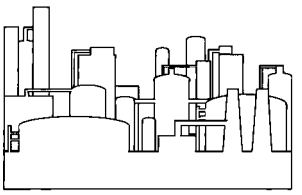

Fort Hood Investigates Beneficial Reuse of Pesticide-Contaminated Soil

Jeff Salmon and Cheryl Detloff

*The management of pesticide-contaminated soil on military installations is becoming an important issue. Fort Hood found itself having to deal with this issue, excavating 3,000 cubic yards of chlordane-contaminated soil. The question of what can be done with this soil has prompted Fort Hood to begin a multiphase investigation into the beneficial reuse of chlordane-contaminated soil. Fort Hood had been investigating many methods for the remediation and treatment of pesticide-contaminated soil, which led us to the encapsulation method. Phase 1 of this investigation involves proving that encapsulated pesticide-contaminated soil will not leach and securing Texas Commission on Environmental Quality (TCEQ) approval to use this encapsulated soil as daily cover on the Fort Hood municipal solid waste landfill. Phase 1 is the focus of this article. © 2005 Wiley Periodicals, Inc.**

During a field investigation in 2003, approximately 3,000 cubic yards of chlordane-contaminated soil was excavated on Fort Hood. This soil is currently being stored in a lined, closed-loop area. When tested, these samples contained chlordane levels ranging from 15.4 ppm to 82.9 ppm. Initial investigation revealed that disposal of this soil will cost approximately $135 per ton, or over $550,000, while placing this soil in Fort Hood's special waste trench will cost approximately $29 per ton, or approximately $117,000. Searching for a more efficient option, Fort Hood investigated encapsulation of chlordane-contaminated soil for beneficial reuse in lieu of disposal or placing in a landfill. Initial study also showed that encapsulation of chlordane-contaminated soil will cost approximately $8.64 per ton, or around $35,000. Fort Hood desires to use this soil as a test for reuse methods in lieu of disposal.

The primary purpose of this project is the beneficial reuse of 3,000 cubic yards of chlordane-contaminated soil by using it as daily cover

Jeff Salmon *currently serves as a program manager in the Directorate of Public Works, Environmental Division, Environmental Management Branch. He is responsible for Fort Hood's solid waste, restoration, and remediation programs.* ***Cheryl Detloff*** *is the chief chemist/environmental specialist for Midwest Industrial Supply Inc. Her duties include working with customers and regulatory agencies on environmental compliance and soundness related to the use of chemical dust suppressants.*

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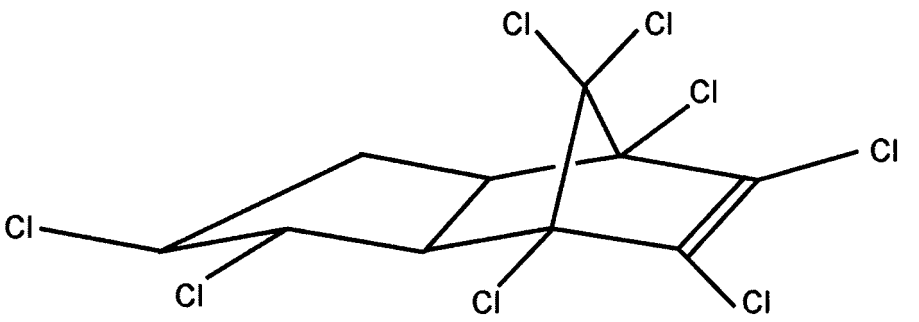
Exhibit 1. Chemical Structure of Chlordane ($C_{10}H_6C_{18}$)



on a preselected, isolated area of the Fort Hood municipal solid waste (MSW) landfill. In the execution of this project, many other objectives will be accomplished that will significantly aid Fort Hood and the U.S. Army. The execution of this project will include the investigation into encapsulation methods, the testing of leaching characteristic of encapsulated chlordane, the validation of a lined MSW cell and leachate monitoring as an acceptable location, and the final disposition of a household hazardous waste. To accomplish this, Fort Hood must first secure the Texas Commission on Environmental Quality's (TCEQ's) approval to conduct this test. The objective of the testing was to show that chlordane-contaminated soil treated with Soil Sement® polymer emulsion would not leach the pesticide.

