

A STUDY OF TRITIUM IN MUNICIPAL SOLID WASTE LEACHATE AND GAS

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ABSTRACT

It has become increasingly clear in the last few years that the vast majority of municipal solid waste landfills produce leachate that contains elevated levels of tritium. The authors recently conducted a study of landfills in New York and New Jersey and found that the mean concentration of tritium in ten municipal solid waste landfills was 33,800 pCi/L with a peak value of 192,000 pCi/L. A 2003 study in California reported a mean tritium concentration of 99,000 pCi/L with a peak value of 304,000 pCi/L. Studies in Pennsylvania and the UK produced similar results. The USEPA MCL for tritium is 20,000 pCi/L. Tritium is also manifesting itself in landfill gas and landfill gas condensate. Landfill gas condensate samples from landfills in the UK and California were found to have tritium concentrations as high as 54,400 and 513,000 pCi/L, respectively. The tritium found in MSW leachate is believed to derive principally from gaseous tritium lighting devices used in some emergency exit signs, compasses, watches, and even novelty items, such as “glow stick” key chains.

This study reports the findings of recent surveys of leachate from a number of municipal solid waste landfills, both open and closed, from throughout the United States and Europe. The study evaluates the human health and ecological risks posed by elevated tritium levels in municipal solid waste leachate and landfill gas and the implications to their safe management. We also assess the potential risks posed to solid waste management facility workers exposed to tritium-containing waste materials in transfer stations and other solid waste management facilities.

KEYWORDS

Tritium, municipal solid waste leachate and gas, radioactivity

INTRODUCTION

In 2006, HydroQual, in conjunction with Manhattan College, conducted a study of tritium in municipal solid waste leachate from landfills in New York and New Jersey. The mean level of tritium found in the leachate of active landfills was 49,900 picocuries per liter (pCi/L), which is well above the USEPA-prescribed Maximum Contaminant Level (MCL) of 20,000 pCi/L. This study is not the first study to detect elevated levels of tritium in municipal solid waste leachate. Elevated tritium levels in leachate-contaminated groundwater have been reported as far back as 1982 (Egboka, et al, 1982). Generally regarded as outliers, these early detections of tritium in

municipal solid waste leachate generated only mild interest at the time. More recently, however, studies in Pennsylvania, California, the United Kingdom, and our study in New York and New Jersey have demonstrated that elevated levels of tritium are quite common in municipal solid waste leachate (PADER, 2006; CSWQB, 2003; Robinson and Grunow, 1996). Moreover, the levels being found in all these studies are not only high enough that tritium can serve as a useful tracer of leachate migration in the environment, which was the initial focus of our study, but are at levels that commonly exceed USEPA-established MCLs. Elevated tritium levels are also being detected in landfill gas and landfill gas condensate. Landfill gas has been shown to contain both tritiated water vapor and tritiated methane (Coleman, et al 1993). The particular wastes responsible for the tritium may also pose a risk to solid waste management workers in transfer stations, waste-to-energy plants, and construction and demolition (C&D) waste processing facilities.

In this paper, we briefly look at the behavior of tritium in the environment, the levels of tritium being found in municipal solid waste leachate gas and landfill gas condensate, the likely sources of tritium, the human health and ecological risks associated with tritium, the applicable regulatory standards, and the resulting implications to leachate and gas management.

Tritium in the Environment

Tritium, a radioisotope of hydrogen, is formed naturally in the upper atmosphere as a result of bombardment of nitrogen and oxygen nuclei by cosmic rays. Anthropogenic sources of tritium include nuclear weapon detonations, nuclear power plants, and some manufactured products. Prior to the atmospheric testing of nuclear weapons in the late 1950s and early 1960s, levels of tritium in precipitation averaged 5 to 10 tritium units (TU) or 15 to 30 picocuries per liter (pCi/L). Pre-nuclear age tritium levels in precipitation have been determined by sampling of wine bottles between 1927 and the 1940s as illustrated in Figure 1. Figure 1 also depicts the initial rise of tritium levels in precipitation caused by some of the first nuclear weapon detonations. Levels of tritium in precipitation continued to rise, as illustrated in Figure 2, peaking in 1963 at alarming levels of several thousand tritium units. The Nuclear Test Ban Treaty between the United States and the Soviet Union in 1963 ended almost all atmospheric testing of nuclear weapons and levels of tritium have been steadily declining. Nonetheless, current levels of tritium in precipitation over North America still average 10 to 30 TU (30 to 90 pCi/L).

