019 through September 2019 follow: PCE – 17.52 µg/m^3; TCE – 0.51 µg/m^3; cis-1,2-DCE – 1.02 µg/m^3; trans-1,2-DCE – 0.21 µg/m^3; and VC – 0.15 µg/m^3.

The maximum average chemical concentrations or detection limit values at a testing location for the time period from October 2019 through February 2010 follow: PCE – 3.06 µg/m^3; TCE – 0.73 µg/m^3; cis-1,2-DCE – 0.59 µg/m^3; trans-1,2-DCE – 0.61 µg/m^3; and VC – 0.16 µg/m^3.

Exposure-Adjusted Data Evaluation

TDH also evaluated the same highest and average levels, and specific time period average values outlined above after they were adjusted to account for the number of hours each day, number of days per week, and number of years a typical student, teacher, and staff member would be in the school.

We evaluated the exposure for a student, teacher, or staff member being in the school for a period of 6 years while a student attended kindergarten through 5th grade. We estimated a student, teacher, or staff member would spend 10 hours each day, 5 days each week for 6 years exposed to PCE, TCE, and cis-1,2-DCE vapors in indoor air in classrooms at the school. Table 3 shows adjusted maximum PCE, TCE, 1,2-DCE, and VC concentrations and detection limit values for students, teachers, and staff along with ATSDR and EPA comparison values.

Table 3. Measured maximum, average, and time-adjusted 8-hour indoor air sampling results and locations measured for PCE, TCE, cis-1,2-DCE, trans-1,2,-DCE, and VC. Time-adjusted levels are based on a 10 hour per day, 5 day per week, 6 year exposure. U.S. EPA and ATSDR comparison values shown. Weekly sampling results from July 21, 2019, to February 24, 2020 were reported in micrograms per cubic meter (µg/m³) [Fisher Arnold 2020].

Measurement Time Frame / Comparison Values	tetrachloroethylene (µg/m³)		trichloroethylene (µg/m³)		cis-1,2-dichloroethylene (µg/m³)		trans-1,2-dichloroethylene (µg/m³)		vinyl chloride (µg/m³)	
	measured	adjusted	measured	adjusted	measured	adjusted	measured	adjusted	measured	adjusted
Maximum (Jul 2019 - Feb 2020)	35.6	0.82	8.41	0.19	3.31	0.08	1.84 DL	0.04 DL	1.17 DL	0.03 DL
Maximum Average (Jul 2019 - Feb 2020)	7.58	0.17	0.58	0.01	0.49	0.01	0.44	0.01	0.14	0.003
Maximum Average (Jul 2019 - Sep 2019)	17.52	0.40	0.51	0.01	1.02	0.02	0.21	0.004	0.15	0.003
Maximum Average (Oct 2019 - Feb 2020)	3.06	0.07	0.73	0.02	0.59	0.01	0.61	0.01	0.16	0.004
EPA residential air RSL for cancer risk of 10^{-6}		11		0.48		N/A		N/A		0.17
EPA residential air RSL for non-cancer health risk HI=1		42		2.1		N/A		N/A		100
ATSDR CREG		3.8		0.21		N/A		N/A		0.11
ATSDR EMEG		41		2.1		N/A		790		100

Notes:
35.6 µg/m³ = Measured result of chemical in indoor air in micrograms per cubic meter (µg/m³)
DL = value shown is the highest test detection limit which was used in further calculations.
N/A = Not Applicable. EPA RSLs or ATSDR screening levels not developed
EPA RSL = U.S. Environmental Protection Agency Residential Screening Level
ATSDR CREG = Agency for Toxic Substances and Disease Registry Cancer Risk Evaluation Guide
ATSDR EMEG = Agency for Toxic Substances and Disease Registry Environmental Media Evaluation Guide

Similar to the unadjusted time evaluation above, when these chemicals were not found in indoor air tests, the laboratory detection limit for the analysis was used as the measured value for the test for trans-1,2-DCE and VC. Again, using laboratory detection limits as actual test results is a conservative approach. This approach likely overestimates the potential chemical exposure for children, teachers, and students.

TDH further evaluated exposures to teachers and school staff for longer periods of time. We evaluated potential exposures for teachers and staff if they worked in the school for periods of 6, 10, 15, and 20 years. This was done to understand potential adverse health effects to long-term employees. Calculated potential exposures along with ATSDR and EPA comparison values are shown in Table 4.

PCE Levels Inhalation Evaluation

Non-Cancer Health Effects

Based on the measured highest and averaged non-time-adjusted PCE indoor air data shown in Table 1, and the time-adjusted highest and averaged PCE indoor air data shown in Tables 2 and 3, students, teachers, and staff were exposed to significantly lower levels of PCE than those associated with health effects. Therefore, students, teachers, and staff were not in the past, and are not currently at risk for non-cancer health effects associated with exposure to PCE in indoor air.

Evaluating the potential for non-cancer health effects from PCE in the school, we used non-adjusted highest and averaged, and the time-adjusted highest and averaged levels of PCE found in the building. These levels were compared with the effect levels from two studies used to derive the EPA RfC 40 $\mu g/m^3$ and ATSDR EMEG of 41 $\mu g/m^3$. The Echeverria study (1995) that reported an increased risk of color blindness among workers exposed to PCE at 15,000 $\mu g/m^3$ and the Cavelleri study [1994] reported neurological effects (delayed reaction time and cognitive effects) from exposure to PCE at levels of 56,000 $\mu g/m^3$. An uncertainty factor of 1,000 was applied to these studies to derive PCE's RfC and EMEG. All levels found in the school were much lower than levels these studies found to cause these non-cancer health effects.

