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TOXIC SUBSTANCES

While carbon tetrachloride has been banned for over two decades, the authors of this article say current understanding about the extent of the carbon tetrachloride contamination in the United States may only represent the tip of the iceberg. The authors note the chemical's history as a fumigant used at farms throughout the United States and say it is a tenacious, prevalent, and carcinogenic substance with a growing reputation for being difficult to remediate. They focus on contamination of groundwater in the Midwest by carbon tetrachloride. The authors suggest state and federal governments become more actively involved in the investigation of grain silos where the fumigant was widely used.

A Well of a Problem: The Legacy of Carbon Tetrachloride in U.S. Groundwater

BY MARK R. MISIOROWSKI AND JOEL D. EAGLE

At the turn of the 20th Century, German immigrants passed through Ellis Island in large numbers, hoping to start new lives in towns such as Dubuque, Iowa, Lincoln, Neb., and Fort Wayne, Ind. Indeed, by the mid-20th century Germans made up the largest rural population in much of the Midwest.[1] At this time, a large German population was not the only emigrating force to make its way from the Rhine Valley to the wheat fields of the United States. In 1898, carbon tetrachloride, the first chlorinated solvent of general use in the United States, left Germany and landed in the manufacturing mix at chemical companies such as Dow and Dupont de Nemours Co.[2]

Carbon tetrachloride was a multi-purpose chemical, used as a degreasing solvent for industrial and domestic purposes, as a fire suppressant, as a cleaning agent for dry cleaning, in making nylon, and for many years was used as a fumigant in grain operations throughout the Midwest. Farmers sprayed or applied liquid product directly onto stored grain at large grain elevators, small storage sheds, flat storage, government surplus storage

[1] *See* Encyclopedia of Chicago, Germans, http://www.encyclopedia.chicagohistory.org/pages/512.html.

[2] Solventhistory.com, carbon tetrachloride, http://www.concentric.net/~Rnk0228/solhist.html.

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facilities, and in railroad loading areas. After decades of application at thousands of farmsteads and grain elevators throughout the bread basket of the country, revelations about the carcinogenic effects of carbon tetrachloride exposure caused the Environmental Protection Agency to place an outright ban on carbon tetrachloride as a pesticide.

Today, many of the sites known for using carbon tetrachloride are being investigated for possibly heavy contamination, and at many sites the results are cause for concern. The stubborn nature of the chemical makes remediation a difficult undertaking, and to date, investigations have been conducted at only a fraction of the sites where the chemical may have been applied, stored or disposed of. While the chemical has been banned for over two decades, current understanding about the extent of the carbon tetrachloride contamination in the United States may only represent the tip of the iceberg. The recognized risk of exposure from ingesting, inhaling, or physical contact with the chemical will likely spur additional investigation, detection, and remediation in years to come—and rightly so, considering the potential health concerns associated with carbon tetrachloride exposure.

Carbon Tetrachloride Profile

Carbon tetrachloride (CCl_4) is one of a number of chlorinated solvents with a rich history in the United States.[3] Carbon tetrachloride is a clear, colorless liquid with a heavy sweet odor similar to chloroform.[4] As with the other chlorinated solvents, direct exposure to carbon tetrachloride or to locations with even moderate soil and/or groundwater contamination poses a significant threat to human health.

There are four significant release mechanisms for carbon tetrachloride into the environment. First and foremost, carbon tetrachloride entered the environment due to fumigation or direct application of 80 percent carbon tetrachloride and 20 percent carbon disulfide on the stored grain itself. Second, for purposes of rodent and pest control, 80/20 was applied in the grain elevator boot, as well as directly on the ground by way of gopher holes and around building foundations to kill mice, rats, and other pests. Third, contamination came at the hands of spills and leaks from various transporting devices and equipment, such as rail cars, delivery trucks, leaky hoses, and onsite storage tanks, and the improper disposal of excess product by simply pouring it on the ground. Finally, because carbon tetrachloride was used for other industrial and domestic purposes, the chemical has entered the environment in ways unrelated to grain fumigation.