Chlordane is a man-made pesticide approved for use by the Environmental Protection Agency (EPA) from 1948 until its ban in the United States in 1988. Before 1978, chlordane was used as a pesticide in agricultural crops, lawns, and gardens as a fumigating agent. Concerned over cancer risks and evidence of human exposure, persistence in the environment, and danger to wildlife, the EPA phased out aboveground use of chlordane. From 1983 until 1988, chlordane was approved for use to control termites in homes and was only applied underground to foundations. Today, chlordane is not used in the United States; however, because of the chemical's persistence, it remains in the environment and is a human health concern. Chemically, chlordane is a chlorinated cyclodiene with chemical formula $C_{10}H_6C_{18}$ (**Exhibit 1**). Technical chlordane is not a single chemical, but a mixture of over 140 chemicals. Major components are trans-chlordane (also know as gamma-chlordane or beta chlordane), cis-chlordane (also know as alpha-chlordane), beta-chlordane, heptachlor, and trans-nonachlor. Because technical chlordane contains so many chemicals, it is difficult to specify some chemical and physical properties. Technical chlordane is clear-to-amber-colored viscous liquid. The volatility changes over time as the more volatile components are removed. Chlordane is not soluble in water; however, it is miscible in aliphatic and aromatic hy-

drocarbon solvents. Chlordane loses its chlorine in alkaline solvents. When applied in the environment, specifically soil, about half of the chlordane evaporates in two to three days. The remaining chlordane is very persistent and may remain in the soil for as long as 20 years. Chlordane attaches strongly to soil particles and is unlikely to leach into groundwater. One study by the California Department of Food and Agriculture classified chlordane as a "nonleacher" based on records of groundwater contamination after normal agricultural use. Persistence is greater in heavy, clayey, or organic soils than in sandy soils due to increased evaporation in sandy soils. Studies indicate that technical chlordane degrades very slowly in water and does not degrade in anaerobic conditions. Chlordane breaks down in the atmosphere by reacting with light and other chemicals. Chemical persistence of chlordane in soil causes human health concerns, particularly for children that play around homes that were treated with the pesticide. Everyone in the United States has been exposed to chlordane, either due to prior agricultural use and subsequent absorption by current food crops or primarily through contact with soils around homes. Exposure occurs through skin contact, inhalation, or ingestion, where it remains in body fat until it is released to other parts of the body. The nervous system, digestive system, and liver can be affected by chlordane exposure in humans.

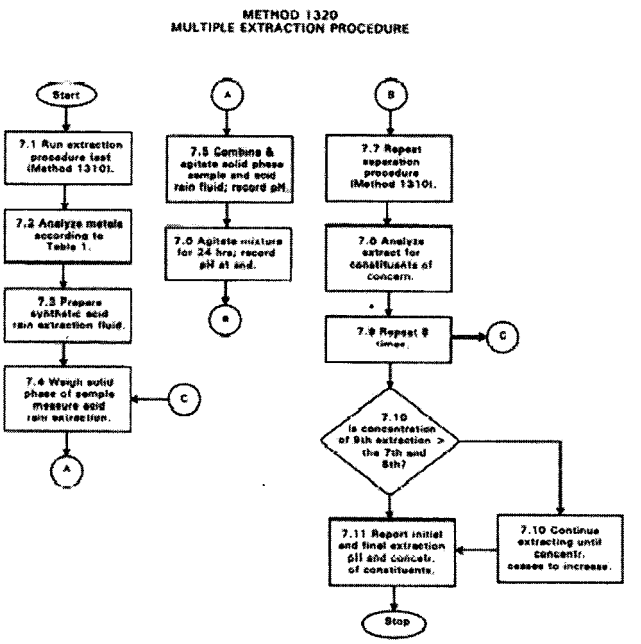
There is a great need to minimize human exposure to chlordane, and use of contaminated soil as a daily cover in a control landfill will fulfill that need.