Tritium's half life of 12.32 years dictates that vestiges of the peak rainfall concentrations of the early 1960s can still be detected in many groundwater systems. These remnants of the peak levels of the 1960s permit age dating of groundwaters and have helped answer many questions relating to hydrospheric circulation. As is the case in precipitation, tritium commonly binds with another normal hydrogen and oxygen to form that most common of substances, water. Water containing substituted tritium is referred to as "tritiated water." One Tritium Unit (3.221 pCi/L) equals one tritium atom in 10^{18} normal hydrogen atoms. Tritium exchanges with the hydrogen in other hydrogen-containing molecules. In the atmosphere over Japan, Okada and Momoshima, (1993) reported finding almost equal levels of tritiated water (HTO), tritiated methane, and tritiated hydrogen gas in a cubic meter of air. Being part of the water molecule, tritium travels conservatively with water making it an ideal tracer in surface water and groundwater systems.

Tritium has historically been used in surface water tracer studies (T. Gallagher, 2007). Nuclear power plants routinely release tritium to the environment. It is estimated that in 1987 all 417 nuclear power stations in 26 countries released approximately 680,000 Curies of tritium into the environment (UASCEAR, 1988). The Indian Point Power Plant in New York is permitted to release 1,800 Ci/year to the adjacent Hudson River (Times Herald Record, 2007).

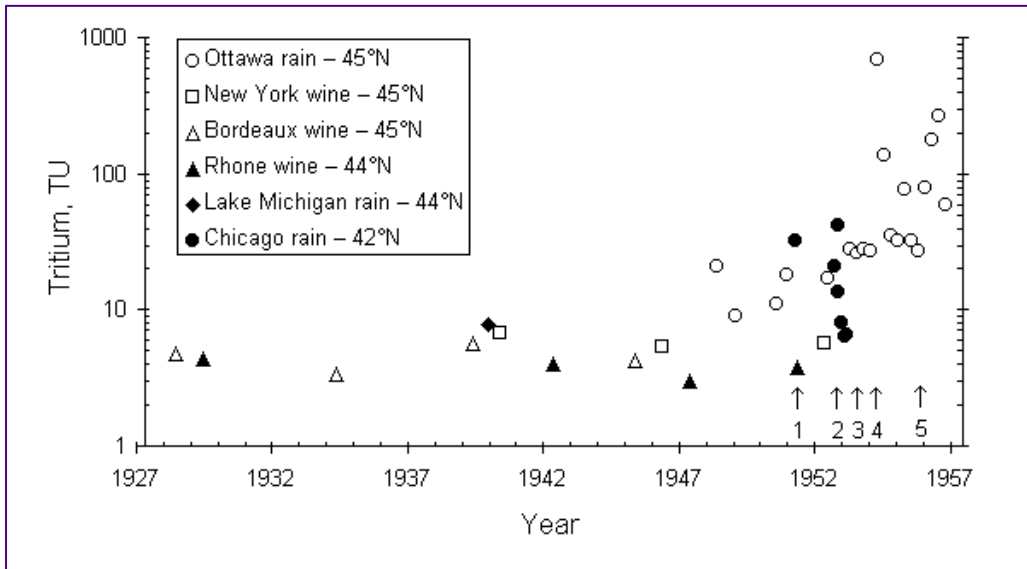


Figure 1. Levels of Tritium in Precipitation (1927-1957)

