Frequently Asked Questions (FAQ) About Trichloroethylene (TCE) at the Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire

These FAQs are provided for the public. Please note that quarterly Restoration Advisory Board (RAB) meetings are held, and are open to the public (check the website for past meeting presentations and upcoming meeting dates). The FAQs are presented under the following four categories/sections.

I. **Background – What is TCE and how did it get here?**
II. **TCE Investigations at CRREL – How is TCE sampled and where has it been found?**
III. **Actions – What actions have been taken to prevent exposure and protect health and the environment?**
IV. **Health – Questions Regarding TCE Health Effects**

I. Background

What is TCE and how did it get here?

1. What is TCE?

TCE is a nonflammable, colorless liquid with a somewhat sweet odor. Prior to its listing as a hazardous material, TCE was widely used as a solvent for degreasing, an intermediate compound for producing other chemicals, a refrigerant, and a general anesthetic. TCE is still used in consumer products including arts and crafts, office supplies, hunting or weapons cleaning solvents, and automotive supplies and for such uses as cleaners and penetrating fluids. TCE was previously used at CRREL as a secondary refrigerant, but has not been used there since 1987. TCE does not occur naturally in the environment, however, it has been found in underground water sources and many surface waters as a result of the manufacture, use, and disposal of the chemical.

2. How did TCE contamination occur at CRREL?

Prior to 1987, the US Army Corps of Engineers (USACE) at CRREL predominantly used TCE in secondary refrigerant pipes. Secondary refrigerants transfer heat from equipment to heat exchangers chilled by primary refrigerants such as freon. CRREL has extensive refrigeration capability in the Main Laboratory

building as well as other facilities. There were reports of several large spills of liquid TCE at various locations on the laboratory grounds during the 1970s and 1980s. Responses to spills occurring before 1987 included practices that would not be allowed today (i.e., TCE washed into storm drains from spills). High volume releases occurred at two main Areas of Concern (AOC): a leaking underground storage tank at the north end of the Main Laboratory, called AOC 2, and a deep refrigerated ice well called AOC 9. The ice well was frozen in the past utilizing TCE, but has now been abandoned. TCE has not been used as a secondary refrigerant at CRREL since 1987. Investigations to determine the extent of TCE contamination and to remediate the TCE have been underway since 1990.

3. What happens to TCE when it enters the environment?

A migration pathway is the route that a compound takes when it moves from the point of release to the point of exposure. TCE was primarily released to soil (surface and subsurface) at CRREL. As TCE is highly volatile and evaporates quickly when exposed to air, surface releases would have included some immediate volatilization to air. Once entering the soil environment, liquid TCE migrated through partitioning to other media such as soil vapor and groundwater. Soil vapor moves through tiny spaces in the soil. Where the soil vapor plume is present beneath existing buildings (see Figure 1), soil vapors have the potential to migrate through diffusion and advection through cracks or penetrations in floor slabs into the buildings (vapor intrusion). TCE volatilizing into outdoor air can also enter buildings through open doors and windows. Soil vapor may also provide a migration pathway for TCE to contaminate groundwater. Because TCE is water soluble and does not readily biodegrade, it may remain in groundwater until partitioning back to soil vapor, or unless removed during remediation of groundwater. TCE contaminated groundwater at CRREL is contained and treated at an on-site treatment plant located near the Frost Effects Laboratory.

TCE was also released to the Connecticut River from storm drains following major releases, which may have impacted surface water and sediment, along with several groundwater wells on the Vermont side of the River. Impacted wells in Vermont are not used for potable purposes. TCE volatilizes quickly in surface water when exposed to air, however TCE may migrate from sediment further into the subsurface environment. TCE has been detected in deep sediment within the CT River, but concentrations above screening thresholds have only been detected at depths where there is minimal chance for exposure.

4. What is vapor intrusion and how does this differ from other sources of TCE?

Vapor intrusion (VI) occurs when vapor-forming chemicals within any subsurface source migrate into an overlying building. Vapor-forming chemicals may include volatile organic compounds (VOCs), such as TCE. Figure 1 illustrates common VI considerations. More information is available from USEPA: https://www.epa.gov/vaporintrusion/what-vapor-intrusion.