There is a great need to minimize human exposure to chlordane, and use of contaminated soil as a daily cover in a control landfill will fulfill that need. Chlordane is not water-soluble and is not expected to leach into groundwater. However, should the chemical leach, it will be collected, monitored, detected, and remediated as needed in the landfill. There is no possibility of this sort of control in a home setting. Waste regulations dictate that only nonhazardous material may be put or used in a municipal waste landfill. The purpose of this experiment is to prove that the chlordane-contaminated soil on the base at Fort Hood can be used, with encapsulation treatment by Soil Sement®, as a daily cover on the Fort Hood municipal solid waste landfill.

Waste regulation historically utilizes EPA Method 1311, "Toxicity Characteristic Leaching Procedure (TCLP)," testing as measure for acceptability for disposal in nonhazardous landfills. The TCLP is an agitated extraction test that was designed to reach steady-state, acidic conditions as quickly as possible. It is a snapshot of conditions that prompt leaching of hazardous compounds of concern in landfill conditions. The pH of the extraction fluid is slightly acidic in an attempt to simulate landfill conditions.

The Texas Department of Environmental Quality (TDEQ) offered their experience and guidance for method determination. The proposed use for the chlordane-contaminated soil is outside the scope of disposal; it will be used as daily cover on an isolated cell on Fort Hood's municipal solid waste landfill. For this reason, more stringent testing and evaluation was required to prove that chlordane will not leach into groundwater. The TCLP would not demonstrate the desired

Exhibit 2. Method 1320 Multiple Extraction Procedure

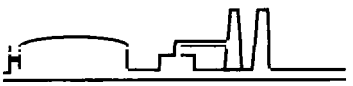


degree of technical assurance that chlordane would not leach from the Soil Sement® encapsulated soil into the groundwater. EPA hazardous regulatory levels for chlordane are 0.6 mg/kg for total chlordane and 0.03 mg/L for TCLP chlordane. Most recent testing for total chlordane shows 4.39 mg/kg in the soil at Fort Hood, making it a hazardous waste. Testing needed to demonstrate that although the total chlordane was above regulatory levels, it would not leach and that best control technologies utilizing Soil Sement® for encapsulation would render the soil nonhazardous by EPA TCLP regulatory standards. Testing should show Soil Sement® would encapsulate the chlordane in the soil for a long period of time in landfill conditions. This necessitated a test method that would repeatedly "attack" the integrity of encapsulation under long-term landfill conditions. EPA Method 1320, "Multiple Extraction Procedure (MEP)," was recommended by the TCEQ (**Exhibit 2**). The MEP was designed to simulate the leaching that a waste will undergo from repetitive precipitation of acid rain on an improperly designed or constructed sanitary landfill. Repetitive insults of the waste to "acid rain" reagent show the highest concentration of the test constituents (chlordane in our test) that could potentially leach in a natural environment.

The Multiple Extraction Procedure is a serial batch extraction test that subjects the waste to successive batches of fresh acidic buffer (pH 3.0 + 0.2). A sample of waste is first subject to extraction with deion-

ized water and separated from the leachate (extract). Extraction consists of placing a known weight of waste in a tumbling vessel with a specified volume of acid rain–buffered water. The pH is recorded and the sample is tumbled at room temperature for 18 hours. The pH is once again recorded at the conclusion of the extraction procedure. Standard laboratory separation procedures are used to isolate the extract from the waste. The leachate is analyzed for the desired constituent(s). The waste sample remains in the extraction vessel, where it is subjected to nine turns of synthetic acid rain extraction. At the conclusion of each turn, the waste is separated from the leachate, and the leachate is tested for desired constituent(s).

Because Fort Hood samples showed only two instances where chlordane was detected in the leachate, the TCEQ requested that at the conclusion of the tenth turn of the MEP, the TCLP utilizing the slightly higher pH buffer should be run on the waste sample. The procedure of the TCLP is the same as a single turn of MEP, except for the change in extraction fluid.



The procedure of the TCLP is the same as a single turn of MEP, except for the change in extraction fluid.

A composite sample of the chlordane-contaminated soil stockpiled on the property of Fort Hood in Texas was tested for total chlordane and treated with various levels of Soil Sement®, and extraction procedures were used to determine the leaching characteristics of the chlordane. Samples of untreated and treated Fort Hood soil had to be prepared prior to extraction testing. A composite sample of soil was retrieved from the chlordane-contaminated soil pile by Fort Hood personnel and shipped to Midwest Industrial Supply Inc. The unaltered soil was sent to Tri-State Laboratories for total chlordane testing. Results showed total chlordane at 4.39 mg/kg. Once an above-regulatory level of chlordane was established for the soil, test samples were prepared in the Midwest lab.