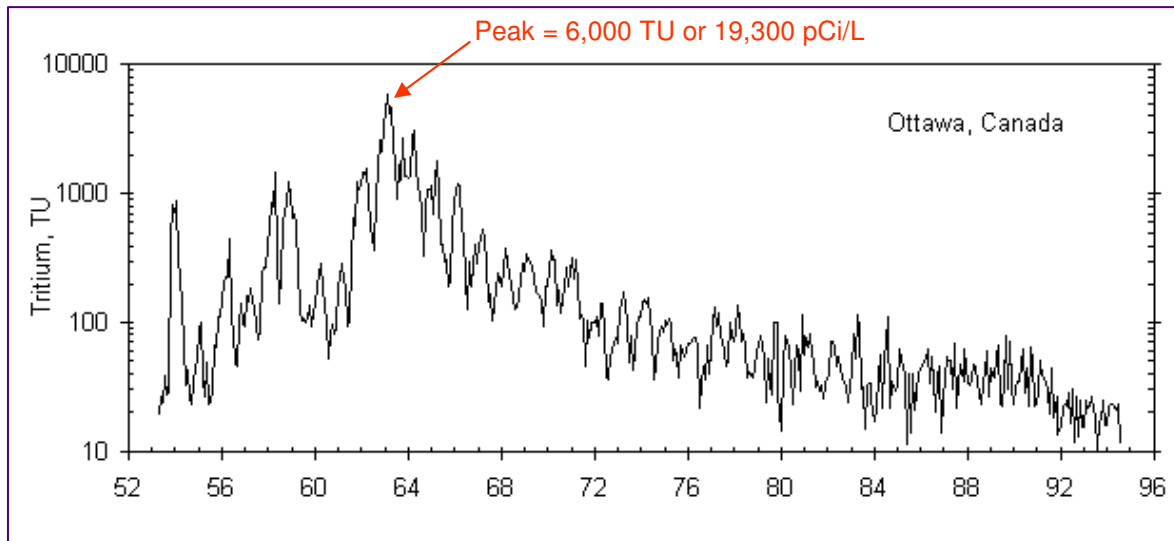


Figure 2. Levels of Tritium in Precipitation at Ottawa, Canada (1953-1995)

Tritium Levels in Municipal Solid Waste Leachate

In October of 2006, HydroQual conducted a study of tritium levels in leachate from ten landfills in New York and New Jersey. Six of the landfills were active. Four were closed and had ceased receiving waste from nine to thirty years earlier. Three of the landfills had also received some industrial waste. Key specifics of the ten landfills are given in Table 1.

Table 1. Specifics of Ten New York and New Jersey Landfills

Site Designation	Landfill Operational Status	Years Since Cessation of Operation	Nature of Solid Waste
1	Inactive	29	MSW ¹ , IW ²
2	Inactive	12	MSW
3	Active	0	MSW, IW
4	Inactive	30	MSW, IW
5	Active	0	MSW
6	Active	0	MSW
7	Active	0	MSW
8	Active	0	MSW
9	Inactive	9	MSW
10	Active	0	MSW

¹ Municipal Solid Waste

² Industrial Waste

In all cases, leachate samples were collected from leachate collection systems, which effectively integrated the leachate from either the entire landfill or a major segment of the landfill. The samples are, therefore, composite samples of the leachate generally reflecting the average leachate composition at the time sampled. Samples were collected in 100 mil plastic bottles and shipped to Waterloo Environmental Isotopes Laboratory at the University of Waterloo in Waterloo, Ontario. The samples were analyzed by direct counting using a liquid scintillation detector.

The results of the leachate analysis are presented in Figure 3. In the six active landfills, tritium levels varied from 1,254 to 191,835 pCi/L, with a mean of 49,900 pCi/L. The closed landfills had levels ranging from 96 to 35,942 pCi/L. The mean tritium level in all ten landfills was 33,800 pCi/L.

The tritium levels found in landfills in New York and New Jersey are comparable to levels found in other studies of municipal solid waste landfills. In a study of thirty municipal solid waste landfills in the United Kingdom, Robinson and Grunow (1996) reported a mean and maximum level of tritium of 24,900 and 126,500 pCi/L, respectively. A 2003 study of ten landfills in California conducted by the California State Water Quality Board (CSWQB) found a mean tritium level in leachate of 99,000 pCi/L, and a peak value of 304,000 pCi/L. Even more recent studies of 59 landfills in Pennsylvania were conducted by the Pennsylvania Department of Environmental Protection in 2004 and 2005. In 2004, they found mean and maximum levels of tritium in municipal solid waste leachate of 24,400 pCi/L and 93,500 pCi/L, respectively. Levels

in 2005 were similar with a mean of 20,900 pCi/L and a maximum of 182,000 pCi/L. The mean concentration from all these studies is 28,200 pCi/L.