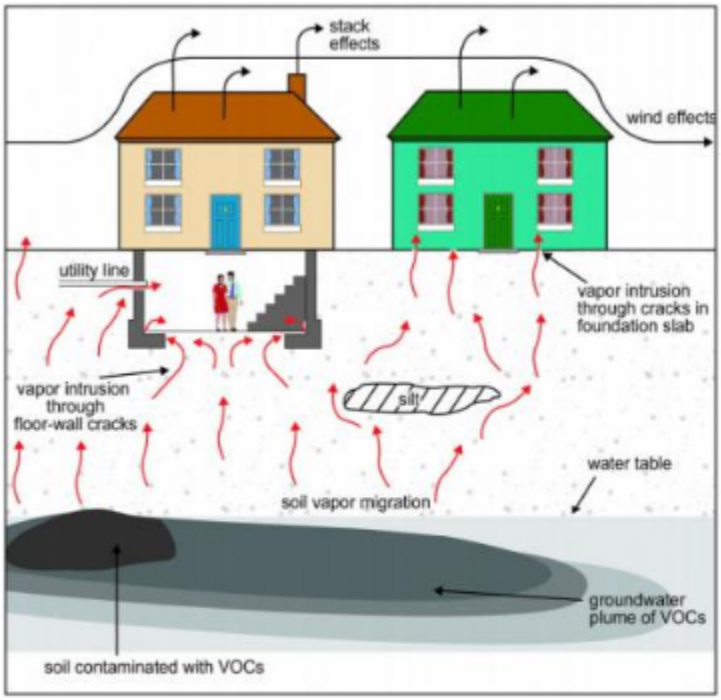

Figure 1: Migration of Soil Vapors to Indoor Air

This figure depicts the migration of vapors in soil gas from contaminated soil and groundwater into buildings. Vapors in soil gas are shown to enter buildings through cracks in the foundation and openings for utility lines. Atmospheric conditions and building ventilation are shown to influence soil gas intrusion.

TCE from VI is distinguished from other common sources of TCE in buildings, such as use of TCE containing products, residual TCE from building materials, and other situations where workers may be exposed to TCE, such as workers using TCE routinely during manufacturing. The distinction is made because TCE exposures are regulated under OSHA for workers exposures and under CERCLA if from VI. Concentrations of TCE at CRREL are always assessed and mitigated as if they were from VI, although in reality vapors may come from a variety of sources over time. It is important to distinguish the sources of TCE because the solutions for mitigating VI are different than the solutions for mitigating exposures due to contaminated building materials, manufacturing process, or TCE-containing products.

II. TCE Investigations at CRREL

How is TCE sampled and where has it been found?

5. What investigation work has been done? What is the current understanding of the contamination in the ground and the pathways for TCE movement into the buildings or off-site at CRREL?

A Remedial Investigation (RI) has been completed. The RI documents a multi-year, multi-media investigation, performed with the goal of providing sufficient information to characterize the site, define site dynamics, define risks, and develop a remedial program to mitigate current and potential threats to human health and the environment. The RI found that historic releases of TCE resulted in contamination of soil around the Main Laboratory. The released TCE formed a soil vapor (also called soil gas) plume that migrated deeper into the subsurface and toward other CRREL buildings and the CRREL property boundary, and contaminated groundwater. Soil vapor can move through soil and enter buildings through cracks and gaps in building foundations (this is called vapor intrusion [VI]).

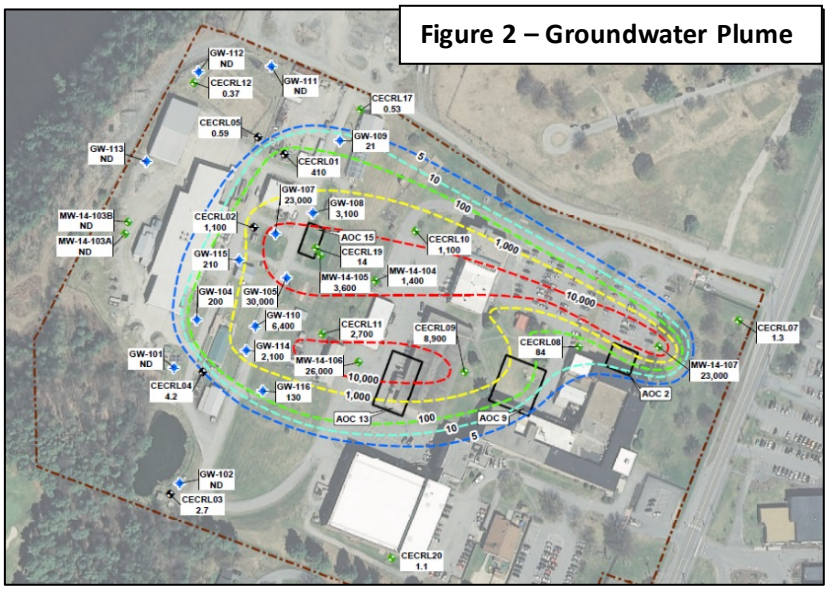

Figure 2 – Groundwater Plume

Figure 2 shows the CRREL campus with TCE concentrations in groundwater overlaid. The colors show the levels of TCE in groundwater. The highest levels are shown in red.

