National Aeronautics and Space Administration

Space flight and exploration begin with developing innovative technologies here on Earth.

Our commitment to environmental stewardship is central to that effort. NASA is identifying chemical substitutes, alternative primers and coatings, and improved lead-free solder for use in future missions. At the same time, NASA is addressing the result of historical disposal practices at our Centers and Component Facilities across the country. NASA is committed to protecting public health and the environment, and we are working with government agencies, industry, and local communities to plan and implement effective cleanup strategies. One area of focus is on trichloroethylene (TCE), a chemical that was commonly used in the past.

The Use & Remediation of TCE at NASA

TCE was first commercially produced in the United States in the 1920s, and it proved to be a versatile solvent. Its use in industry surged through the 1950s, primarily as a degreaser of metal parts. TCE was used widely in manufacturing processes, in the dry cleaning business, computer chip development, and as an ingredient in a variety of household items including varnishes, adhesives, and spot removers.


Metal shops typically used TCE to clean and degrease parts.

Much like others working in the 1950s, NASA began using TCE as a degreaser in equipment maintenance and cleaning operations. The majority of TCE use by NASA was at the Centers and Component Facilities involved in early rocket engine testing and aircraft maintenance. Identifying TCE substitutes and modifying processes have dramatically reduced NASA's use of TCE. The small volume of TCE in use today is properly disposed of in compliance with regulations.

TCE

NASA's pollution prevention efforts significantly reduced TCE use

Keep reading to see how NASA is developing innovative ways to clean up TCE.

About TCE in the Environment

TCE is a non-flammable, colorless liquid that belongs to a group of chemicals known as volatile organic compounds (VOCs). It evaporates and it can enter the air when products having TCE as an ingredient are being used. At some sites, TCE has been directly discharged into surface waters, such as ponds and rivers, requiring cleanup of sediments. When released to soil — from spills, leaking storage tanks, or disposal sites — TCE can bind to soil and sediment particles and remain for a long time. It can also move through soil and eventually move into groundwater. Because of its makeup, TCE has relatively low ability to dissolve in water, and like some other chlorinated solvents TCE can be present as a dense non-aqueous phase liquid, or DNAPL. In this form it is heavier than water and is likely to sink, in some cases eventually settling on top of low-permeability geological layers. These layers are sometimes at great depths and in hard-to-reach places. As groundwater moves through subsurface areas containing TCE, groundwater can transport it away from the source. It takes a long time for TCE to break down naturally in the environment. Some treatment methods try to speed up the rate of breakdown but in doing so, this process can form less desirable chemicals such as vinyl chloride. TCE can enter the air through a process known as volatilization. This occurs when TCE is in the vadose zone (the unsaturated soil above the groundwater and below the ground surface), where it can become a gas, migrate up through the soil, and be released into the air. The soil gas can move upwards into the air space of an overlying building and TCE can enter indoor air (referred to as vapor intrusion).

Determining Exposure

Exposure to TCE may occur from drinking, breathing, eating, or by it passing through the skin. The effects of exposure to TCE, like any chemical, depend on several factors: how much of a chemical is present (concentration); whether and how much a person is exposed to (dose); how long a person is exposed (duration); how often a person is exposed (frequency); and a person's general health, age, and lifestyle.

NASA continues to comply with federal and state requirements to address TCE that remains from historic use. We are committed to protecting public health and the environment.

Understanding Health Effects

The potential for health impacts from TCE has been studied by scientists for many years. Studies in animals have found that inhaling or drinking water contaminated with very high levels of TCE over a long period of time (several years or more) can cause kidney, liver, and lung damage and potentially increase cancer risk. Human health studies have been limited and some health effects have been observed under certain exposure conditions. Government agencies have set standards and guidelines regarding exposure to TCE to be protective of public health and the environment. The Occupational Safety and Health Administration (OSHA) has guidelines for safe use in the workplace. The United States Environmental Protection Agency (USEPA) and some states are in the process of updating the human health information for TCE based on the latest science and research. The USEPA released a Final Health Assessment for TCE and intends to issue new guidance.

Identifying TCE at NASA


Testing water quality


Installing a groundwater monitoring well

When TCE was recognized as a concern, NASA took an aggressive approach to investigate all NASA sites where TCE was used historically, to identify where it may have entered the environment. The first step was to conduct a review of documents and records at each of the locations and interview current and past employees to understand historical use, storage, and disposal practices. NASA then conducted soil and groundwater sampling at locations where releases may have occurred to determine the nature and extent of TCE. Sampling is often an iterative process. Based on sampling results, NASA installed wells to monitor TCE in groundwater. Computer modeling has been used to help predict TCE movement. Additional wells have been installed to better understand and monitor the slow movement of TCE in groundwater. Where the potential for indoor air concerns exists, air monitoring is used to measure vapor intrusion in buildings overlying the groundwater plume.


A core sample, shown here, provides information about conditions deep underground.

Preparing to sample groundwater

NASA took an aggressive approach to investigate where TCE had been used in the past.

Cleanup is Underway

From the site investigation work that was done, NASA identified the presence of TCE in soil and groundwater at 13 Centers and Component Facilities. NASA took action and began cleanup efforts at several locations. Three NASA Centers (at right) have made considerable progress.

The NASA-funded groundwater treatment facility in Pasadena, California

Jet Propulsion Laboratory (JPL) - Pasadena, California

The first step in cleaning up TCE was removing soil vapor from the source area beneath JPL. This was followed by construction of three NASA-funded treatment plants that have been successfully removing groundwater chemicals from the source area at JPL, and also from what is referred to as the mid-plume in Pasadena, and from the farthest reaches of the area affected by the chemicals, in Altadena. As a result of these efforts, Pasadena Water & Power (PWP) has been able to re-open previously-closed water production wells to serve treated water from those wells to its customers, and Lincoln Avenue Water Company is able to serve treated water to its customers.