When it enters the environment, carbon tetrachloride volatilizes quickly in the air, where it can remain for several years before breaking down into its degradation products.[5] Carbon tetrachloride does not easily stick to soil particles; instead, the chemical either evaporates into the air or enters the soil and/or groundwater, presenting a particular challenge for remediation efforts.[6]

At normal temperature and pressure, carbon tetrachloride is a dense non-aqueous phase liquid (DNAPL). In plain English, carbon tetrachloride has a higher density and is almost insoluble in water, making it hard to contain and extract. When it enters the groundwater, carbon tetrachloride will migrate downward until it encounters a geologic barrier that prevents further vertical transport. At this point, it will continue to break down at a slow rate, and may persist in various constituent forms for many years, decades, or longer.[7] The extent of carbon tetrachloride contamination is closely linked to the interminable nature of the hydrologic cycle. Rain and snow events all year long at farm fields throughout the country draw the pollutant into the groundwater, and over time this continuous cycle drives the heavy contaminant deeper into the ground. By this process, many aquifers in the Midwest and throughout the country have become contaminated with carbon tetrachloride and, because of its physical characteristics, carbon tetrachloride remediation has proven extremely difficult.

Health, Safety, and Deregulation

Early on in its production life, carbon tetrachloride became a grain fumigant for the grain-producing states of the Midwest. In 1911, carbon tetrachloride was recommended as a substitute insecticide for carbon disulfide, and by the end of World War I, better equipment and technology increased its use as an insecticide and pesticide.[8] For the next several decades, carbon tetrachloride was a primary fumigant for harvested grain at tens of thousands of farmsteads in the United States. As a fumigant, carbon tetrachloride was produced in a concentration of 80 percent carbon tetrachloride and 20 percent carbon disulfide and was commonly known in the farming industry simply as 80/20.[9] The fumigant was so powerful that a worker could spray grain at the top of a 100-foot grain elevator and be confident that the chemical would destroy all pests, down to the bottom of the grain elevator within three days.[10]

Along with the emergence of environmental awareness in the late 1960s and early 1970s came concern over the health effects associated with carbon tetrachloride exposure. In 1974, Congress passed the Safe

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[3] Other chlorinated solvents used in the U.S. throughout the 20th Century include: PCE (Perchloroethylene) , TCE (Trichloroethylene), TCA (1, 1, 1 – Trichloroethylene), Methylene Chloride, and 1, 2 dichloroethylene.

[4] EPA, Groundwater & Drinking Water, Carbon Tetrachloride Consumer Factsheet, http://www.epa.gov/safewater/dwh/c-voc/carbonte.html.

[5] The degradation, or daughter, products of CCl_4 in air, water, or soil include chloroform, chloromethane, and methylene chloride. See Table 1, http://www.engg.ksu.edu/hsrc/ag/2002/proceed/c02.pdf.

[6] Agency for Toxic and Substances and Disease Registry, U.S. Department of Health and Human Services, ToxFaqs for Carbon Tetrachloride Fact Sheet, available at http://www.atsdr.cdc.gov/tfacts30.pdf.

[7] U.S Federal News, *Scientists Help in Cleaning Up Contaminated Groundwater to Restore Wetland Wildlife Sanctuary Near Utica*, June 10, 2005.

[8] Solventhistory.com, carbon tetrachloride, http://www.concentric.net/~Rnk0228/solhist.html.

[9] Other trade names or synonyms, both as a grain fumigant and in its other uses, include tetrafume, dowfume, tetraform, tetrasol, perchloromethane, methane tetrachloride, benzinoform, univerm, necatorina, facsiolin, flukoids, R10 (refrigerant), Freon 10, and Halon 104. See EPA Consumer Factsheet on Carbon Tetrachloride, http://www.epa.gov/safewater/dwh/c-voc/carbonte.html.

[10] Mark Obmascik, *Bitter Harvest: Carbon Tetrachloride Was Used to Protect Grain from Rodents; Now it Taints Well Water in the Midwest, and Perhaps Colorado*, http://denverpost.com, Feb. 28, 2002.

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Drinking Water Act, setting non-enforceable maximum contaminant level goals for chemicals in drinking water that may cause health problems. The maximum contaminant level goal for carbon tetrachloride was set at zero, as this was the level EPA believed was necessary to protect against the health effects of exposure to the chemical. EPA's enforceable standards for carbon tetrachloride in drinking water, known as the maximum contaminant level (MCL), is currently set at 5 parts per billion, or approximately five eye drops of carbon tetrachloride in a 130,000 gallon Olympic-size swimming pool.[11]

EPA began a special review of carbon tetrachloride in 1980;[12] by 1986, manufacturers of carbon tetrachloride-based grain fumigants voluntarily and completely ceased all production, without seeking to reformulate, repackage, or add new warnings. Today, carbon tetrachloride's use as a grain fumigant is completely banned by EPA.