Cancer Health Effects

The U.S. EPA concluded that PCE is likely to be carcinogenic in humans by all routes of exposure based on sufficient evidence in animals and suggestive evidence of a causal association between PCE exposure in humans and bladder cancer, multiple myeloma, and non-Hodgkin's lymphoma. The National Toxicology Program (NTP) concluded that PCE is reasonably anticipated to be a human carcinogen based on sufficient evidence in experimental animals [NTP 2011]. Based on increased risks of esophageal cancer, cervical cancer, and non-Hodgkin's lymphoma in several epidemiologic studies, and increased liver tumors in mice, increased mononuclear cell leukemia in rats, and renal tumors in male rats, the International Agency for Research on Cancer (IARC) classified PCE as probably carcinogenic to humans [IARC 2019].

We calculate site-specific lifetime excess cancer risk (LECR) estimates, which are usually expressed in terms of excess cancer cases in an exposed population in addition to the background rate of cancer. For perspective, the lifetime risk of being diagnosed with any type of cancer in the United States is 3 per 10 individuals for both males and females, or about 1 person in 3 [ACS

Table 4. Measured maximum, average, and time-adjusted indoor air sampling estimations (8-hour) and locations measured for PCE, TCE, cis-1,2-DCE, trans-1,2,-DCE and VC. Time-adjusted levels are based on being in the school 10 hours each day, 5 days each week, for 10, 15, and 20 years of exposure for teachers and staff. U.S. EPA and ATSDR comparison values shown. Weekly sampling results from July 21, 2019, to February 24, 2020 were reported in micrograms per cubic meter (μg/m^3) [Fisher Arnold 2020].

Measurement Time Frame / Comparison Values	tetrachloroethylene (μg/m^3) / Years Worked			trichloroethylene (μg/m^3) / Years Worked			cis-1,2-dichloroethylene (μg/m^3) / Years Worked			trans-1,2-dichloroethylene (μg/m^3) / Years Worked			vinyl chloride (μg/m^3) / Years Worked		
	10	15	20	10	15	20	10	15	20	10	15	20	10	15	20
Maximum (Jul 2019-Feb 2020)	1.36	2.03	2.71	0.32	0.48	0.64	0.13	0.19	0.25	0.07	0.11	0.14	0.04	0.07	0.09
Maximum Average (Jul 2019-Feb 2020)	0.3	0.43	0.58	0.02	0.03	0.04	0.02	0.03	0.04	0.02	0.03	0.03	0.005	0.008	0.01
Maximum Average (Jul 2019-Sep 2019)	0.67	1.00	1.34	0.02	0.03	0.04	0.04	0.06	0.08	0.008	0.012	0.016	0.006	0.009	0.011
Maximum Average (Oct 2019-Feb 2020)	0.12	0.17	0.23	0.03	0.04	0.06	0.02	0.03	0.04	0.02	0.03	0.05	0.006	0.009	0.012
EPA residential air RSL for cancer risk of 10^{-6}	11			0.48			N/A			N/A			0.17		
EPA residential air RSL for non-cancer health risk for HI of 1	42			2.1			N/A			N/A			100		
ATSDR CREG	3.8			0.21			N/A			N/A			0.11		
ATSDR EMEG	41			2.1			N/A			790			100		

Notes:
35.6 μg/m^3 = Measured result of chemical in indoor air in micrograms per cubic meter (μg/m^3).
N/A = Not Applicable. EPA RSLs or ATSDR screening levels not developed
EPA RSL = U.S. Environmental Protection Agency Residential Screening Level
ATSDR CREG = Agency for Toxic Substances and Disease Registry Cancer Risk Evaluation Guide
ATSDR EMEG = Agency for Toxic Substances and Disease Registry Environmental Media Evaluation Guide

2019]. The lifetime risk of being diagnosed with any of several common types of cancer ranges between 1 in 10 and 1 in 100 [ACS 2015]. EPA's target excess cancer risk range from chemical exposure is between 1 in 10,000 and 1 in a million [EPA 1991]. EPA's target risk range is much lower than a lifetime cancer risk. The estimated excess cancer risk we calculated would be added to the normal everyday background cancer risk of 3 per 10 people.

The highest PCE level of 35.6 µg/m^3 was measured on August 12, 2019. Using this value, we calculated a lifetime excess cancer risk (LECR) of about 1 in 100,000, or one additional cancer in 100,000 people. We based this estimate on using the EPA's Inhalation Unit Risk Factor (2.6 x 10^{-7} per µg/m^3) and the maximum non-time-adjusted measured level of PCE of 35.6 µg/m^3 (Table 5). This additional estimated cancer risk of 1 in 100,000 people is in addition to the normal daily background cancer risk in the United States stated above and is considered a very low added risk, especially considering worse-case (highest) levels of the chemical were used.

Using the time-adjusted exposure point concentration of the highest measured level of PCE in indoor air of August 12, 2019, of 0.82 µg/m^3, the excess cancer risk is estimated to be approximately 2 in 10,000,000, or 2 additional cancers in 10 million people (Table 6). This would be for those children, teachers, and staff being in the school 10 hours a day, 5 days each week during a 6 year time frame. As outlined above, this excess cancer risk is in addition to the normal excess cancer risk for children, teachers, and staff. This excess risk is considered minimal when compared to the background or everyday cancer risk of all or specific cancers. All other highest levels for specific time periods and averaged levels of PCE as outlined in Table 3 would have excess cancer risks even lower. This means there would be an extremely low potential for additional cancers caused by breathing air in the school.

