

PCE – A Dark Alchemy

By Lisa Alexander

Tetrachlorethylene, or Perchlorethylene, has a history that is obscured by its modern usage. Miracle cleaner, degreaser, safe to apply to ancient fabrics like wool and silk without shrinking or staining them, powerful enough to dissolve grease from modern micro-circuitry, it was originally synthesized in 1821 by physicist Michael Faraday of electricity and magnetism fame. Non-flammable, sweet smelling and highly stable (indeed – some estimates suggest up to 40% of residue may still be present in dry cleaned clothes three months after cleaning¹), it seemed to solve many of the problems associated with previous incarnations of “dry” cleaners.

Non-water cleaning goes back to at least the ancient Roman Empire, when a urine-based ammonia process for cleaning wool togas was so profitable and widely used that it was taxed by the Empire. In the mid-1800s, kerosene spilled on a tablecloth inspired dye works merchant Jean Baptiste Jolly to begin using petroleum-based cleaners commercially. Problems with fires and explosions led to some of the first government regulations of the industry. In 1924, Joseph Stoddard altered the formula to create a less flammable alternative. The resulting Stoddard Solvent was widely used from 1928 to the late 1950s. And finally, PCE began to be used as a dry cleaning solvent and industrial degreaser in the 1930s, after World War I.

In the early 20th century, PCE was used as a treatment for hookworm. Like various mercury (“quicksilver”) and coal tar remedies, the adverse health effects of PCE were mostly unknown and are still being unraveled. Listed as a “probable” human carcinogen by EPA (and now under consideration as a “known” carcinogen), PCE can accumulate and be stored in body fat, or in butter and cheese which is why Germany no longer allows dry cleaning facilities using chlorinated solvents to be located near grocery stores. While conducting research for this article, this writer found studies from North Carolina to California, Texas to Vermont - and from Canada (along with forty other countries looking to ban many organochlorine compounds including PCE) - all re-evaluating whether PCE should be used *at all*, particularly for dry cleaning which tends to be a business found in more densely populated areas where even relatively minor emissions can result in exposures. Studies on workers who were in the dry cleaning industry for one year or more showed lingering long-term neurological effects for up to six years after the exposures had ceased².

Articles regarding the PCE health risks reveal long lists of acute and chronic health effects depending on the exposure³. In women, PCE can cross the placenta barrier, and be released by nursing mothers directly to their infants in breast milk⁴. Additionally, as a consequence of its persistence in the environment, PCE has been found in the blubber of marine mammals and fish⁵. A central nervous system depressant, PCE can cause headaches, vertigo, nausea, fatigue and irritability. It can dissolve fat from skin (think wrinkles, dry skin, redness, irritation and pain, *not* chemical liposuction) and may be linked to Parkinson’s and a number of reproductive system defects, including infertility, miscarriages and birth defects.

The stability of PCE in groundwater has created problems across the country. It has been estimated that in California, from five⁶ to ten⁷ percent of drinking water wells are impacted by

PCE. The presence of PCE residue on dry cleaned clothes months after cleaning is further evidence of its stability. California is phasing out the use of PCE by 2023, at least for dry cleaning, and there is a race to find safer alternatives. One of these, called, “D5,” is a proprietary liquid silicon that breaks down in a “short” time (i.e., “days”) into silica, carbon dioxide and water. Research on PCE and possible replacements continues today on a number of fronts.

Amid all of this ongoing research where is Massachusetts with respect to disposal sites where PCE is the primary contaminant of concern?

In 1993, MassDEP issued cleanup standards for PCE and many other common contaminants found in soil and groundwater based on the best science available at the time. MassDEP set standards for the protection of human health based on a number of what were believed to be conservative fate and transport assumptions. BWSC then truth-tested these assumptions as site data became available (Fitzgerald and Fitzpatrick evaluation, 1996). What that testing found was that the fate and transport model used to generate the original GW-2 standards needed to be adjusted based on the empirical site data, including assumptions about biodegradation of chlorinated contaminants. In fact, while we had observed 100- to 1000-fold reduction of *petroleum* concentrations after diffusion through the vadose zone, the study revealed that the attenuation of *chlorinated solvents* was much *less*, often only a 10- to 100-fold reduction.