As the generation of farmers and industrial workers most often exposed to carbon tetrachloride continue to age, and the medical community's interest in carbon tetrachloride wanes, the decision to ban 80/20 production and use becomes an obvious one. According to EPA studies, carbon tetrachloride has short-term effects on the liver, kidney, and lungs, all of which are very sensitive to the chemical. Long-term health effects may include liver damage and a heightened risk of cancer.[13] The Department of Health and Human Services has determined that carbon tetrachloride may *reasonably be anticipated to be a carcinogen;* the International Agency for Research on Cancer has classified carbon tetrachloride in Group 2B, *possibly carcinogenic to humans;* and EPA has determined that carbon tetrachloride is a *probable human carcinogen*.[14]

The highest risk of occupational exposure to carbon tetrachloride, prior to being banned in 1986, was during fumigation processes. Today, carbon tetrachloride exposure can occur in two primary ways. First, humans may be exposed to carbon tetrachloride by ingesting contaminated groundwater.[15] Second, studies over the last 20 years have shown that because contaminated water may be used for cooking, bathing, and showering, the chemical may cause significant harm to humans by inhalation or absorption into the skin through physical contact.[16]

Because of the chemical's ability to volatilize quickly, especially in warm air or water, a warm or hot shower may create high concentrations of toxic vapors that are easily inhaled into the bodies of unsuspecting bathers.[17] According to estimates from the National Academy of Sciences, between 200 and 1,000 people die each year in the United States from cancers caused by ingesting chlorinated contaminants in water, and the most significant health risk may be from inhalation as air pollutants.[18] A study conducted by a professor of water chemistry at the University of Pittsburgh found that exposure to vaporized chemicals in the water supplies through inhalation from showering and bathing is 100 times greater than through drinking the water.[19]

The ''safe'' lifetime environmental exposure level for inhalation of carbon tetrachloride set by EPA, underscores the concern over volatilized carbon tetrachloride entering the air of one's home through drinking, cooking, or bathing with contaminated water. For the general population, EPA typically will use an acceptable cancer rate of one out of a million. At the 'one out of a million' rate, the acceptable lifetime exposure level for inhalation of carbon tetrachloride is 0.01 part per billion. Thus, the safe level for inhalation is 500 times less than the 5 ppb acceptable level set for ingesting the contaminant.[20]

Ingestion, inhalation, and dermal contact with carbon tetrachloride are not the only pathways that create concern. Human health may be indirectly affected by carbon tetrachloride through its effect on the earth's atmosphere. The 1992 Amendments to the Montreal Protocol included a complete ban on carbon tetrachloride pro-

[11] Carbon tetrachloride is regulated in various contexts under the Federal Clean Air Act (listed as Hazardous Air Pollutant, subject to control of VOC emissions), Clean Water Act (Toxic pollutant under Effluent Guidelines), CERCLA (Reportable quantity of 10 lbs), EPCRA (Toxics Release Inventory, subject to reporting requirements), FIFRA (all registrations now cancelled), RCRA (Characteristic Toxic Hazardous Waste – TCLP threshold of .5 ppm), SDWA (MCL of .5 ppb), the FDA (maximum permissible level in bottled water of .5 ppb; all medical devices containing or manufactured with carbon tetrachloride must contain a warning statement that the compound may destroy ozone in the atmosphere), and OSHA (various hourly exposure limits).

[12] The Special Review process is set in motion when EPA has reason to believe that the use of a pesticide may result in unreasonable adverse effects to people or the environment. *See* criteria for initiating a Special Review, 40 C.F.R. Part 154.7

[13] Environmental Protection Agency, Groundwater & Drinking Water, Carbon Tetrachloride Consumer Factsheet, http://www.epa.gov/safewater/dwh/c-voc/carbonte.html.

[14] Toxicological Profile for Carbon Tetrachloride, U.S. Department of Health and Human Services, August 2005.

[15] Wisconsin Department of Health and Family Services, Carbon Tetrachloride Chemical Fact Sheet, http://www.dhfs.state.wi.us/eh/ChemFS/fs/carbontet.html.