For teachers and staff at the school, an excess cancer risk was also calculated for the highest measured PCE level over a 10, 15, and 20 year timeframe. Using the highest measured PCE value is more cautious. The estimated excess cancer risk for teachers and staff working 10 years in the school and subjected to the highest measured level of PCE (35.6 µg/m^3) 10 hours each day, 5 days each week was 4 excess cancers in 10 million people. For 15 years the excess cancer risk is 6 in 10 million, and for 20 years the excess cancer risk is 7 in 10 million (Table 7). All these estimated excess cancer risks indicate insignificant additional risk of cancer to teachers and staff. The estimated excess cancer risk using averaged PCE levels is even lower, indicating further insignificant additional risk.

TCE Levels Inhalation Evaluation

Non-Cancer Health Effects

TDH assessed the exposure to breathing TCE to students, teachers, and staff. TDH compared the adjusted highest TCE level found to the effects levels from animal studies used to derive the EPA RfC [Johnson et al. 2003, Keil et al. 2009]. The EPA used physiologically based pharmacokinetic (PBPK) modeling to convert the oral dose in animals to a human equivalent concentration (HEC) of TCE in air [IRIS 2014]. EPA predicts there is a small risk of fetal heart malformations for pregnant women exposed to TCE at 21 µg/m^3 [Johnson et al. 2003]. An uncertainty factor of 10 was applied to this study to derive the RfC of 2 µg/m^3. Exposures during the critical period of development, during the first trimester of pregnancy, are the largest concern for cardiac effects. The EPA RfC is also based on an additional study of immune system impacts from exposure to TCE at 190 µg/m^3 which incorporated an uncertainty factor of 100 [Keil et al. 2009]. In late 2014, ATSDR adopted the EPA RfC as its chronic and intermediate Minimal Risk Level/EMEG for TCE [ATSDR 2014a].

The one-time highest measured level of TCE in indoor air of 8.41 µg/m^3. This TCE level was an immediate health concern for that classroom. The highest average TCE level from July through September 2019 of 0.58 µg/m^3, the average level of TCE from July 2019 through February 2020 of 0.51 µg/m^3, and the average for October 2019 through February 2020 level of 0.73 µg/m^3 were all well below the study effect level of 21 µg/m^3 for fetal heart effects (this study is outlined further below) and are exceedingly low compared to the study effect level for immune system effects of 190 µg/m^3. The time-adjusted levels of TCE in indoor air in the school (high and average over different time periods) are lower than the actual measured levels. When evaluating health effects of time-adjusted levels of TCE in the school, students, teachers, and staff were not in the past, and are not currently at risk for non-cancer health effects associated with exposure to TCE measured in indoor air.

Cancer Health Effects
The National Toxicity Program classified TCE as reasonably anticipated to be a human carcinogen. In humans, occupational exposure to TCE was associated with excess incidences of several cancers, particularly liver cancer, non-Hodgkin lymphoma, and kidney cancer [NTP 2011]. The IARC has determined TCE is a probable human carcinogen based on epidemiological studies showing increased rates of liver cancer and non-Hodgkin lymphoma (NHL), primarily in workers who were exposed to TCE on the job and animal studies showing increased numbers of liver and kidney tumors upon oral administration. The EPA characterized TCE as carcinogenic to humans by all routes of exposure. The oral slope factor estimate for TCE is calculated from route-to-route extrapolation of the inhalation unit risk estimate for kidney cancer with a factor of 5 applied to include NHL and liver cancer risks [EPA 2014b].

TDH calculated a lifetime excess cancer risk (LECR) of about 3 in 100,000, or 3 additional cancers in 100,000 people for highest non-time-adjusted measured TCE level (8.41 µg/m^3 - Table 5). We based this estimate on using the EPA's Inhalation Unit Risk Factor (4.1 x 10^{-6} per µg/m^3) and the highest non-time-adjusted measured level of TCE of 8.41 µg/m^3. The additional cancer risk is in addition to the normal daily background cancer risk in the United States of 3 per 10 people and is considered a minimal added risk.

Again, using EPA's Inhalation Unit Risk Factor (4.1 x 10^{-6} per µg/m^3) and the highest time-adjusted exposure point concentration for TCE in indoor air measured on December 23, 2019, of 0.19 µg/m^3, the excess cancer risk is estimated to be approximately 8 in 10 million for students, teachers, and staff with a constant 6-year exposure (Table 6). This excess cancer risk is considered an insignificant increased risk when compared to the background risk of all or specific cancers.

Teachers and staff who work at the school 10, 15, or 20 years would have excess cancer risks in the range of 9 in 100 million to 1.3 in 1 million using the highest TCE value and adjusting for exposure time (Table 7). These excess cancer risks are minimal and would not likely cause additional cases of cancer.

Table 5. Non-time-adjusted, measured maximum and average (non-time-adjusted) indoor air sampling estimations (10-hour) and estimated excess lifetime cancer risk (LECR) for PCE, TCE, cis-1,2-DCE, trans-1,2,-DCE and VC at various monitoring points. U.S. EPA and ATSDR comparison values shown. Weekly sampling results from July 21, 2019, to February 24, 2020 were reported in micrograms per cubic meter (µg/m³) [Fisher Arnold 2020].