Research suggests most PCE (up to 85%) that is released to the atmosphere breaks down in 130 days on average, and yet, because it is so widely used it remains ubiquitous in low levels in ambient air, particularly in urban and suburban areas⁸. But, as this audience knows, when released to soil and groundwater, PCE degrades very slowly and persists in the environment for years, even decades. It can sink relatively unchanged through soil and groundwater, traveling in long thin plumes, migrating along bedrock dips and cracks, posing a number of assessment challenges - to put it mildly. Some plumes have been traced a half mile or more back to their original source areas. The stability that made it safer to work with than petroleum may create a persistent presence in groundwater and a cleanup problem with long lasting risk and liability for owners, prospective owners and downgradient receptors. Fortunately, effective indoor air mitigation systems are available to prevent or reduce exposures of that kind once they are discovered, although effective cleanup of source areas can still be a difficult and expensive challenge.

BWSC files document many cases where a facility has been closed for a decade or more, perhaps abandoned by owners, and an enterprising developer comes along and encounters previously unreported concentrations of PCE in groundwater or soil requiring Immediate Response Actions. In some cases, years after the original release, there may still be Imminent Hazard levels of PCE in indoor air.

In April 2006, the MCP GW-2 PCE standard decreased from 3000 to 50 micrograms per liter in groundwater, reflecting the data that showed that PCE poses the potential for vapor intrusion at much lower concentrations than previously modeled. The magnitude of the change indicated that there were potentially some sites “closed out” prior to this change using the previous GW-2 PCE standard where there could be indoor air impacts to nearby residences or other buildings that were not considered when the site was assessed. Additionally, site assessment practitioners and regulators across the US were recognizing that the vapor intrusion pathway demonstrated significant variability in site-specific attenuation and increasingly there was a call for using a

“multiple lines of evidence” approach for evaluating whether or not PCE vapors would get from groundwater to indoor air.

In 2009, the LSPA Loss Prevention Committee reviewed 89 Notices of Audit Findings (from July 2007 through December 2008) with indoor air issues to see what kind of findings were most common in these cases. The survey did not include a review of the original submittals, but did note that in many cases the audit findings identified a need for more complete site characterizations and more detailed evaluations, including more sampling to evaluate indoor air pathways. There was a conclusion that MassDEP needed to be clearer as to what was expected for compliance. The LSPA and other program stakeholders) have made a significant commitment to work with MassDEP on the vapor intrusion guidance and subsequent training⁹. (Hint: Watch for announcements about courses later this year.)

In its review of pre-2006 RAOs at PCE sites, BWSC identified approximately 600 RAOs (out of a total of some 32,000 RAOs) where PCE was a contaminant of concern and the potential for vapor intrusion had not been evaluated, or the site had been closed based on either the old cleanup standard or modeling. (Sites which were closed based on an evaluation of actual indoor air samples were not included in this review.) Upon screening these closed sites, the majority were ruled out as requiring no further review; 96 were selected for closer evaluation. The case screening was based on the groundwater concentrations of PCE at the time of the RAO, the presence of potential receptors at and near the site, and the nature and extent of contamination as described in the site assessment reports.

A comprehensive (Level 3) audit was then conducted. As with all audits, the sites were evaluated based on the standards that were in place at the time of RAO (*not* the newly revised GW-2 standard, but the level of investigation conducted in the previous submittals used to RAO the sites). The first revised NOAFs went out in early 2007.

By the end of the project, we had reviewed 96 sites and found:

- 18 previously filed RAOs were determined to be invalid; 12 had Imminent Hazard Conditions;
- At least 57 buildings were potentially affected by vapor intrusion and 22 of these had Imminent Hazard conditions (many sites had multiple buildings affected by vapor intrusion);
- 60 Notice of Audit Findings included Notices of Noncompliance; 55 required additional work, usually additional assessment work, particularly to document the extent of the contamination under the new cleanup standard;
- DEP spent public funds to do work at 19 sites;
- Of the 96 sites, 72 of the sites require no further action under the PCE initiative at this time; additional assessment and/or remediation/mitigation work is ongoing at the remaining 24 sites with Financial Inability status being filed for one of these.