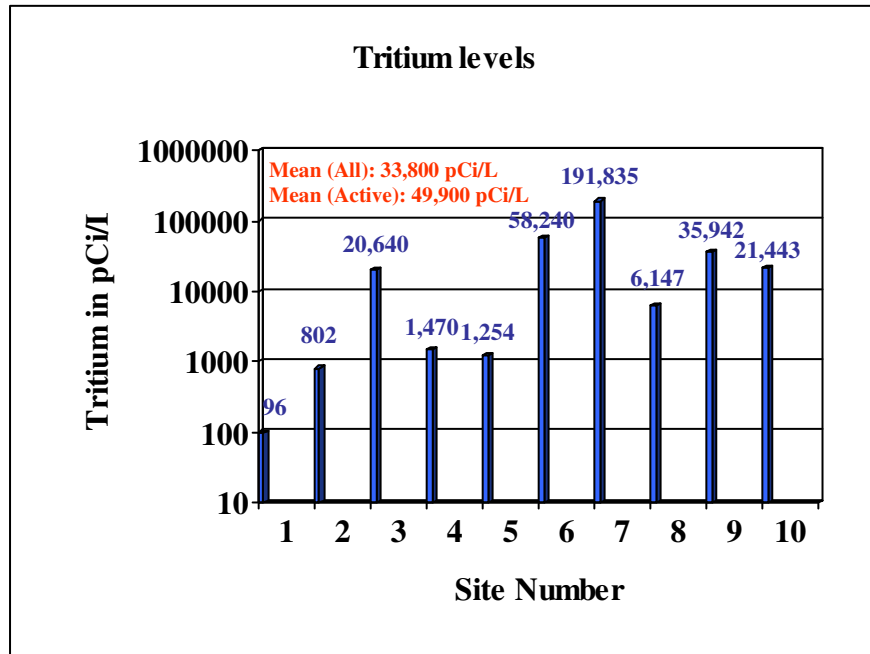
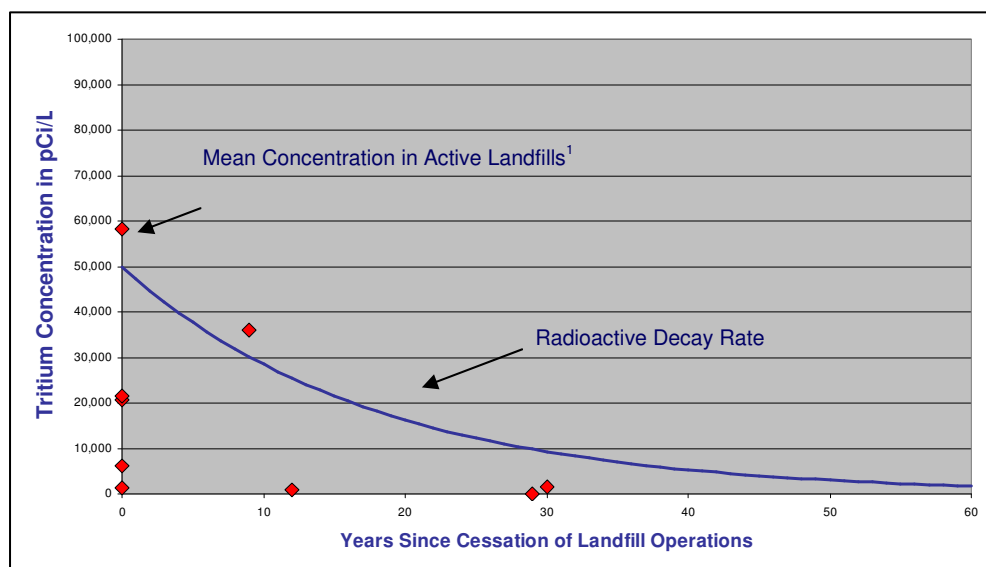


Figure 3. 2006 HydroQual/Manhattan College Study of Landfills in New York and New Jersey

In our study of landfills in New York and New Jersey, four of the landfills had ceased operation. The Pennsylvania landfills studied were all still operational (Allard, D., 2007). It is also believed that the landfills investigated in the United Kingdom and California were fully operational. Although the dataset is limited, a plot of leachate tritium levels versus time since cessation of landfill operations using only the New York/New Jersey data from our study provides some insight into the rate of decline in leachate tritium levels after landfill closure as illustrated in Figure 4. Also illustrated in the figure is the radioactive decay rate of tritium based upon its half life of 12.32 years and a starting concentration of 49,900, which was the mean concentration observed in the New York/New Jersey study. There is a suggestion in the limited data that tritium levels decline more rapidly than the radioactive decay rate. Such a finding is not surprising since recharge of precipitation through the landfill should gradually flush tritiated water from the landfill. Obviously, the rate of flushing by precipitation will be a function of the type of final cover material or cap employed at the landfill and local characteristic factors.