Measurement Time Frame / Comparison Values	tetrachloroethylene (µg/m³)		trichloroethylene (µg/m³)		cis-1,2-dichloroethylene (µg/m³)		trans-1,2-dichloroethylene (µg/m³)		vinyl chloride (µg/m³)	
	Result	LECR	Result	LECR	Result	LECR	Result	LECR	Result	LECR
Maximum (Jul 2019-Feb 2020)	**35.6**	1 in 100,000	**8.41**	3.4 in 100,000	3.31	NA	1.84 DL	NA	**1.17 DL**	1 in 100,000
Maximum Average (Jul 2019-Feb 2020)	**7.58**	2 in 1 million	**0.58**	2.4 in 1 million	0.49	NA	0.44	NA	**0.14**	1.2 in 1 million
Maximum Average (Jul 2019-Sep 2019)	**17.52**	4.6 in 1 million	**0.51**	2 in 1 million	1.02	NA	0.21	NA	**0.15**	1.3 in 1 million
Maximum Average (Oct 2019-Feb 2020)	3.06	8 in 10 million	**0.73**	3 in 1 million	0.59	NA	0.61	NA	**0.16**	1.4 in 1 million
EPA residential air screening level (RSL) for 1 extra cancer in 1 million people	11		0.48		N/A		N/A		0.17	
EPA residential air screening level (RSL) for non-cancer health risk Hazard Index =1	42		2.1		N/A		N/A		100	
ATSDR Cancer Risk Evaluation Guide (CREG)	3.8		0.21		N/A		N/A		0.11	
ATSDR Environmental Media Evaluation Guide (EMEG)	41		2.1		N/A		790		100	

Notes:
LECR = Estimated Excess Lifetime Cancer Risk = the added cancer risk, over a lifetime, in addition to normal everyday cancer risk of 3 in 10 for both men and women
35.6 µg/m³ = Measured result of chemical in indoor air in micrograms per cubic meter (µg/m³)
DL = value shown is the highest test detection limit which was used in further calculations.
BOLD result = measured level of chemical exceeds ATSDR or EPA Hazard Index of 1 or cancer effects screening value for one additional cancer in 1 million people
N/A = Not Applicable. EPA RSLs or ATSDR screening levels not developed
EPA RSL = U.S. Environmental Protection Agency Residential Screening Level
ATSDR CREG = Agency for Toxic Substances and Disease Registry Cancer Risk Evaluation Guide
ATSDR EMEG = Agency for Toxic Substances and Disease Registry Environmental Media Evaluation Guide

Table 6. Time-adjusted maximum and average indoor air sampling estimations (8-hour) and estimated lifetime excess cancer risk (LECR) for PCE, TCE, cis-1,2-DCE, trans-1,2,-DCE and VC at various monitoring points. U.S. EPA and ATSDR comparison values shown. Weekly sampling results from July 21, 2019, to February 24, 2020 were reported in micrograms per cubic meter (µg/m³) [Fisher Arnold 2020].

Measurement Time Frame / Comparison Values	tetrachloroethylene (µg/m³)		trichloroethylene (µg/m³)		cis-1,2-dichloroethylene (µg/m³)		trans-1,2-dichloroethylene (µg/m³)		vinyl chloride (µg/m³)	
	Adjusted Result	LECR	Adjusted Result	LECR	Adjusted Result	LECR	Adjusted Result	LECR	Adjusted Result	LECR
Maximum (Jul 2019-Feb 2020)	0.82	2 in 10 million	0.19	8 in 10 million	0.08	NA	0.04 (DL)	NA	0.03 (DL)	2.6 in 10 million
Maximum Average (Jul 2019-Feb 2020)	0.17	4 in 100 million	0.01	4 in 100 million	0.01	NA	0.01	NA	0.003	3 in 100 million
Maximum Average (Jul 2019-Sep 2019)	0.40	1 in 10 million	0.01	4 in 100 million	0.02	NA	0.004	NA	0.003	3 in 100 million
Maximum Average (Oct 2019-Feb 2020)	0.07	2 in 100 million	0.02	8 in 100 million	0.01	NA	0.01	NA	0.004	4 in 100 million
EPA residential air screening level (RSL) for 1 extra cancer in 1 million people	11		0.48		N/A		N/A		0.17	
EPA residential air screening level (RSL) for non-cancer risk for Hazard Index of 1	42		2.1		N/A		N/A		100	
ATSDR Cancer Risk Evaluation Guide (CREG)	3.8		0.21		N/A		N/A		0.11	
ATSDR Environmental Media Evaluation Guide (EMEG)	41		2.1		N/A		790		100	

Notes:
LECR = Estimated Excess Lifetime Cancer Risk = the added cancer risk, over a lifetime, in addition to normal everyday cancer risk of 3 in 10 for both men and women
35.6 µg/m³ = Measured result of chemical in indoor air in micrograms per cubic meter (µg/m³)
N/A = Not Applicable. EPA RSLs or ATSDR screening levels not developed
EPA RSL = U.S. Environmental Protection Agency Residential Screening Level
ATSDR CREG = Agency for Toxic Substances and Disease Registry Cancer Risk Evaluation Guide
ATSDR EMEG = Agency for Toxic Substances and Disease Registry Environmental Media Evaluation Guide

Table 7. Measured maximum, average, and time-adjusted indoor air sampling estimations (10-hour) and locations measured for PCE, TCE, cis-1,2-DCE, trans-1,2,-DCE and VC at various monitoring points. Time-adjusted levels are based on being in the school 10 hours each day, 5 days each week, for 10, 15, and 20 years of exposure for teachers and staff. U.S. EPA and ATSDR comparison values shown. Weekly sampling results from July 21, 2019, to February 24, 2020 were reported in micrograms per cubic meter (µg/m^3) [Fisher Arnold 2020].