[16] Dr. John Andelman, University of Pittsburgh, BOTTOM LlNE, August 1987. Studies have shown that a simple shower in contaminated water can be worse than drinking contaminated water because hot water gives off a toxic gas that can be inhaled. *See also* Carpenter, B., Hedges, S.J., Crabb, C., Reilly, M., & Bounds, M.C., *Is your water safe?* US News and World Report (July 29, 1999) pp. 48-55; Mark Obmascik, *Bitter Harvest: Carbon Tetrachloride Was Used to Protect Grain from Rodents; Now it Taints Well Water in the Midwest, and Perhaps Colorado*, http://denverpost.com, Feb. 28, 2002.

[17] Dr. John Andelman, University of Pittsburgh, BOTTOM LlNE, August 1987; *see also* Carpenter, B., Hedges, S.J., Crabb, C., Reilly, M., & Bounds, M.C., *Is your water safe?* US News and World Report (July 29, 1999) pp. 48-55.

[18] Janet Raloff, *Toxic Showers and Baths*, 130 Science News 190. According to conservative calculations, inhalation exposures can be as significant as exposure from drinking the water: one can be exposed to just as much by inhalation during a shower as by drinking 2 liters of water a day. Raymond Gabler, IS YOUR WATER SAFE TO DRINK? Consumer Reports Books (1988). Other reports have found that chlorinated contamination sent into the air through showering or cooking can spread throughout the house, and that ''householders can receive 6 to 100 times more of the chemical by breathing the air around the showers and bath than they would by drinking the water.'' Ian Anderson, *Showers Pose a Risk to Health*, New Scientist, Sept. 18, 1986.

[19] *Troubled Waters on Tap: Organic Chemicals in the Public Drinking Water Systems and the Failure of Regulation*, Duff Conacher and associates, Center for Study of Responsive Law, January 1988.

[20] *See* EPA Air Toxics, Toxic Transfer Network, Carbon Tetrachloride, http://www.epa.gov/ttn/atw/hlthef/carbonte.html#ref9.

duction and use as of Jan. 1, 2000, because of its tendency to deplete the stratospheric ozone.[21]

80/20 Hot Spots

Finding a carcinogenic chemical anywhere in the environment is a cause for concern. But is there reason to believe that a stubborn chemical like carbon tetrachloride persists in any considerable amount in the United States, possibly being ingested or inhaled by residents unaware of its presence? The recent upswing of private, state, and federal investigations of sites historically known for carbon tetrachloride storage, use, or disposal would appear to answer that question. In many of the states where significant numbers of carbon tetrachloride-impacted sites have been found (Kansas, Nebraska, Missouri, Iowa, and Colorado), state and federal agencies including EPA, the Department of Energy, and the Department of Agriculture have provided resources for detection, remediation, and support for locally-affected residents. At thousands of former USDA surplus grain storage facilities, 80/20 fumigant was applied in large amounts for decades. In addition to grain elevator sites, carbon tetrachloride contamination also has occurred at sites operated by the Department of Energy.[22]

In the late 1940s, the Department of Agriculture, through a subsidiary known as the Commodity Credit Corporation (CCC), began a large scale plan to buy and/or lease grain storage locations in the Midwest. The purpose of the CCC plan was to secure surplus grain storage locations for purposes of price regulation and national security. According to the Agriculture Department, at its peak in the mid 1950s the CCC operated grain storage facilities (known as Quonset Huts) at several thousand leased properties throughout the United States.[23] Even though the CCC began to sell off its interests to local, private farmers starting in the late 1960s, the effect of 80/20 fumigant on the land appears to have been less transitory.

EPA Region 7, in conjunction with the Department of Agriculture, recently has conducted studies at former CCC sites in four states (Nebraska, Kansas, Missouri, and Iowa). Although the farmland at these sites continues to be used today, revelations from the federal investigations are noteworthy. Of the thousands of sites estimated to have existed, the USDA has to date tested 829 former CCC locations in Region 7, and 130 of those sites revealed detections of carbon tetrachloride in the water samples. In fact, at 47 percent of those positively detected locations, the carbon tetrachloride level was above the maximum contaminant level. Bottled water has become a necessary short-term preventative measure for many rural residents in these and other areas, with USDA and other agencies even providing temporary supplies of bottled water while investigation or remediation is conducted.[24]

At the Waverly, Neb., site, sampling revealed carbon tetrachloride at an alarming 3,128 ppb, more than 600 times the maximum contaminant level of 5 ppb. Concentrations of 3,000 ppb were found at a site in Murdock, Neb.[25] As is the case in Nebraska, the Kansas Department of Health and Environment has dozens of sites that are currently in its Voluntary Cleanup Program (or have pending applications) for carbon tetrachloride impacts. Two former CCC sites are thought to be the source of carbon tetrachloride contamination at the Powhattan Public Water Supply in Powhattan, Kan. The Kansas Department of Health and Environment has conducted investigations at the site dating back to 1988, and in 2000 detected carbon tetrachloride at 500 ppb. On July 17, 2007, the Kansas Department of Health and Environment approved the Voluntary Cleanup Investigation Work Plan. However, as of October 2007 actual field work at the site has still not commenced.