Santa Susana Field Laboratory (SSFL) – California

A Groundwater Extraction System (GETS) has been treating groundwater at SSFL on an interim basis since 2009. Groundwater is extracted from wells and sent to a centralized facility containing a number of technologies capable of removing chemicals, including TCE. Chemicals removed from the water are captured in the filter media which is disposed off site at approved facilities. The treated water is monitored and discharged into regional drainages. When fully operational, the GETS will treat water extracted from seven wells across NASA's portion of SSFL.

At SSFL, the GETS facility contains several technologies capable of removing chemicals.

Ames Research Center (ARC) - Moffett Field, California

Groundwater treatment at ARC involves a system using granular activated carbon (GAC) filtration. NASA has been assessing vapor intrusion in overlying buildings by collecting thousands of indoor, outdoor, and background air samples during the past decade. Where levels have been detected above the indoor action level, NASA has modified heating ventilation and air conditioning (HVAC) systems — a standard and usually effective vapor intrusion mitigation measure. Air monitoring is continuous to protect occupants working in the buildings.

See page five for a description about technologies being developed by NASA researchers.

Progress Continues

Science is the basis for developing and implementing comprehensive cleanup strategies. NASA is actively engaged in TCE cleanup initiatives and is using a range of commercially available technologies. Depending on site conditions, TCE is treated in place, called in situ treatment, or extracted for aboveground treatment, called ex situ treatment. At some locations, in situ and ex situ methods work concurrently or in succession.

From laboratories to field tests, from demonstration projects to full-scale implementation, NASA strives to identify innovative and effective TCE remediation methods that:

- have potential for improved outcomes
- more quickly meet or exceed cleanup goals
- generate less waste, noise, and disruption during installation and operation
- use less materials and energy
- and are cost effective

In Situ Chemical Oxidation

At Stennis Space Center (SSC) in Mississippi, in situ chemical oxidation (ISCO) was introduced in 2012 to remediate TCE in saturated soil and groundwater. ISCO is enhancing the performance of a pump and treat system operating since 2004. This innovative ISCO process involves slowly and continuously injecting a substance (such as hydrogen peroxide and a catalyst, or activator) that comes into contact with the TCE. This contact helps residual contamination from saturated soil to be released into the dissolved phase where it can be readily oxidized. Any dissolved-phase TCE that has not oxidized can be collected by the existing extraction wells and treated aboveground. A small demonstration project was followed by three large-scale projects in 2012. Results showed levels of TCE had dropped by more than 50% in groundwater samples and were non-detectable in the treated soils. The ISCO process at SSC incorporates several sustainable technologies and practices. For example, an automated injection control lowers energy use and minimizes material waste, and an integrated solar photovoltaic panel powers the control valves and web-enabled monitoring system. NASA is assessing opportunities for full-scale implementation of this ISCO technology.

A solar-powered In Situ Chemical Oxidation control system at Stennis Space Center.

Emulsified Zero-Valent Iron (EZVI)

NASA researchers at Kennedy Space Center (KSC) in Florida have developed an innovative in situ remediation technology to be used on very high concentrations of DNAPL in groundwater. EZVI involves placing extremely small (microscale) zero-valent iron particles into a surfactant-stabilized, biodegradable water-in-oil emulsion. This is injected into the DNAPL-contaminated zones in the subsurface. The DNAPL gradually migrates into the emulsion where the contaminant reacts with the zero-valent iron. Through reductive dehalogenation, DNAPL and its daughter products degrade into ethane and other hydrocarbons. These byproducts safely diffuse into groundwater and are finally broken down through biological activities in the subsurface. During field testing, typical results show 90% or greater reduction in DNAPL groundwater concentrations within one to four months, and undetectable concentrations within nine to twelve months. NASA is holder of the EZVI patent and KSC has licensed the technology to seven companies.

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Monitored Natural Attenuation: A Molecular Approach

Physical, chemical, and biological processes occur naturally to break down TCE in the environment over time. At Ames Research Center in California NASA is looking on a molecular level at this process, known as monitored natural attenuation. NASA has developed "fingerprinting" of the communities of microbes at work in groundwater. This fingerprinting is able to sort and compare the mix of thousands of bacteria species present in one small (five grams) sediment sample. Standard monitoring methods have only measured a single type of bacteria, and thus can underestimate the natural processes at work. With only one sampling, NASA has identified 60 novel microbes that metabolize TCE, some of which are useful on other contaminants. This provides a vastly expanded picture of the range of functions associated with natural attenuation. The microbes and their enzymes newly identified by this work are being adapted to address a mix of contaminants and specific groundwater conditions.

NASA is working with other agencies and with industries to find TCE cleanup solutions.

NASA scientists are researching new ways of cleaning up TCE.

In Situ Thermal Treatment

NASA conducted a pilot test using in situ thermal treatment (ISTT) technology at Marshall Space Flight Center (MSFC) in Alabama. Due in part to the variable and complex geology beneath MSFC, NASA selected the in situ thermal desorption (ISTD) technology, originally developed by Shell Oil Company. This process involves in situ heating of the groundwater to temperatures near the boiling point of water. Vacuum wells then extract and separate vapors and fluids bringing them to the surface. The vapors are treated through a granular activated carbon (GAC) filtering system and treated air is released to the atmosphere. The fluids are piped to an aboveground facility and treated using a liquid/GAC system. Results proved successful at removing 400 lbs. of TCE from the source area and significantly reducing TCE concentrations in the subsurface.

The Work Continues and So Does NASA's Commitment

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NF-2013-05-564-HQ
OCTOBER 2013