Measurement Time Frame / Comparison Values	Tetrachloroethylene (µg/m^3) / Years Worked			Trichloroethylene (µg/m^3) / Years Worked			cis-1,2-Dichloroethylene (µg/m^3) / Years Worked			trans-1,2-Dichloroethylene (µg/m^3) / Years Worked			Vinyl chloride (µg/m^3) / Years Worked		
	10	15	20	10	15	20	10	15	20	10	15	20	10	15	20
Maximum (July 2019-February 2020)	35.6			8.41			3.31			1.84 (DL)			1.17 (DL)		
Estimated Lifetime Excess Cancer Risk (LECR)	4 in 10 million	6 in 10 million	7 in 10 million	1.3 in 1 million	2 in 1 million	3 in 1 million	NA	NA	NA	NA	NA	NA	4 in 10 million	6 in 10 million	8 in 10 million
Maximum Average (July 2019-February 2020)	7.58			0.58			0.49			0.44			0.14		
Estimated Lifetime Excess Cancer Risk (LECR)	8 in 100 million	1 in 10 million	1.5 in 10 million	9 in 100 million	1 in 10 million	2 in 10 million	NA	NA	NA	NA	NA	NA	5 in 100 million	7 in 100 million	9 in 100 million
Maximum Average (July 2019-September 2019)	17.52			0.51			1.02			0.21			0.15		
Estimated Lifetime Excess Cancer Risk (LECR)	2 in 10 million	3 in 10 million	4 in 10 million	8 in 100 million	1 in 10 million	2 in 10 million	NA	NA	NA	NA	NA	NA	5 in 100 million	8 in 100 million	1 in 10 million
Maximum Average (October 2019-February 2020)	3.06			0.73			0.59			0.61			0.16		
Estimated Lifetime Excess Cancer Risk (LECR)	3 in 100 million	4 in 100 million	6 in 100 million	1.2 in 10 million	2 in 10 million	2.5 in 10 million	NA	NA	NA	NA	NA	NA	5 in 100 million	8 in 100 million	1 in 10 million

Notes:
LECR = Estimated Excess Lifetime Cancer Risk = the added cancer risk, over a lifetime, in addition to normal everyday cancer risk of 3 in 10 for both men and women
35.6 = Measured result of chemical in indoor air in micrograms per cubic meter (µg/m^3)
N/A = Not Applicable. EPA RSLs or ATSDR screening levels not developed

Cis- and Trans-1,2-DCE Levels Inhalation Evaluation

Breathing high levels of 1,2-DCE can make you feel nauseous, drowsy, and tired. When animals breathed high levels of trans-1,2-DCE for short or longer periods of time, their livers and lungs were damaged. The effects were more severe with longer exposure times. Animals that breathed very high levels of trans-1,2-DCE had damaged hearts. The LOAEL for 1,2-DCE of 200 parts per million (ppm) is the basis for the intermediate-duration inhalation MRL of 0.2 ppm for trans-1,2-DCE [ATSDR 1996].

The long-term human health effects after exposure to low concentrations of 1,2-DCE are not known. Results of an animal study suggest an exposed fetus may not grow as quickly as one that is not exposed. We did not find studies suggesting whether cancer in people or animals is caused by exposure to 1,2-DCE; exposure has not been shown to affect fertility in people or animals. Limited toxicological data are available for 1,2-DCE (U.S. National Library of Medicine 2008). We did not find any human toxicity characterizations of 1,2-DCE for inhalation exposure nor for 1,2-DCE as a carcinogen [ATSDR 1996].

Non-Cancer Health Effects Evaluation
Cis-1,2-DCE does not have health comparison values. Trans-1,2-DCE has an ATSDR EMEG of 790 µg/m^3. The highest cis-1,2-DCE level measured was 3.31 µg/m^3 and for trans-1,2-DCE, we used a detection limit value of 1.84 µg/m^3 as the highest level. We used the trans-1,2-DCE EMEG for the evaluation of both cis- and trans-1,2-DCE. As one can see, both non-time-adjusted and time-adjusted levels of both chemicals found in the school are well below the trains-1,2-DCE EMEG.

Cancer Health Effects Evaluation
According to ATSDR [1996], there are no adequate data either to support or refute human carcinogenicity of 1,2-DCE.

Vinyl Chloride Levels Inhalation Evaluation

Vinyl Chloride, or VC is a breakdown product of the biodegradation of tetrachloroethylene and trichloroethylene. VC has a mild sweet odor. VC is the last chemical in the chain of breakdown products of PCE and it is the most toxic chemical in the breakdown chain. VC was only found once in one classroom during the 31 weeks of indoor air sampling in the school.

VC has been determined to be a known carcinogen. Studies in workers who breathed in VC over many years showed an increased risk of liver, brain, and lung cancer. Some cancers of the blood were observed in such workers [ATSDR 2006]. The IARC, U.S.EPA, and the NTP have all determined VC is a known human carcinogen [ATSDR 2006].

No studies are available specifically address the effects of VC in children. Studies of women who live near VC manufacturing plants did not show VC produces birth defects. Studies using pregnant animals showed breathing high levels of VC (5,000 ppm) can harm unborn baby animals. Animal studies show VC can produce more miscarriages early in pregnancy and decrease weight and delay skeletal development in fetuses. Inhalation studies with animals have suggested VC might also affect growth and development. Animal studies suggest infants and young children might be more susceptible than adults to VC-induced cancer [ATSDR 2006].

Non-Cancer Health Effects Evaluation

VC was only measured once in the 31 weekly samples collected from the school. In an abundance of caution, we used the highest reported laboratory detection limit of 1.17 µg/m3 in our evaluation of both non-cancer and cancer health effects.

The ATSDR non-cancer EMEG for VC is 100 $\mu g/m^3$. There was only one confirmed result of VC of 0.52 $\mu g/m^3$ measured in a classroom on September 23, 2019. Again, VC was not measured in any other classroom in any of the other 30 weekly sampling events in the school. The highest detection limit value found, 1.17 $\mu g/m^3$, was used as the highest VC level, a very conservative assumption. The compound is likely not in the indoor air in the school.