Tritium in Landfill Gas and Landfill Gas Condensate

Elevated levels of tritium have also been found in both landfill gas and landfill gas condensate. Figure 5 illustrates the results of landfill gas condensate sampling from six landfills in the United Kingdom and two landfills in California (Robinson and Grunow, 1996; CSWQB, 2003). The mean level of tritium in landfill gas condensate was 89,622 pCi/L. Although this value is based on a smaller population of samples, it is notably higher than the mean level found in landfill leachate. Since landfill gas condensate is derived from the water vapor in landfill gas, one can



1. HydroQual/Manhattan College

Figure 4. Tritium Levels in Leachate Versus Time after Cessation of Landfill Operations

readily calculate the tritium level in landfill gas associated with water vapor. A simple psychrometric calculation, assuming a gas temperature of 70°F and a relative humidity of 100%, indicates that one cubic meter of landfill gas contains 19 grams of water vapor. Assuming that this water vapor contains the mean concentration of tritium observed in landfill gas condensate dictates that the water vapor-associated tritium in landfill gas would be 1,700 picocuries per cubic meter (pCi/m^3). The particularly elevated level of tritium found in the landfill gas condensate from the one California landfill (513,000 pCi/L) would correspond to a water vapor-associated level of tritium in landfill gas of 9,900 pCi/m^3 .

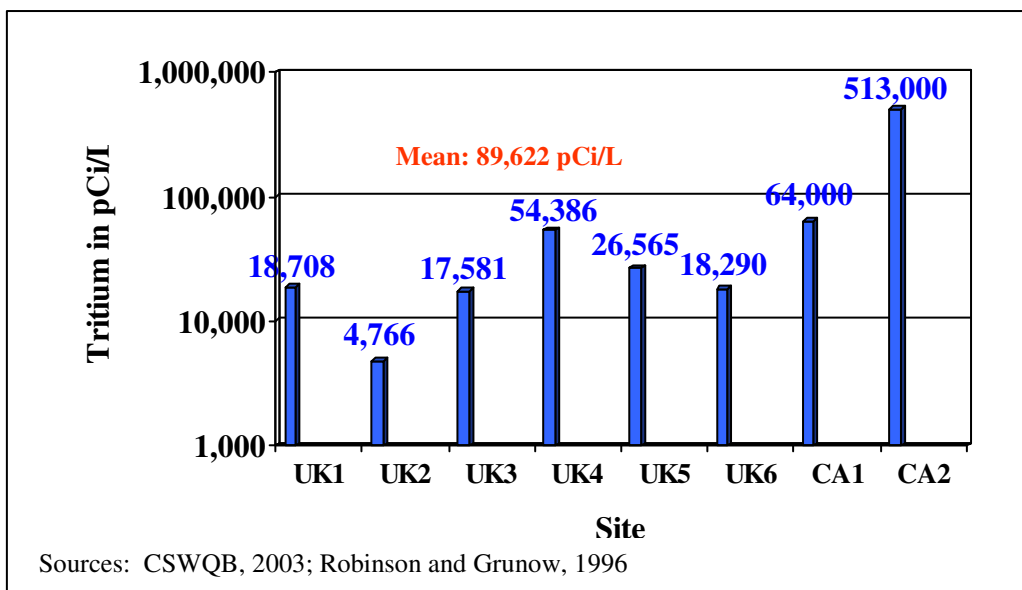


Figure 5. Tritium in Landfill Gas Condensate

The propensity of tritium to readily substitute for the hydrogen in both inorganic and organic molecules suggests that tritium should also be present in the methane and other hydrocarbons found in landfill gas. This has been confirmed by a study by Coleman, et al (1993) that found levels of tritiated methane in landfill gas ranging from 57.6 to nearly 2,800 tritium units. This corresponds to methane-associated levels of tritium ranging from 267 to 13,000 pCi/m³. The mean level of tritiated methane found by Coleman, et al (1993) was 4,900 pCi/m³. Therefore the combined level of tritiated methane and tritiated water vapor in landfill gas based upon the results of these studies would be approximately 6,600 pCi/m³.

It is useful to consider the flux of tritium from a landfill having tritium levels in landfill gas and leachate of the magnitude described above. Take, for example, a landfill with the following properties:

- 100 acres
- Average depth of 75 feet
- Recharge rate of 15 inches per year
- Peak gas generation rate of 0.5 standard cubic feet per minute per thousand in-place cubic yards
- Average leachate tritium level of 50,000 pCi/L (based upon mean levels found in the active landfills in the New York/New Jersey study)
- Average landfill gas concentration of 6,600 pCi/m³ (based upon mean levels in water vapor and methane)

Given the above characteristics, the example landfill would have a flux of tritium in the leachate of 7.7 curies per year. In contrast, landfill gas from the example landfill would contribute a flux of 0.59 curies per year. The total flux of tritium would, therefore, be 8.3 curies per year with leachate representing 93 percent of the tritium flux. This total flux is not particularly high given that many nuclear reactors are permitted to discharge in excess of 1000 curies per year of tritium, usually into large bodies of receiving water.