Three Soil Sement® application rates were used for testing:

- Sample A prepared at 7.2 gal Soil Sement® per yd^3
- Sample B prepared at 4.0 gal Soil Sement® per yd^3
- Sample C prepared at 27.0 gal Soil Sement® per yd^3

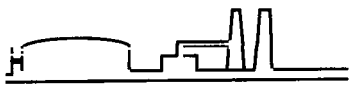
The Sample A rate represents the rate proposed for use at the Fort Hood site. The Sample B rate was used to bracket a possible low endpoint, and the Sample C rate was the application rate used in the initial leachate testing performed by Fort Hood personnel to establish the viability of this project.

Fort Hood soil was blended with the appropriate amount of Soil Sement® concentrate and water; this method simulates the proposed application method of "mix and blend" proposed for the Fort Hood application. Samples were compacted and allowed to dry in laboratory conditions (approximately 68°F) for four days before being taken to Tri-State Laboratories for leachate testing. Samples were not crushed, but left intact for leachate testing. It should be noted that the vigorous tumbling broke the samples into small particles during the first rota-

tion. Vacuum filtration was required, indicating very small silt-/clay-size particles were produced.

Seven samples were tested corresponding to the following TSL ID #:

- 25030821 Untreated control
- 25030822 Sample rate A
- 25030823 Sample rate A, spike
- 25030824 Sample rate B
- 25030825 Sample rate B, spike
- 25030826 Sample rate C
- 25030827 Sample rate C, spike



Chlordane was detected only in the untreated control sample and the sample treated at Rate B "spiked" with chlordane.

A total of 11 extraction rotations were performed on all of the samples. The first 10 extractions were performed per EPA Method 1320 ("Multiple Extraction Procedure"). The final extraction was performed per EPA Method 1311 ("Toxicity Characteristic Leaching Procedure"). The basic mechanics of all of the extractions was the same; the pH of the extraction fluid (buffer) was the relevant difference between the first extraction, the next nine extractions, and the final TCLP extraction. Method 1320 specifies that the first extraction be performed using deionized water, that the initial pH of the sample is recorded, and that the final pH of the sample be recorded before the addition of the acid rain buffer. The pH is reflective of the test sample pH, not reflective of the buffering solution conditions. The purpose of the extraction is to simulate acid rain on an "improperly constructed landfill," irrelevant of the pH of the system. The Fort Hood sample pH indicates a slightly basic soil pH. Method 1311 specifies that the extraction be forced to an acidic environment. The Fort Hood sample required the use of extraction fluid II, with the sample being forced to a pH of 5. This is reflected in the initial and final pH of the extraction fluid.

Chlordane was detected only in the untreated control sample and the sample treated at Rate B "spiked" with chlordane. These results indicate chlordane is available in the soil samples for low levels of leaching. The use of a control sample as well as multiple "spiked" samples demonstrates the validity of the method for the leaching and detection of chlordane. Chlordane was not detected in any of the unspiked treated samples, further indicating the efficacy of Soil Sement® encapsulation of pesticide-contaminated soil.

Soil Sement® effectively encapsulates chlordane in the soil obtained from Fort Hood. Acrylic and polyvinyl acetate polymers are used in the formulation of Soil Sement®. These plastics have a long history of persistence in landfill conditions; in fact, the lack of degradation of plastics in landfills has prompted EPA plastic recycling programs. Biodegradation of the polymers in Soil Sement® requires oxygen and ultraviolet exposure, neither of which will be available in this application as a daily cover in the landfill. Landfills are, in essence, a "tomb" for materials, preserving or "mummifying" wastes for decades. Exca-

vation of decades-old landfills has uncovered intact newspapers from 35 years ago, as well as 10-year-old carrots and 15-year-old corn! Degradation in landfills is anaerobic, and the polymers in Soil Sement® do not degrade anaerobically. Plastics such as those in Soil Sement® have to be made to degrade in landfill environments by the addition of natural starch materials.