The Region 7 former USDA Grain Bin study is of course limited to states in Region 7, leaving gaping questions as to former CCC/USDA sites in other states. For example, the State of Colorado may have had as many as 2,185 CCC silos alone.[26] Currently, no other EPA regional office has conducted a similar survey of grain silos that historically used 80/20. Based on the USDA estimate of ''several thousand'' sites in Region 7, plus thousands of sites in other states like Colorado, the number of former CCC locations is likely quite extraordinary.

Of course, carbon tetrachloride was not only used at CCC grain storage; during its height, 80/20 was a primary fumigant for all types and sizes of farms throughout the country. It is not surprising that even a modest inquiry at state environmental protection agencies reveals a growing trend in detection and remediation of carbon tetrachloride. Nebraska and Kansas have a particularly high incidence of sites with carbon tetrachloride contamination, and are home to superfund sites of CCC as well as solely private origins.[27] Taking into account the known and unknown former CCC sites as well as the thousands of known and unknown farmsteads throughout the country that used large quantities of carbon tetrachloride, the total number of rural sites with possible 80/20 contamination is truly massive.

One curious sidenote of the carbon tetrachloride tale is its presence in spots seemingly without explanation. During investigation of one former CCC/USDA storage facility in Nebraska, the highest results came not from

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[21] Solventhistory.com, carbon tetrachloride, http://www.concentric.net/~Rnk0228/solhist.html.

[22] At the Hanford site near Richland, Wash., the Department of Energy has been involved in the multi-billion dollar, two-decade long remediation of a site containing, among other pollutants, an extraordinary amount of carbon tetrachloride contamination. Other sites impacted by carbon tetrachloride continue to pop up with increased frequency, raising questions as to the extent of its existence in our nation's soil and groundwater.

[23] USDA estimates as many as 4,400 CCC sites were operated in the 1950s-1960s. Mark Obmascik, *Bitter Harvest: Carbon Tetrachloride Was Used to Protect Grain from Rodents; Now it Taints Well Water in the Midwest, and Perhaps Colorado*, http://www.denverpost.com, Feb. 28, 2002. Not included in the Region 7 study is the State of Colorado, who may have had as many as 2,185 silos alone. *See* Obmascik, http://www.denverpost.com, *supra* note 17.

[24] Kansas Environmental News, October 1998, available at http://www.kdheks.gov/sbcs/download/ken9810.html.

[25] *See* Former Department of Agriculture Grain Bin Project, EPA Region 7, available at http://www.engg.ksu.edu/hsrc/ag/2002/proceed/b01.pdf.

[26] *See* Obmascik, http://www.denverpost.com, *supra* note 17.

[27] For example, the Hastings Ground Water Contamination Site in Hastings, Neb., has been a superfund site since 1988. Millions of dollars of remediation activity has been performed at the site. *See* EPA, Hasting Superfund Site, at http://www.cluin.org/products/costperf/SVE/hasinf.htm.

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underneath Quonset huts, circular bins, or storage sheds, but below the local Gun Club offsite from the former CCC storage facility.[28] The investigation concluded that the carbon tetrachloride came from irrigation water brought to the Gun Club. Although the actual carbon tetrachloride hit was at an otherwise unexpected place, at least the facility was in a state known for carbon tetrachloride use. Alternatively, at a site in Athens, Ga., sampling by the State Environmental Protection Division revealed carbon tetrachloride at grain silos, which created surprise and confusion at EPA. A unit coordinator at the state environmental department, likely unaware of 80/20 in Georgia, stated ''[t]he theory is that carbon tetrachloride was used as a fumigant for the grain.'' However, the department stated it was unable ''to find anyone who actually used them at silos, which means there's a lot we don't know about how silos were operated.''[29] With so many uninvestigated sites and locations containing unexpected contamination popping up, the two ''mysteries'' at the Gun Club and in Georgia may signify only the beginning of the significant new recognition of carbon tetrachloride impacts in the United States.