Suspected Sources of Tritium in Municipal Solid Waste Landfills

Initial speculations suggested that luminescent paint in solid waste materials may account for the observed tritium in leachate (Robinson and Grunow, 1996; Hackley et al, 1993). More recently, however, attention has focused on gaseous tritium lighting devices (GTLD) as likely being the principal culprit. An example of a GTLD is self-powered exit signs. The majority of the common exit signs used in buildings, ships, and aircraft are either powered by batteries, direct hard wired electricity or both. GTLDs on the other hand require neither batteries nor direct electrical connections. In GTLD exit signs, the letters consist of sealed glass tubes filled with tritium gas and coated on the interior with a phosphor material. As the tritium decays, the beta rays generated excite the phosphor causing it to emit a greenish glow that is visible in a darkened environment. These exit signs typically contain 10-15 Curies of tritium but some contain as much as 30 Curies. They have usable life spans of 10-12 years due to the relatively short 12.32 year half life of tritium. Other GTLDs include military-style compasses, some watches, some gun sites, and even glow-in-the-dark novelty items such as key chains.

Tritium-based exit signs are regulated by the Nuclear Regulatory Commission. Purchasers are licensed and are required to return exit signs that have exceeded their normal lifespan through a licensed tritium recycling facility. GTLD exit signs all include warning labels indicating the amount of tritium initially contained within the exit sign and warning against disposal of the sign other than by transfer to persons specifically licensed by the NRC or an agreement state (several states have been delegated responsibility by the NRC and are referred to as agreement states).

The Product Stewardship Institute (PSI) of the University of Massachusetts (2003) estimates that over two million exit signs have been registered in the United States in the 20 year period between 1983 and 2002. A significant, but unknown, percentage of tritium signs are not properly returned and recycled. Manufacturers often charge a fee of \$30 to \$100 to accept returned signs (PSI, 2003). These recycled exit signs are shipped to tritium tube manufacturing facilities outside the United States for recycling/disposal. It is suspected that a significant percentage, perhaps even a majority, of these signs ultimately find their way into municipal solid waste or construction and demolition wastes.

Human Health Risks, Ecotoxicity and Applicable Regulatory Standards

As radionuclides go, tritium is not particularly hazardous. Nonetheless, as a beta generator it is a known human carcinogen. Tritium can enter the body through ingestion, inhalation or by direct dermal contact. Once in the body, it is distributed fairly uniformly throughout the body. It is readily eliminated from the body with half lives of roughly 10 days, 30 days, and 450 days (Okada and Momoshima, 1993). Body burdens of tritium can therefore be readily measured through urinalysis.

USEPA has set a MCL for most beta or gamma-emitting radionuclides equivalent to 4 mrem/yr to the total body or to any given internal organ. A separate MCL for tritium was established at 20,000 pCi/L and translates to one mrem/yr to the total body. It is based upon drinking two liters per day of tritiated water for a lifetime. Many states have also adopted the 20,000 pCi/L as their surface water quality standard for tritium. Table 2 shows the surface water quality standard for several states. South Dakota has established a much more stringent standard of 300 pCi/L.

Table 2. State Surface Water Quality Standards

State	Surface Water Quality Standard pCi/L	Comments
New York	20,000	Applicable to streams classified for water supply use: A, A-S,AA,AA-S
New Jersey	20,000	Generally applicable
Pennsylvania	20,000	Generally applicable
California	20,000	CA Public Health Goal (PHG) for tritium is 400 pCi/L if used for water supply
Kansas	20,000	Water Supply Use
Virginia	20,000	Human Health
South Dakota	300	

California has also established a Public Health Goal (PHG) of 400 pCi/L for tritium. California's PHGs are "...estimates of the levels of contaminants in drinking water that would pose no significant health risk to individuals consuming the water on a daily basis over a lifetime." California PHGs are based strictly on scientific and public health considerations without regard to economics or technical feasibility. California's PHGs are based on a *de minimus* excess cancer risk of 10^{-6} (one in a million). California's PHG for tritium in drinking water is 400 pCi/L. A 10^{-5} risk would, therefore, correspond to a tritium level of 4,000 pCi/L and a 10^{-4} risk to a level of 40,000 pCi/L. The 20,000 pCi/L MCL for tritium corresponds to a risk of 5×10^{-5} based upon California's risk calculations.