Averaged non-time-adjusted VC levels (30 of which were laboratory detection limit values) for the time periods evaluated ranged from 0.14 to 0.16 $\mu g/m^3$. Time-adjusted VC levels were about 4 to 40 times lower than non-time adjusted levels. These levels are 100 to 30,000 times lower than the ATSDR EMEG. There should not be non-cancer health effects from breathing indoor air in the school.

Cancer Health Effects Evaluation

ATSDR's CREG for VC is 0.11 $\mu g/m^3$. The highest detection limit value was 1.17 $\mu g/m^3$. The one measured VC detection in indoor air was 0.52 $\mu g/m^3$. As above, averaged, non-time-adjusted VC levels (laboratory detection limits) for the time periods evaluated ranged from 0.14 to 0.16 $\mu g/m^3$ (Table 2). Time-adjusted VC levels were about 4 to 40 times lower.

Using the maximum detection limit value of 1.17 $\mu g/m^3$ as a measured value and multiplying it by VC's IUR of $8.8x10^{-6}$ results in an estimated LECR of 1 excess cancer in 100,000 people (Table 4). This is a low excess cancer risk. Using averaged VC levels (laboratory detection limits) would result in excess cancer risk of about 1 excess cancer in one million people. Time-adjusted VC levels ranged from 0.03 to 0.004 $\mu g/m^3$. The estimated excess cancer risk for these levels ranges from 2.6 in 10 million to 4 in 100 million (Table 5), overall a very insignificant excess risk. For teachers and staff working 10, 15, or 20 years in the building, the estimated excess cancer risk ranged from 9 in 100 million to 4 in 10 million; an insignificant excess risk (Table 6). Teachers and staff should not have increased cancer risk from breathing VC in the air in the school.

Limitations

Vapor intrusion can vary over time. The amount of chemical levels in vapors that migrate into a building can vary depending on season, rainfall, wind, temperature, building conditions, and occupant behaviors such as opening windows and doors. Vapors in soil in the subsurface can vary by location, including under different areas of the same building, and from building to building, which would affect the amount of chemicals migrating into a building.

Indoor air sample collection during multiple seasons is able to characterize seasonal variability in soil gas and indoor air levels. Winter is considered the worst season for vapor intrusion variability in the northern United States. Higher vapor intrusion was seen in summer and in buildings with air conditioning in southern states. Therefore, accuracy improves with sample results from multiple seasons at sites. Year-to-year variation in vapor intrusion can occur because of factors such as weather patterns and occupant behaviors [ATSDR 2016].

In our evaluation, we used maximum values to be cautious. The maximum values were also adjusted based on how long children, teachers, and staff learn or work in the school. The adjusted values come closer to a real world representation of the possible exposure in the school but the adjusted values may not necessarily represent what the true exposure may have been.

We did not evaluate the levels of chemicals together as a mixture because it is difficult to be accurate with the interpretation. Some mixtures of chemicals can cause additive health effects while others cause health effects to remain the same or even decrease. Because PCE and TCE have similar metabolic pathways, evidence suggests the PCE and TCE can interfere with the way each chemical can be metabolized in the body (Seiji et. al. 1989). Occupational studies indicated that workers exposed to both PCE and TCE had lower levels of TCE metabolites in the urine than workers exposed only to TCE at about the same concentrations that occurred in the mixture. The metabolites of PCE and TCE are considered to be responsible for the chemical's toxicity to the liver and kidneys; however, it is unclear whether the parent compounds or their metabolites (particularly TCE metabolites) have the greater impact on neurological effects. Overall, the available weight-of-evidence suggests that co-exposure of humans to PCE and TCE may inhibit the metabolism of TCE and thereby may inhibit carcinogenic and non-carcinogenic responses in the liver and kidney to TCE metabolites. ATSDR scientists concluded PCE had a less-than-additive effect on TCE, whereas TCE had an additive effect on PCE [ATSDR 2004].

The Vapor Intrusion Mitigation System beneath the floor of the school has a major influence on levels of drycleaner-related chemicals in the indoor air of the classrooms. As outlined above, TDH recommends the school and their environmental consultant continue to operate and monitor the HVAC system, perform monthly pressure field tests, and continue work to further decrease levels of PCE, TCE, 1,2-DCE, and VC to preferably non-detect levels in the indoor air of the school.

Additional Considerations

The overall investigation of the Mendenhall Square Shopping Center Site has been a stepwise process of environmental investigation, soil gas, groundwater, indoor air testing, and a series of engineering and institutional controls.

In May 2020 the school's consultant performed confirmatory indoor air testing after additional engineering controls were implemented. These controls included adjustment of the HVAC system to allow more outside air to flow through the building as well as adding additional vapor removal points for three classrooms to further capture and greatly reduce the potential for chemical vapors to enter the indoor air of the school. The confirmatory sampling showed a significant decrease in chemical levels in indoor air.

As stated above, TDH recommends indoor testing to be done for a minimum of one year on a quarterly basis. Thereafter, testing should be conducted semi-annually, and annually as needed for a period of time to show if drycleaner-related chemicals are absent or only present in very low levels in the indoor air and to protect the health of students, teachers, and staff of the school. The testing would confirm the mitigation system is continuing to function as intended. The frequency of future indoor air testing will be reviewed by both TDEC and TDH.

We recommend the continued air sampling even though our analysis showed current levels of drycleaner-related chemicals should not cause negative health effects to the children, teachers, or staff. As seasons, weather, and site conditions may change, it is important to continue to monitor this site for a period of time to ensure any measured variability in chemical levels are noted and to protect children and teachers in the school.