At perhaps the largest single area of carbon tetrachloride contamination, the Hanford Site in Washington State has a colorful past wholly unrelated to grain fumigation. From 1953-1973, the Department of Energy operated the 586 square-mile site, including ''the Z Plant,'' a Plutonium Finishing Plant in which carbon tetrachloride was used to recover plutonium from aqueous streams resulting from the manufacturing process.[30] While the facility made positive contributions of nuclear materials for our nation's defense, it left a less beneficial impact on the local environment. Hanford's 20 years of operation left an inauspicious legacy on the environment—the disposal of roughly 750,000 kg of used carbon tetrachloride created a 10 km^2 plume of carbon tetrachloride in the surrounding soil.[31] The site was placed on the National Priorities List in 1989, and from 1991 through early 2003, remedial efforts removed 171,478 pounds of carbon tetrachloride from the ground.[32] As we will see below, soil vapor extraction, a common remedial device for carbon tetrachloride, has begun to show diminishing efficiency, and the Energy Department and EPA are looking into new technologies to remove carbon tetrachloride from both soil and groundwater.[33]

Detection and Remediation Techniques

Innovative technologies for detection and remediation of carbon tetrachloride continue to develop, while traditional methods remain viable alternatives to clean up contamination. Historically, detection of carbon tetrachloride involves soil boring and groundwater testing. Recent research at Argonne National Laboratory has used surface vegetation sampling to uncover carbon tetrachloride residing below.[34] In the Nebraska towns of York and Humphrey, between 19 and 51 grasses and other vegetation (foxtail grass, knotwood and Chinese elm trees, plus other grasses, herbs, and plant tissues) were sampled for carbon tetrachloride impacts in the vadose soil zone, the region lying between surface level and the subsurface zone of groundwater saturation. The results showed that, in combination with groundwater analytical data, the plant analysis was an effective tool in characterizing the vadose zone, for purposes of identifying carbon tetrachloride contamination in the deeper subsurface below the high concentrations found in the vegetation above.

The most widely used remediation techniques for carbon tetrachloride are known as pump-and-treat (for groundwater contamination) and soil vapor extraction (for soil contamination). However, today innovative technologies such as phytoremediation and spray irrigation systems are being utilized with greater frequency, providing efficient and cost-effective remediation alternatives.

Phytoremediation uses plants and genetically engineered trees to soak up contaminated water and to process the accompanying chemicals through natural processes. Tests have shown that a hybrid form of Poplar trees with a long, specially-engineered root system work as effective and natural pumps to soak up contaminated water, and the trees then ''exhale'' the chemical, leading to near instant vaporization.[35] Phytoremediation may be a lower cost, natural, and aesthetically pleasant alternative to traditional mechanical pumping systems. In one study using the contaminant trichloroethylene (TCE), the special poplar trees were able to intercept a moving plume of TCE-contaminated water and greatly reduce the level of contamination in the soil and groundwater.[36] At the former CCC site in Murdock, Neb., the Department of Agriculture planted 2,000 trees to soak up an estimated 30 gallons of water per-day-per-tree, all in an effort to prevent carbon tetrachloride-laden groundwater from reaching tributaries feeding into the Platte and Missouri Rivers.[37]

Another potential remediation technique is known as spray irrigation. Using simple irrigation technologies available in most Midwestern communities, a typical irrigation system can remove contaminated water and disperse the water and carbon tetrachloride over a large area. Because of the chemical's ability to volatilize rapidly when it hits the air, the impacted water requires no additional treatment, while simultaneously achieving its original purpose as a farm field irrigation system. A pilot program in Utica, Nebraska that used this technique

[28] J.L. Walker, B.W. Nashold, and J.C. Burton, *Carbon Tetrachloride in Vegetation and its Application Expedited Site Characterization*.

[29] Don Nelson, *Silos Thought to be Source of Chemicals*, Athens Banner-Herald, Jan. 11, 2007.

[30] M.J. Truex, C.J. Murray, C.R. Cole, R.J. Cameron, M.D. Johnson, R.S. Skeen, and C.D. Johnson, *Assessment of Carbon Tetrachloride Groundwater Transport in Support of Hanford Carbon Tetrachloride Innovative Technology Demonstration Project*, prepared for Department of Energy, July 2001.

