

Persistence of Sarin, Soman, VX, and Lewisite and Destruction of Tabun, and Mustard Gas in Municipal Solid Waste Landfill Leachates

EXTENDED ABSTRACT # 379

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INTRODUCTION

The 2001 terror incident with five contaminated letters resulted in contaminating 56 buildings in 10 US states and Washington, D.C. Items that were contaminated were such things as: books, paper, wall hangings, staplers, telephones, furniture, computers, mail processing equipment, carpeting, ceiling panels, wallboard, paneling, nail, trash, spoiled food, contaminated decontaminate water, personal protective equipment and air scrubbing equipment. The ultimate fate of “decontaminated” building materials, that is, the permanence of the disposal technique, is of concern long after final disposal at a landfill site. The United States Environmental Protection

Agency Office of Research and Development National Homeland Security Research Center (NHSRC) in collaboration with the Department of Defense Edgewood Chemical Biological Center (ECBC) are evaluating the permanence of biological and chemical warfare agents in municipal solid waste landfills. Decontaminated waste that can be verified as 100% free of residual chemical contaminant should present no problem in the landfill environment short of straining national capacity. Materials that contain some residual active contaminants, however, may present a different scenario and a different concern for the landfill operator. Exposure pathways for movement of residual contaminants out of landfills are primarily leachate and air (fugitive emission and collected gas); but the pathways may also include long-term potential for groundwater contamination or even movement through solids (e.g., soil), both from movement through leachate. If individual waste containers (sub-containment systems) become compromised in the landfill, leachate may contain components of the disposed, and presumed decontaminated, waste. Leachate is often discharged to wastewater treatment systems, and may pose a threat to human health and the environment. Study of the permanence of the final disposal of the inactivated or active agent of terrorism must be examined by looking at the fate of various agents in the most likely pathway of escape.

MATERIALS AND METHODS

The purpose of this research is to determine the permanence of disposal of weapons of warfare that may be introduced into municipal solid waste (MSW) landfills with insufficiently treated rubble from contaminated sites. Because of capacity problems with incinerators and hazardous waste sites, it is more likely that we will need to depend on MSW landfills to contain the uncontaminated building products. Our approach is to spike raw unsterilized MSW leachate with known quantities of chemical agents, developing leachate microcosms in a secure laboratory, and analyzing the spiked leachates for agent through a 12-month time course. The samples were handled as waste would be: initially aerobically, sealed and then allowed to reach anaerobiosis. Landfill temperatures vary over their lifetime and in the waste mass. To look at a worst case scenarios 12⁰ C incubations were used to simulate soil temperature. The chemical agents were evaluated at 0.09 percent concentration. Unspiked samples serve as negative controls and spiked water samples serve as positive controls.

Spiked leachates (triplicate samples) were tested for quantities of chemical agent or metabolites weekly for the first 2 months, then twice a month for 5 months, then monthly for 5 more months (unless data indicated otherwise) or until no detects are observed in all replicates for 2 consecutive sampling periods. This would identify the termination of the experiment for that agent. Quantifiable tests were performed using approved methods. The analysis for Lewisite was actually chlorovinyl arsenious acid (CVAA) or dithiol derivatives of this agent due to its rapid hydrolysis and thermally labile nature.

Numerous assumptions were made with this research, some of which are: 1. Results obtained from a MSW landfill's leachate will be representative of the results we may expect to see with leachate from other landfills. We are analyzing leachates from only one site and may or may not be able to extrapolate to what would occur at a different landfill. This landfill is closed, synthetically covered, and has waste that is between 5-15 years old. However, using the one site is a start and future studies may include multiple landfill sites. 2. Triplicate microcosms will

allow us to better understand the real-world situation. 3. Three ml microcosms will mimic anaerobic conditions of landfills. 4. Temperatures vary greatly in landfills. Looking at average soil temperature (12⁰ C) mimics the world () 5. The agents will always encounter undiluted leachate in the landfill before any release is possible.

CONCLUSIONS

Sarin

Sarin is a colorless and odorless liquid . It is one of the most volatile of the G agents with a vapor pressure of 2.10 mm Hg. (Munro *et al.* 1999). It is very soluble in water and can hydrolyze at high and low pHs. At 12⁰ C, Sarin was still present in the MSW leachate above the 0.02 ug/mL reporting limit as of 11 weeks after start of the baseline.