Conclusions

The Tennessee Department of Health's Environmental Epidemiology Program reached two conclusions about breathing indoor air at the charter school located in the Mendenhall Square Shopping Center:

1. Breathing drycleaner solvent vapors is not expected to harm the health of students learning in the school as long as the VIMS continues to operate as intended. Measured and averaged indoor air sampling results for PCE, TCE, 1,2-DCE, and VC were adjusted to represent a 10 hour per day, 5 day per week, and 6 year exposure for students. Chemical vapor levels were lower than both non-cancer and cancer health comparison values.

2. Breathing drycleaner solvent vapors is not expected to harm the health of teachers or staff working in the school for many years as long as the VIMS continues to operate as intended. Measured and averaged indoor air sampling results for PCE, TCE, 1,2-DCE, and VC were adjusted to represent a 10 hour per day, 5 day per week, and 6, 10, 15, and 20 year exposures for teachers and staff. Chemical vapor levels were lower than both non-cancer and cancer health comparison values for all exposure scenarios.

Recommendations

TDH recommends the school and their environmental consultant continue to perform indoor air testing. The indoor air testing should be done quarterly for a minimum of one year. Thereafter, testing should be conducted semi-annually or annually as needed for a period of time to show if drycleaner -related chemicals are absent or only present in very low levels in the indoor air of the school. It is imperative the mitigation system continue to function as intended to protect the health of students, teachers, and staff of the school and testing would confirm it is continuing to do so. The frequency of future indoor air testing will be reviewed by both TDEC and TDH.

Continued use of the VIMS is imperative for lowering chemical levels in the school. The conclusions above were based on continued proper operation of the VIMS. TDH also recommends continuing to operate and monitor the HVAC system, performing monthly pressure field tests, and continuing work to decrease chemical levels in the indoor air of the school to preferably non-detect levels.

TDH further recommends the continued air sampling even though our analysis shows current levels of drycleaner-related chemicals should not cause negative health effects to the children, teachers, or staff. The continued indoor air testing will ensure the charter school and the TDEC Division of Remediation know the remedial system is operating properly and protecting the health of students, teachers, and staff in the school.

Public Health Action Plan

This public health action plan for the Mendenhall Square Shopping Center Site lists steps TDH EEP and other agencies have taken or plan to take to protect the health of students, teachers, and staff of the school. These steps are designed to prevent or limit harmful health effects that might result from exposure to hazardous substances in the environment. TDH EEP is committed to following up on this public health action plan to ensure action steps are completed.

TDH EEP Actions Completed

- Reviewed numerous reports summarizing activities performed and indoor air measurements collected about this site.
- On January 14, 2020, EEP staff met at the school with the school's Chief Operating Officer, environmental consultant Fisher Arnold, and an indoor air contractor Clean Vapor.
- On February 28-29, 2020, EEP staff observed continuous indoor air monitoring performed in the school by Fisher Arnold and Hartman Environmental Geosciences.
- Prepared this Health Consultation evaluating indoor air data.

TDH EEP Actions Planned

- Share this Health Consultation with TDEC Division of Remediation
- Share this Health Consultation with school administrators and the Shelby County Health Department.
- Be available to school administrators should they have questions regarding this health consultation.
- Be available to TDEC Division of Remediation to review and interpret future indoor air measurements.
- Maintain dialogue with all interested stakeholders to safeguard public health.

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Glossary of Terms and Acronyms

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

ATSDR: federal Agency for Toxic Substances and Disease Registry.

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: The theoretical excess risk for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower. The excess cancer risk is often expressed as $1x10^{-6}$ for one excess cancer in 1 million people.

Cancer Risk Evaluation Guide (CREG): CREGs are environmental media (water, soil, air) specific comparison values that are used to identify amounts of cancer-causing substances that are unlikely to result in an increase of cancer rates in people that have been exposed to the media.

chronic exposure: Contact with a substance that occurs over 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 health consultation process. Substances found in amounts greater than their CVs might be selected for further evaluation in the health consultation 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 present in an environment where it does not belong.

DCE: dichloroethylene

detection limit: The lowest concentration of a chemical that a laboratory’s analytical equipment can reliably distinguish from a zero concentration.

EEP: The Tennessee Department of Health’s Environmental Epidemiology Program.

Environmental Media Evaluation Guide (EMEG): EMEGs represent levels of substances in water, soil, or air, to which people may be exposed during a specified amount of time (acute, intermediate, or chronic) without experiencing adverse health effects.

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: 1. a source of contamination (such as an abandoned business), 2. an environmental media and transport mechanism (such as movement through groundwater), 3. a point of exposure (such as a private well), 4. a route of exposure (eating, drinking, breathing, or touching), and 5. a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

hazard: A source of potential harm from past, current, or future exposures.

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

$\mu g/m^3$: micrograms per cubic meter

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.

PCE: Tetrachloroethylene, a chlorinated solvent chemical used in dry cleaning.

release: A release is defined as any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing (including the abandonment or discarding of barrels, containers and other closed receptacles containing any hazardous substance, pollutant, or contaminant) into the to the air water or land.

remediation: Cleanup or other methods used to remove or contain a toxic spill or hazardous materials from a site.

risk: The probability that something will cause injury or harm. For non-carcinogen health effects, it is evaluated by comparing an exposure level over a period to a reference dose derived from experiments on animals. For carcinogenic health effects, risk is estimated as the incremental probability of an individual developing cancer over a lifetime (70 years) as a result of exposure to a potential carcinogen.

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).

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

source area: The location of highest soil or ground water concentrations, or both, of the chemical of concern. The source of contamination is the first part of an exposure pathway.

TDEC: Tennessee Department of Environment and Conservation.

TDH: Tennessee Department of Health.

Tetrachloroethylene (PCE): A chlorinated solvent chemical that has a density greater than water. The most widely used chemical in drycleaning.