Here are some examples of the cases that have been audited in the last few years, most were identified in the PCE initiative; all of them are examples of what can happen with historic releases of PCE to soil and groundwater:

- An old drum cleaning facility became the location of a Head Start preschool; although a passive venting system was installed at construction, no testing was conducted post-construction to confirm effectiveness of system; indoor air testing was required. Fortunately, no indoor air impacts were identified once testing was done (Somerville).
- A Release Notification Form and Class B-1 RAO were submitted together for a site in 2008; following additional assessment, Imminent Hazard levels of PCE were detected in three separate residences (Medford).
- A former toy manufacturing facility was redeveloped into 8 large apartment buildings with passive subslab venting systems. Sampling showed site-related PCE in 4 of 5 buildings tested, in 3 of the buildings PCE was at Imminent Hazard levels. (Salem).
- A former transistor manufacturing facility was converted to commercial and residential properties after Class A-2 RAO was filed in 1998; sampling of indoor air revealed the presence of an Imminent Hazard condition, which has since been addressed with an active sub-slab depressurization system (Cambridge).
- At an active dry cleaner still in operation, pre-RAO sampling of indoor air in two downgradient residences revealed vapor intrusion in both, but a Class B-1 RAO was still filed. Upon audit, DEP required additional sampling in the residences which revealed vapor intrusion condition still existed; subslab depressurization systems were installed in both homes. Subsequent testing demonstrated the effectiveness of the systems (Westwood).
- Former dry cleaner impacted the multi-unit building in which it was located, including commercial tenants and two downstairs apartments; sampling revealed Imminent Hazard conditions at a nearby downgradient building, two multi-unit residences as well as impacts to a parochial school (Andover).
- A groundwater pump and treat system and soil vapor extraction system was installed at the site of a former dry cleaner in the late 1980s, but no evaluation was ever done at nearby residential properties. Subsequent indoor air sampling discovered Imminent Hazard condition at a residence; a subslab depression system was installed and the source remediation has been scaled up (Newton).
- Owners of a former dry cleaner submitted an RAO without considering vapor intrusion based on depth to groundwater 16 feet below the surface; no sampling had been conducted near adjacent commercial parcels. Further sampling (soil gas and indoor air) revealed Imminent Hazard conditions at locations downgradient of the source property, resulting in multiple notifications (Newton).
- A dry cleaner was found to be sharing a common wall with a day care facility. An inspection by the Bureau of Waste Prevention revealed an illegal floor drain and dry

well. The dry cleaner was required to conduct indoor air sampling at the day care facility and found Imminent Hazard conditions. Remedial actions have been taken (Winthrop).