Active remediation through a soil vapor extraction (SVE) pilot study is ongoing at AOC 2, the area illustrated in Figure 3, and has significantly reduced the volume of TCE in soil vapor, groundwater, and soil. However, the TCE vapor plume is still present and is a potential source of VI contamination to CRREL buildings and the underlying groundwater. Active remediation of the vapor pathway in the Main Laboratory building includes a sub-slab depressurization system (SSDS), which limits the vapor intrusion pathway by limiting the potential for vapors to migrate from the subsurface into indoor air. Healthmate Air Purifying Units (APUs) installed within the building capture

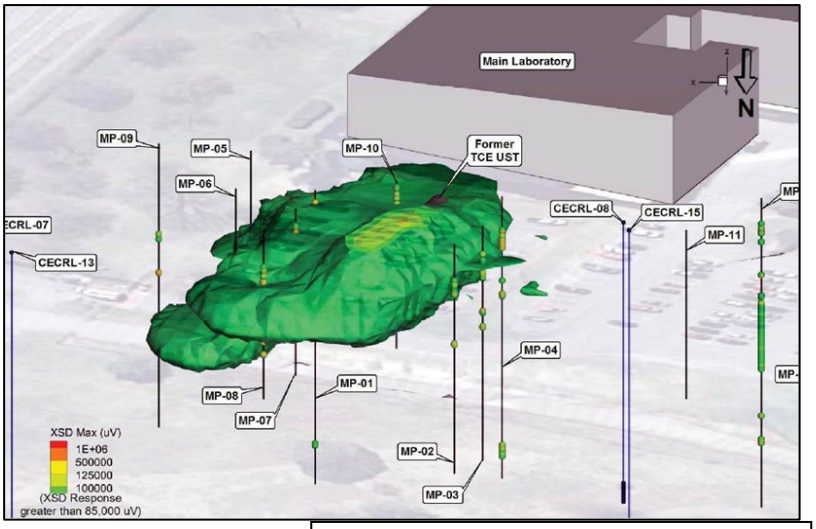

Figure 3 – Soil Vapor Plume at AOC 2

remaining TCE vapors, and daily indoor air sampling at the CRREL buildings is on-going to detect any changes in air concentrations in real time and to protect the workers' health. In addition, an action plan is in place to monitor air concentrations and to implement health-protective steps if health-protective action levels are exceeded in workspaces.

6. Why was indoor air sampling conducted beyond the boundary of CRREL? Is this on-going?

TCE vapors are present deep in the soil at the CRREL property and, to an extent, in soils deep beneath some adjacent properties. Samples of indoor air within buildings outside of CRREL were needed to confirm that TCE was not migrating upwards into buildings beyond the CRREL boundary. Samples were collected from off-site residences and businesses adjacent to CRREL, as well as the Richmond Middle School starting in 2013.

Past and current indoor and outdoor air monitoring at these off-site locations shows that TCE in indoor air and outdoor air was either not detected at all, or was only present at concentrations well below applicable action levels. The only on-going off-site sampling is within the Richmond Middle School, and the sampling frequency has been reduced due to a lack of evidence of VI occurring. Additional testing of residences or businesses further away from CRREL are not warranted.

III. Actions Taken

What actions have been taken to prevent exposure and protect workers' health?

7. What is being done to address potential employee and public exposure to TCE?

There have been several past and ongoing remediation and mitigation measures to remove vapors in indoor air, or to remove the pathway for vapors to move into indoor air. These include:

- Portable air purifiers loaded with activated carbon have been deployed at many occupied offices, several plenum spaces (the space above the ceiling and below the roof), and other locations at CRREL. These were tested in an enclosed space and found it to be effective at removing TCE and other solvents from air when used as directed. It is recommended that the air purifiers continue to be used and maintained until they are no longer needed.
- Increasing the buildings' fresh air exchange where possible.
- Installing Sub Slab Depressurization Systems (SSDSs) in three buildings. The SSDSs are large-scale designs similar to a home radon removal system. They consist of vapor extraction points below grade providing vacuum at numerous points drilled through the building slab.

A series of pipes connected to an air pump exhausts the vapors through activated carbon to remove the TCE and other solvents prior to release to the atmosphere.