Trichloroethylene (TCE): A chlorinated solvent chemical also having a density greater than water. Most commonly used degreasing chemical.

Vapor Intrusion: Process by which chemical vapors migrate upward from underlying contaminated soil, soil gas, or groundwater into buildings. Petroleum hydrocarbons and chlorinated solvent chemicals are the most common chemicals found at sites where vapor intrusion occurs,

Vinyl chloride (VC): A chlorinated solvent chemical. Last chlorinated volatile organic chemical in the tetrachloroethylene breakdown chain.

VIMS: Vapor Intrusion Mitigation System

volatile organic compounds (VOCs): Organic compounds that evaporate readily into the air. VOCs include substances found in indoor air at the school include tetrachloroethylene, dichloroethylene, trichloroethylene, and vinyl chloride.

REPORT PREPARATION

The Tennessee Department of Health's Environmental Epidemiology Program prepared this Health Consultation for the Mendenhall Square Shopping Mall Site located in Memphis, Shelby County, Tennessee, under a cooperative agreement (Grant # CDC-RFA-TS20-2001 with the federal Agency for Toxic Substances and Disease Registry. It is in accordance with the approved agency methods, policies, and procedures existing at the date of publication. The Tennessee Department of Health independently evaluated and summarized the data used in this Health Consultation.

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Appendix A. Example Equations - Estimating Exposure to Chemical Vapors

1. **Evaluating Maximum Levels and Averaged Maximum Levels for Specific Timeframes for Cancer Health Effects Evaluation Example:**

Lifetime Excess Cancer Risk = Maximum Chemical Concentration x Inhalation Unit Risk

where: Maximum Chemical Concentration = Maximum Detected Chemical Concentration in milligrams per cubic meter ($\mu g/m^3$);
IUR = U.S. Environmental Protection Agency's Inhalation Unit Risk for the Chemical ($\mu g/m^3$)

Maximum Chemical Conc. = 35.6 $\mu g/m^3$ x 2.6 x 10^{-7} $\mu g/m^3$ = $\underline{9.3 \times 10^{-6}}$ excess lifetime cancer risk

2. **Adjusting Chemical Results for Student, Teacher, and Staff Time Spent in School Grades K through 5:**

Calculation - Chemical Maximum and Averaged Maximum Concentration Example:

Maximum Chemical Concentration = Maximum Chemical Concentration x ET x EF x LE

where: Maximum Chemical Concentration = Maximum Detected Chemical Concentration ($\mu g/m^3$);
ET = exposure time (hours [hrs]/day); and
EF = exposure frequency (days/week)
LE = length of exposure (yrs/78 yr lifetime)

Maximum Chemical Conc. = 35.6 $\mu g/m^3$ x 10 hrs/24 hr day x 5 days/7 day week x 6 yrs/78 yr lifetime = 35.6 $\mu g/m^3$ x 0.417 x 0.714 x 0.077 = $\underline{0.82\ \mu g/m^3}$

3. **Adjusting Chemical Results for Teacher and Staff Time Spent in School over 10, 15, 20 Years:**

Calculation - Chemical Adjusted Maximum and Adjusted Averaged Maximum Concentration Example:

Maximum Adjusted Chemical Concentration = Maximum Adjusted Chemical Concentration x ET x EF x LE

where: Maximum Adjusted Chemical Concentration = Maximum Detected Chemical Concentration ($\mu g/m^3$);
ET = exposure time (hours [hrs]/day); and
EF = exposure frequency (days/week)
LE = length of exposure (yrs/78 yr lifetime)

For a 10 year exposure of the highest levels of PCE found:

Maximum Chemical Conc. = 35.6 $\mu g/m^3$ x 10 hrs/24 hr day x 5 days/7 day week x 10 yrs/78 yr lifetime = 35.6 $\mu g/m^3$ x 0.417 x 0.714 x 0.128 = 1.38 $\mu g/m^3$

For a 10 year exposure of the highest levels of TCE found:

Maximum Chemical Conc. = 8.41 $\mu g/m^3$ x 10 hrs/24 hr day x 5 days/7 day week x 10 yrs/78 yr lifetime = 8.41 $\mu g/m^3$ x 0.417 x 0.714 x 0.128 = 0.33 $\mu g/m^3$

For a 15 year exposure of the highest levels of PCE found:

Maximum Chemical Conc. = 35.6 $\mu g/m^3$ x 10 hrs/24 hr day x 5 days/7 day week x 15 yrs/78 yr lifetime = 35.6 $\mu g/m^3$ x 0.417 x 0.714 x 0.192 = 2.01 $\mu g/m^3$

For a 15 year exposure of the highest levels of TCE found:

Maximum Chemical Conc. = 8.41 $\mu g/m^3$ x 10 hrs/24 hr day x 5 days/7 day week x 15 yrs/78 yr lifetime = 8.41 $\mu g/m^3$ x 0.417 x 0.714 x 0.192 = 0.48 $\mu g/m^3$

For a 20 year exposure of the highest levels of PCE found:

Maximum Chemical Conc. = 35.6 $\mu g/m^3$ x 10 hrs/24 hr day x 5 days/7 day week x 20 yrs/78 yr lifetime = 35.6 $\mu g/m^3$ x 0.417 x 0.714 x 0.256 = 2.71 $\mu g/m^3$

For a 20 year exposure of the highest levels of TCE found:

Maximum Chemical Conc. = 8.41 $\mu g/m^3$ x 10 hrs/24 hr day x 5 days/7 day week x 20 yrs/78 yr lifetime = 8.41 $\mu g/m^3$ x 0.417 x 0.714 x 0.256 = 0.64 $\mu g/m^3$