[31] *Id.*

[32] Hanford Groundwater Protection Program, 2002 Progress Report, available at http://www.hanford.gov/docs/gpp/library/annualreports/GPP_2002_Annual_Report.pdf.

[33] DOE Hanford Site, First Five Year Review Report, Prepared by EPA Region 10, Hanford Project Office, April 2001.

[34] J.L. Walker, B.W. Nashold, and J.C. Burton, *Carbon Tetrachloride in Vegetation and its Application Expedited Site Characterization.*

[35] Nancy Gaarder, *Science Lets Nature Aid in Toxin Cleanup*, Omaha World-Herald, July 25, 2005.

[36] L.A. Newman, *Phytoremediation of Trichloroethylene and Carbon Tetrachloride: Results from Bench to Field*, available at http://www.engg.ksu.edu/HSRC/97Proceed/Partner4/phytorem.html.

[37] Algis J. Laukaitis, *Murdock Forest ''Pulls Up'' Pollutants in Aquifer,* Lincoln Journal Star, Aug. 26, 2007 (Section H).

proved to be an effective cleanup method for a wetland wildlife sanctuary.[38] The study also indicated that the volatilization of carbon tetrachloride into the atmosphere through the spray irrigation process did not pose a threat to human health.[39] Recalling the health risk of inhaling volatilized carbon tetrachloride while showering, it would follow that the inhalation risk from the irrigation misting operation should also be explored before it becomes a standard remediation technique.

The use of microbes to transform carbon tetrachloride into carbon dioxide and other inert compounds has also been explored. One potential benefit of this particular technology is its ability to turn carbon tetrachloride into less harmful compounds without creating chloroform, one of the traditional daughter products of the chemical.[40]

Conclusion

Once used throughout the United States as a grain fumigant, carbon tetrachloride is now banned by the EPA as a fumigant, has recently spawned state and federal investigations, and continues to present new challenges and opportunities for remediation technologies. With thousands of sites with known impacts, countless sites that have yet to be uncovered, and a growing list of communities drinking bottled water in lieu of groundwater, carbon tetrachloride is a tenacious, prevalent, and carcinogenic substance with a mounting reputation for being difficult to remediate. If left untreated in our nation's soil and groundwater, carbon tetrachloride presents significant health risks to both children and adults through a variety of exposure pathways.[41]

Although federal agencies such as USDA, EPA, and the Department of Energy and various state agencies have begun to investigate the extent of the carbon tetrachloride problem in the United States, these early inquiries only tend to reveal the significant level of unknowns that currently exist. It is apparent that immediate action is necessary to prevent a future outbreak of carbon tetrachloride–related illness or threat thereof. By the beginning of the 111th Congress in 2009, the executive and legislative branches of the federal government (in conjunction with state agencies and private entities) must become more actively involved in the investigation of grain silos in the Midwest and beyond. Two reasonable courses of action include congressional earmarking of research and investigation funding and a more active role of EPA and the Department of Agriculture to study former CCC/USDA sites in states outside Region 7.

Although expedited timetables are seldom seen where government investigation or action is required, the risk posed by carbon tetrachloride contamination is a public health concern that cannot endure delay. For example, although investigation at the Powhattan, Kan., site (where carbon tetrachloride levels of 500 ppb were found in 2000) began nearly twenty years ago, no field activities had been initiated as of October 2007. The Powhattan site is just one of hundreds of sites where carbon tetrachloride contamination continues to lie in the ground, often undetected, waiting to be addressed. The wheels of action are now beginning to turn (albeit slowly), and we should not be surprised to hear more about the effects of carbon tetrachloride on Midwestern groundwater in the coming years.

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[38] *Scientists Help in Cleaning Up Contaminated Groundwater to Restore Wetland Wildlife Sanctuary Near Utica,* U.S. Federal News, June 10, 2005.

[39] *Id.*

[40] *See* The Schoolcraft Project, Michigan State University, available at http://outreach.msu.edu/exmSchProj2.asp.

[41] Reports of residents in Nebraska and Kansas drinking water with carbon tetrachloride at levels 100 times worse than the health standard have added to the potential cost of the carbon tetrachloride problem. Mark Obmascik, *Bitter Harvest: Carbon Tetrachloride Was Used to Protect Grain from Rodents; Now it Taints Well Water in the Midwest, and Perhaps Colorado*, http://www.denverpost.com, Feb. 28, 2002.

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