Other mitigation measures have included:

- Groundwater plume capture by a series of extraction wells used for cooling water. Extracted water is treated through carbon filtration to remove TCE and other solvents, used for building cooling in a closed loop system, and then discharged to the Connecticut River in accordance with state and federal permits. Detailed models that provide a picture of the migration of TCE at CRREL were published in the RI and are continuously being updated by the investigation team.
- Active remediation through a soil vapor extraction (SVE) Pilot Study has been undertaken, which extracts TCE vapors from soil vapor. This pilot study removed a large amount of TCE, reducing concentrations in the soil vapor beneath the building, has resulted in lower TCE concentrations in indoor air, and has also reduced concentrations in groundwater.
- Historical piping within the building was identified as an ongoing source of TCE vapors. This piping, called the -73ºF line, was removed. The removal actions were completed in August 2019.
- Contaminated roofing materials were identified in the Main Laboratory building. Fans and air purifying units have been installed in the plenum (above the ceiling) space to mitigate elevated TCE concentrations occasionally detected in the enclosed plenum space, typically during the summer months.

8. What are the next steps for the CRREL clean-up?

CRREL will continue to operate extraction wells and monitor indoor air daily at the facility, applying health-protective action levels for on-site workers until a final remedy is undertaken for the CRREL site.

The CRREL environmental restoration is currently in the Feasibility Study (FS) phase where alternatives for permanent remediation of TCE are evaluated. The FS will be completed in 2021, and will evaluate the following:

- TCE-contaminated vapor and soil gas as it pertains to potential impacts on current on-site buildings and off-site migration.
- Potential exposures to TCE-contaminated soil and soil gas by construction workers.
- Groundwater as a potential source of drinking water.

The FS will present cleanup alternatives for TCE contaminated soil, soil gas, and groundwater. In the meantime, the mitigation systems described above will continue to operate and remove TCE for protection of human health and the environment. A Supplemental RI (to be completed in the Spring of 2021) will summarize the 2019 investigation of TCE contamination in Vermont groundwater wells, along with sediment and surface water in the Connecticut River.

IV. Health Effects

Questions Regarding TCE Health Effects

9. What are the potential health effects associated with exposure to TCE?

Observed health effects are generally dependent on the intensity and/or duration of exposure. For longer-term exposures, human health risk assessment focuses on two types of effects at low levels of exposure: non-cancer and cancer. Non-cancer effects for TCE include diminished immunity, changes to the liver, and cardiac malformations in developing fetuses. Cancer effects of TCE include non-Hodgkin lymphoma (a type of blood cancer involving white blood cells), liver cancer, and kidney cancer. For short-term high exposures, such as might occur accidentally in a workplace using TCE in current processes, high concentrations of TCE may in the short-term cause headaches, lung irritation, dizziness, poor coordination, and difficulty concentrating.

Experiments on animals are used to better understand possible health effects in humans. Test animals are typically exposed to large amounts of a chemical to rapidly induce an effect. The same effects seen in animals are thought to occur in people exposed to TCE, so the USEPA has developed toxicity values (incorporating safety factors) from the animal studies to estimate human health risk. These toxicity values were used to develop the CRREL workers' site-specific TCE action levels for air. The critical health effect that the non-cancer screening value is based on is cardiac malformations in developing fetuses.

10. I have spent several years in a building that has been sampled. Will I get sick?

At the CRREL facility, during the few instances when the CRREL-specific air action level was exceeded, employees have been notified and given the option to work in non-impacted areas. TCE in off-site locations has never been detected above applicable action levels.

If you are exposed to TCE, many factors determine whether you'll experience any health effects. These include how much you are exposed to (dose), how long you are exposed (duration), how often you are exposed (frequency), and how you are exposed (route of exposure). You must also consider the other chemicals you are exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

11. How would I know if I have experienced any health effects due to TCE exposure?

Because of the uncertainties of measuring TCE vapors in the air, and because many different body processes are involved in responses to environmental toxins, we would not know if any particular health effect is tied to any particular TCE exposure. We would know only whether an effect is more or less likely following exposure. For example, the human immune system is complex system that finds and destroys foreign material such as viruses and bacteria. There are many environmental influences that might affect the immune system, including everyday experiences such as stress. At best, we can only say that there may be an increased risk for a health effect. If that risk is greater than acceptable limits, we can recommend steps to take to reduce the exposure and risk.

High levels of exposure in industrial settings may be detectable in the blood or urine for up to a week. However, these measurements are less reliable at the lower levels of exposure, and the medical tests use equipment that may not be available at most doctors' offices.

At the low levels of air exposure seen within the CRREL workspaces and off-site, medical tests might miss any indication of exposure to TCE. If detected, it would likely be difficult to distinguish exposure from other background exposures, other chemicals producing similar test results, adverse health effects tied to lifestyle choices like smoking and diet, or different states of health among people.

12. Where do I get reliable information about TCE health effects?

Reliable information about toxic effects related to TCE may be found at:

Agency for Toxic Substances and Disease Registry:
https://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=172&tid=30

US Environmental Protection Agency:
https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=199

If you have any questions, please contact:

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