- Due diligence for a property transaction revealed a dry cleaner near a church with a daycare facility in the basement. Imminent Hazard conditions were identified and portable air purifying units were brought in until an SSD could be installed. Additional testing also revealed vapor intrusion at a nearby residence (Dorchester).
- A former machine shop was converted to a preschool, upon sampling of indoor air, Imminent Hazard levels of PCE were detected; an Immediate Response Action was initiated and work is proceeding through the MCP process (Watertown).
- A former dry cleaning supply facility which received bulk PCE shipments by train for distribution to dry cleaners is the source of a large PCE plume that underlies a densely populated residential neighborhood including an early childhood learning center. Testing revealed vapor intrusion at the childhood learning center and several residences. Mitigation measures have been taken at the learning center and at a number of nearby homes (Somerville).
- PCE contamination was detected during construction of a video store at the location of former dry cleaner. This led to an investigation of indoor air at the video store. Exposure to the occupants was severe enough that they were exhibiting physical symptoms. Further assessment revealed hot spots out the back door and around basement floor drains. The store was vacated when Imminent Hazard levels of PCE were detected in indoor air and was closed after the extent of the problems was discovered (Ayer).
- An occupational training and rehabilitation facility serving disabled and handicapped adults was built on the location of a metal valve manufacturer. Both the building and property were impacted by manufacturing operations which used PCE as a parts cleaner and degreaser. Investigation revealed that the clients of the rehabilitation facility were being exposed to concentrations of PCE at Imminent Hazard levels and required an Immediate Response Action to eliminate the Imminent Hazard condition. Efforts to eliminate the IH condition were only partially implemented and thus were ineffective (e.g., air scrubbers were regularly turned off due to noise). Ultimately, under MassDEP supervision, soil gas and indoor air sampling isolated and located a particular source area within the building where a parts dryer had leaked for years. A large section of PCE saturated concrete floor of the building was then removed and further sampling showed a marked decrease of PCE concentrations in indoor air reduced to levels of No Significant Risk. (Worcester).
- A former plating facility with a PCE plume in groundwater was redeveloped into eight multi-unit condominiums post-RAO. Residents were sold and moved into the condominiums without prior evaluation of potential impacts to indoor air. This case resulted in major enforcement actions; several rounds of sampling have been conducted and assessment is ongoing. (North Attleboro).

Considering the two orders of magnitude change in the PCE GW-2 standard, the number of sites requiring additional action had the potential to be much greater. Fortunately, while there were

some sites with big problems, most of the issues uncovered could be addressed in a relatively timely manner. Given the problematic nature of PCE and other chlorinated volatile organics, these chemicals appear destined to be phased out of use all around the country if not the world. Moral of the story? Incorporating the best available science and practice is a hallmark and commitment of the 21E program and critical to its credibility and protectiveness. The regulated community, LSPs and MassDEP were successful in stepping up to address a problem that became apparent as we evaluated updated science on PCE and vapor intrusion. While this has been a difficult challenge, it was one we managed to meet working together.

¹ <http://www.ecocleanaustin.com/content/view6/9/>;
<http://www.health.state.ny.us/environmental/chemicals/tetrachloroethylene>; and
<http://www.anr.state.vt.us/AirToxics/htm/HealthTetrachloroethylene.htm>

² Agency for Toxic Substances and Disease Registry, Toxicological Profile for Tetrachloroethylene. Washington, DC: US DC, U.S. Department of health and Human Services, TP-92/18, 1993.

³ http://www.turi.org/library/turi_publications/massachusetts_chemical_fact_sheets_perchloroethylene
http://www.epa.gov/chemfact/f_perchl.txt

⁴ <http://www.supereco.com/glossary/perchloroethylene/>

⁵ “Why – and How – to Green Your Textile Choices; article from EcoTextiles, December 2008.
oecotextiles.com/PDF/WhyHowtoGreenYourTextileChoices.doc

⁶ California study at <http://www.coreenvironmental.org/drycleanerfund.php> - said that “In February 2003, a bill (AB698) to limit the use of PCE was introduced and sponsored by the Santa Clara Valley Water District. The regulatory agency noted that PCE, a synthetically produced organic compound used as a cleaning solvent, had been found in over 900 water production wells (an estimated 5% of the state’s water supply wells). According to the sponsor, historic dry cleaning operations have had a high incidence of PCE spills and releases, many of which were only then being identified. They estimated that 90% of professional dry cleaners in California had leaked PCE to the environment.” Note, the maximum contaminant level for drinking water in California is 5 ppb for PCE.

⁷ <http://www.supereco.com/glossary/perchloroethylene> from 2008 suggests a higher number of contaminated wells.

⁸ Massachusetts Toxics Use Reduction Institute, chemical fact sheet on PCE, suggests 0.79 ppb in urban/suburban areas, 0.16 ppb in rural areas and up to 1.3 ppb near emission sources, even when appropriate controls are in place..

⁹ Wesley E . Stimpson, Review of NOAFs Addressing Indoor Air Issues – July 2007 through December 2008, presentation given to LSPA Loss Prevention Committee.