Implications to Leachate and Landfill Gas Management

There are no cost-effective technologies for removing tritium from water. Considerable research has been done on the subject by the nuclear industry with little success. Those tritium water treatment technologies that have been developed are exotic and prohibitively expensive. Publicly owned treatment works (POTWs) into which many landfills discharge their leachate afford no treatment of tritium other than by dilution by other waste water streams. Most POTWs in this country also do not have discharge standards or monitoring programs for tritium. Nonetheless, on a case by case basis some POTWs have imposed stringent radiological standards for discharges from closed landfills. A case in point is the GEMS Landfill Superfund site in New Jersey. At this site, the POTW imposed the drinking water standard for uranium and radium for discharge of leachate-contaminated groundwater.

On site leachate treatment plants with a direct discharge to receiving bodies should not have difficulty meeting most state's surface water quality standards (i.e., 20,000 pCi/L), except possibly for large landfills discharging to relatively small streams. Groundwater pump and treat systems that recharge treated, leachate-contaminated groundwater back to an aquifer may be of concern to regulators in some jurisdictions. Some states do not permit recharge of treated waters that exceed groundwater quality standards. Since tritium cannot practically be treated by any groundwater treatment process, violation of this standard would be difficult to avoid in cases where tritium levels in the contaminated groundwater leachate exceed the MCL.

Leachate evaporators pose a somewhat different circumstance. A leachate evaporator will shift the tritium flux from surface water to the air. For example, consider our example 100-acre landfill. A leachate evaporation system that burns landfill gas to evaporate leachate would convert both the tritium in the leachate and the tritiated methane in the landfill gas to tritiated water vapor. In so doing, such a system would eliminate all releases of tritium to surface water, but would increase atmospheric discharge of tritium by 14 times from 0.59 curies per year to 8.3 curies per year.

Landfill gas is composed of roughly 50 percent methane, 50 percent carbon dioxide and a variety of trace gases. Landfill gas exiting the landfill generally has a relative humidity of nearly 100 percent. As discussed earlier, tritium has been found in the water vapor and the methane and is likely present to some extent in the trace hydrocarbons within the landfill gas. Landfill gas is typically pre-treated by condensation to remove excess water vapor prior to burning the gas for

energy generation. This preprocessing step removes much of the water vapor from the gas and in so doing removes some of the tritium from the gas. With most of the water vapor removed, the data reported by Coleman, et al (1993) would suggest that most of the remaining tritium would be associated with the methane in the gas. If the gas is then combusted in either a landfill flare, a leachate evaporator or a gas-to-energy facility, the tritiated methane would be converted to tritiated water vapor. Although combusting the methane has obvious benefits from an energy recovery and reduction of greenhouse gases standpoint, the conversion of tritiated methane to tritiated water vapor puts the tritium in its potentially most harmful form. The absorption efficiency of tritiated water vapor is virtually 100 percent while the absorption efficiency of tritiated methane is only 0.1 percent (ICRH, 2006). Even with these assumptions, the risk to landfill workers and any nearby residents would be minimal. For example, assume that a landfill gas is combusted, thereby converting each mole of tritiated methane to two moles of tritiated water vapor. The resulting concentration of tritium in the exhaust would be roughly 4,150 pCi/m³ (1,700 pCi/m³ of original water vapor plus one half of 4,900 pCi/m³ of tritiated methane, now converted to water vapor). Under such a scenario, an exposed individual would have to continuously breathe landfill gas exhaust, 24 hours per day, 365 days per year, to produce an Effective Dose Equivalent (EDE) greater than 3 mrem/yr as illustrated below. Of course, no one breathes landfill gas exhaust directly and in all likelihood atmospheric dispersion would reduce the concentrations of tritium by orders of magnitude before any exposure occurs.

Calculation of Worst-Case Effective Dose Equivalent (EDE)

$$\text{EDE} = \text{C} \times \text{SAF} \times \text{BR} \times \text{DCF}$$

C	=	Concentration of tritium in pCi/m ³
SAF	=	Skin absorption factor (1.5)
BR	=	Breathing rate (8,400 m ³ /yr)
DCF	=	Dose conversion factor (6.4 x 10 ⁻⁸ mrem/pCi)
EDE	=	4,150 pCi/m ³ x 1.5 x 8,400 m ³ /yr x 6.4 x 10 ⁻⁸ mrem/pCi

$$\text{EDE} = 3.3 \text{ mrem/year}$$

The absence of a viable treatment technology for removing tritium from water dictates that tritium must be released to the environment in some manner that disperses it into the environment without exceeding water quality standards or representing an unacceptable risk to public health or the environment. The above preliminary analysis suggests that this should be readily managed at most landfill sites, although further research on tritium levels in leachate and landfill gas and its dispersal into the environment from landfills would be useful.