Soman

Soman is also a colorless liquid with a colorless vapor with a fruity odor but is less soluble in water than other agents. Soman survived at 12⁰ C for at least 22 weeks in MSW leachate.

VX

VX is another odorless liquid but it is amber colored and less volatile and resistant to hydrolysis than many other G agents (Munro *et al.* 1999). VX was still in MSW leachate after 23 weeks at 12⁰ C.

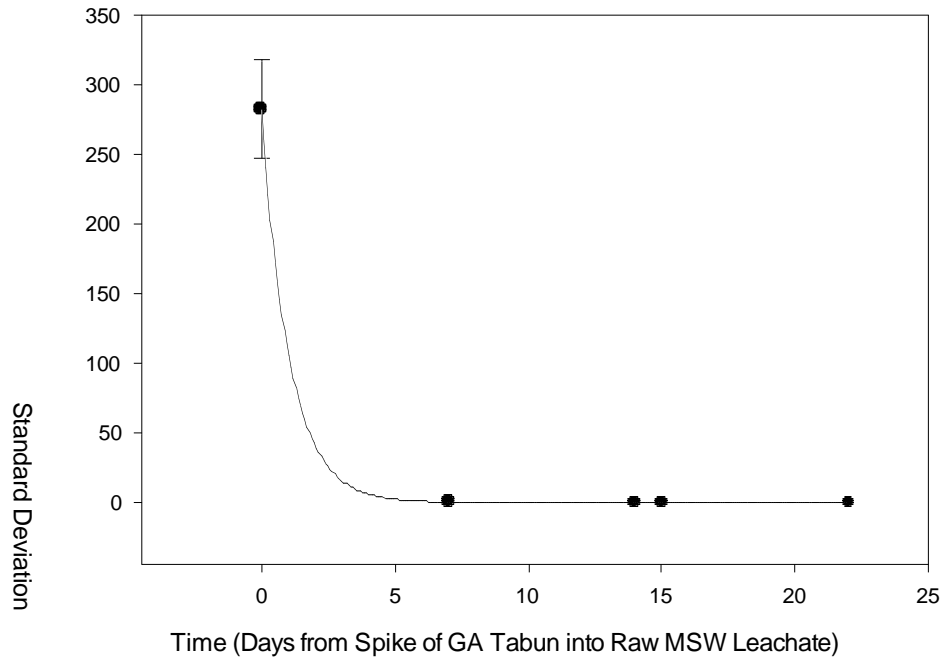
Lewisite

Lewisite (dichloro (2-chlorovinyl) arsine) is practically odorless when pure, colorless and an oily liquid. However, the synthesized chemical agent is an amber-colored with a geranium-like odor (Munro *et al.* 1999). Lewisite derivatives (chlor vinyl arsenious acid) were still identified in MSW leachate after 23 weeks incubation at 12⁰ C.

Tabun

Tabun is a colorless to brownish liquid with lower volatility than other G agents. However, it is water and organic solvent soluble. (Munro *et al.* 1999). As Figure 1 shows, at 12⁰ C, Tabun was determined to be less than the reporting limit of 0.02ug/mL after 21 days. A good formula which fits the decay rate is shown in Figure 1.