Further testimony to the environmental stability of Soil Sement® is our application history. For more than 30 years, Midwest Industrial Supply Inc. has been treating open areas for dust control and erosion and has a reputation for effectively sealing coal piles for the minimization of moisture penetration. All of these applications require that Soil Sement® maintain integrity in extreme environmental conditions, including UV exposure, for up to three years. Granted, these applications do not require 30 years of persistence as in a landfill, but a landfill is void of the two necessary components for degradation—oxygen and ultraviolet exposure.

Results show that after 11 rotations of extractions, chlordane does not leach from the treated soil.

How do you determine biodegradation of polymers? If a chemical has any tendency to degrade, it will degrade in soil. Ideal degradation testing of polymers is nonexistent. The matrix interference in soil, as well as monitoring complications makes testing difficult and inconclusive at best. There are four established methods for measuring polymer degradation in soil: carbon dioxide evolution, weight-loss measurement, viscosity measurement, and loss of tensile strength. All are difficult and severely limited in accuracy. Carbon dioxide evolution is best done with 14C labeling but is expensive and at times unobtainable, and the interpretation of carbon dioxide evolution results is complicated and ambiguous.

Results show that after 11 rotations of extractions, chlordane does not leach from the treated soil. **Exhibit 3** contains a summary of results.

Chlordane was detected in the control sample and in the Rate B spike sample during Rotation 2 of EPA 1320. The untreated control sample indicated chlordane in the leachate at 0.0054 mg/L, slightly over the method detection limit of 0.0025 mg/L; the Rate B Spike sample showed a level of 0.0026 mg/L of chlordane in the leachate. Both chlordane "hits" were well below the 0.03 mg/L (TCLP) regulatory level of chlordane in leachate. All remaining samples showed no detection of chlordane at the method detection levels of 0.0025 mg/L.

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Based on the leaching test results, the fact that the environmental conditions are not conducive to polymer degradation, historical data from Soil Sement® applications in more severe environments,

Exhibit 3. Fort Hood Soil Analysis Results

Total Chlordane of Soil Sample (EPA 8081) = 4.39 mg/kg

	Control	Rate A	Rate A spike	Rate B	Rate B spike	Rate C	Rate C spike
Lab ID #	25030821	25030822	25030823	25030824	25030825	25030826	25030827
Soil Sement Application Rate (gal/cu yd)	Untreated	7.2	7.2	4.0	4.0	27.0	27.0
EPA 1320 Multiple Extraction Procedure; Chlordane Levels Detected (mg/L)							
Note: Detection Limit = 0.0025mg/L							
Rotation 1	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Rotation 2	0.0054	BDL	BDL	BDL	0.0026	BDL	BDL
Rotation 3	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Rotation 4	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Rotation 5	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Rotation 6	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Rotation 7	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Rotation 8	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Rotation 9	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Rotation 10	BDL	BDL	BDL	BDL	BDL	BDL	BDL
EPA 1311 Toxicity Characteristic Leaching Procedure; Chlordane Detected (mg/L)							
Note: Detection Limit = 0.0025mg/L							
Rotation 11	BDL	BDL	BDL	BDL	BDL	BDL	BDL

the consuming problem of persistence of plastics in landfills, the lack of a reliable test method for polymer degradation, and, finally, a test design that eliminates potential ground- or surfacewater exposure to leachate, further evaluation of the integrity of the polymers in Soil Sement® is not warranted. Soil Sement® is an effective means for the encapsulation of chlordane in contaminated soil for use as a daily cover in a municipal waste landfill under the controlled conditions.

Once we have proven the chlordane will not leach from the encapsulated soil, our next task is to prove that Fort Hood's municipal solid waste landfill is the ideal place for this project. Area 3 of Fort Hood's landfill is a lined cell with a leachate collection system. If the chlordane were to leach from the soil, it would be collected on the liner in the leachate sump. The leachate can then be collected and treated in accordance with proper established methods. At the time of this article's publication, the TCEQ and Fort Hood are discussing the application of Soil Sement® on the chlordane-contaminated soil for use as a daily cover on the municipal solid waste landfill. ❖