Implications to Worker Safety in Other Solid Waste Management Facilities

The fact that GTLDs find their way into MSW landfills is at this point quite evident. It is worth noting that in getting to a landfill, MSW and the GTLDs contained within it, often pass through intermediate solid waste management facilities, such as transfer stations. Significant quantities of MSW also go to waste-to-energy plants with only the ash ultimately reaching a landfill.

Preliminary calculations suggest that workers in these types of facilities could potentially be subject to intermittent, although possibly substantial, exposures to tritium.

Consider, for example, a transfer station scenario with the following assumptions:

1. The building is 20 meters wide, 30 meters long and 7 meters high.
2. A GTLD exit sign containing 5 Curies of tritium is broken open during trash handling activities.
3. The 5 Curies of tritium become uniformly dispersed within the air of the transfer station.

Under these circumstances, the resulting concentration of tritium in the air of the transfer station would be 1.2×10^9 pCi/m³. This concentration exceeds the Nuclear Regulatory Commission (NRC) recommended maximum annual air concentration for exposure to members of the public living near nuclear power plants of 1×10^5 pCi/m³ (USNRC, 2007) by more than 10,000 times. The NRC standard is based upon an annual tritium dose of 50 mrem (USNRC, 2007). Of course, transfer station workers are not continuously exposed to tritium over the course of an entire year which is the basis of the NRC's threshold concentration. However, even a one-hour exposure to the predicted concentration of 1.2×10^9 pCi/m³ would more than equal the annual tritium dose associated with the NRC's airborne limit of 1×10^5 pCi/m³. An exposure of less than five minutes would exceed the USEPA's recommended exposure to beta radiation, which is based upon a maximum annual dose of 4 mrem. At this point, there is apparently no information regarding the frequency of GTLD exit sign breakage in transfer stations or other solid waste management facilities, the amount of tritium released in each event, the extent the tritium is converted to tritiated water vapor, and its airborne persistence in the facility. Consequently, it is difficult to assess the actual risk posed to workers in transfer stations or other solid waste management facilities. Nonetheless, the above, preliminary analysis suggests that further investigation of this issue is warranted.

CONCLUSIONS

Our study of landfills in New York and New Jersey, combined with studies in the United Kingdom, California, and Pennsylvania, have demonstrated that elevated levels of tritium in municipal solid waste leachate and gas are commonplace. Moreover, the majority of landfills in all the studies have tritium levels in excess of USEPA's MCL for tritium. Predictably, the tritium also manifests itself in landfill gas both as tritiated water vapor and as tritiated methane. The principal source of the tritium appears to be gaseous tritium lighting devices, most notably self-powered exit signs that contain up to 30 curies of tritium. Tritium levels in leachate or landfill gas do not likely pose a significant threat to the landfill workers or residents living near landfills since exposure to leachate and gas is generally minimal. Nonetheless, further study of this issue seems warranted given the public's well documented concern over exposure to radiologic agents. Although data is lacking, preliminary calculations suggest that tritium released from breakage of GTLDs in transfer stations and other solid waste management facilities could, under some circumstances, pose a risk to workers.

Further research seems warranted in the following areas:

- Tritium levels in leachate over a broader geographical area of the United States
- Tritium levels in construction and demolition debris landfills which may also be the recipient of improperly disposed GTLD exit signs
- Levels of tritium in landfill gas and specifically how it is partitioned between water vapor, methane and possibly other constituents within the gas.
- The tritium concentration in the exhaust of leachate evaporators and landfill gas-to-energy facilities and the specific forms of the tritium.
- Tritium exposure to workers in other solid waste management facilities, such as transfer stations, waste-to-energy plants, and C&D processing facilities.

Even if the above described recommended studies demonstrate that solid waste tritium associated with solid waste management facilities poses no significant risk to public health or the environment, experience suggests that a perception of risk may still pose a problem for many facilities. Relations between solid waste facilities and local populations are often contentious and having solid waste management facilities become associated with tritium, a topic that is normally reserved for nuclear power plants, cannot be helpful however small the levels may be compared to those associated with nuclear power plants. Experience suggests that the issue of risk perception can best be overcome by a careful analysis of the real risk together with well planned and managed risk communication.

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