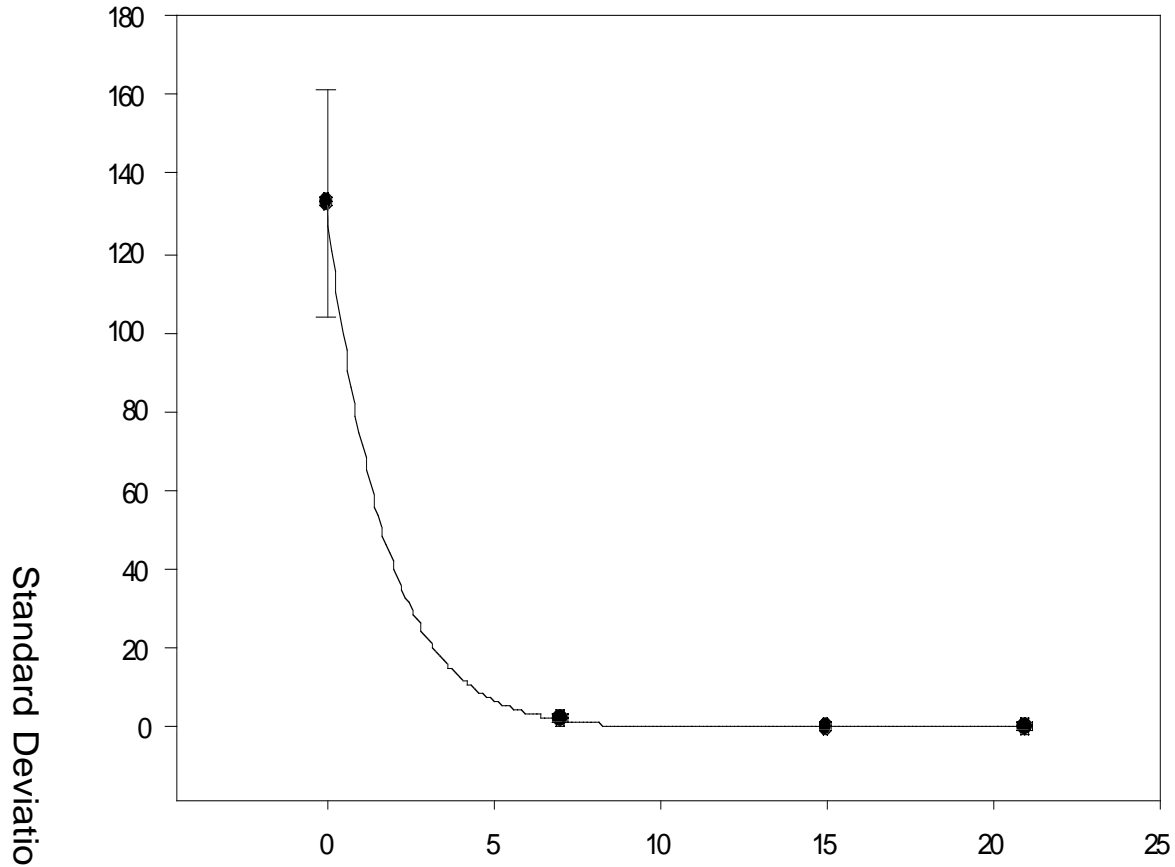
Figure 1. GA Tabun Persistence
 $f = a \cdot \exp(-b \cdot x)$



Mustard Gas

Mustard Gas, a blistering agent attacks mucus membranes and at high doses can be lethal. It is a colorless oily liquid with a garlic-like odor. Impurities may make it appear amber in color. Mustard Gas was determined to be less than the reporting limit of 0.2ug/mL after 28 days at 12⁰ C in the MSW landfill leachate (Figure 2). It's decay rate is fitted by the formula listed in Figure 2.

Figure 2. HD Mustard Gas Persistence
 $f = a \cdot \exp(-b \cdot x)$



Sarin has a volatility of 2.48 torr and as such may not even be present in waste before burial. However, these results indicate that it would have a moderate persistence in leachate. These results indicate that Soman would persist longer in leachates than its half life of 2.5 days to 6 weeks in soils. VX persists in leachate as it does on surfaces at room temperature. It does have a low mobility in soils and will absorb to sediments and suspended solids. Thus perhaps it will remain mostly absorbed to the waste. Lewisite is not volatile but hydrolysis by acidic and neutral solutions. Thus its survival in MSW leachate is puzzling. Furthermore it has a very high mobility in soils, making its persistence troubling. Tabun has a short half life so its lack of persistence in MSW leachate was hypothesized. Conversely, Mustard Gas often persists so its inability to do so in leachate was a surprise but encouraging.

In conclusion, although it would be hoped that survival of chemical weapons would not be insured in landfill leachates, the persistence of some of these agents must be considered before deciding to place them into municipal solid waste landfills. However, landfills are never sterile or risk free. Thus concentration of agent, lethal doses, and likelihood of exposure to a sensitive

population must be taken into account.

REFERENCES

Munro, N. B., S.S. Talmage, and others .1999. The sources, fate and toxicity of chemical warfare agent degradation products. Environmental Health Perspectives **107**:933-974.