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NATURAL ATTENUATION REMEDIATION OF LEAD-CONTAMINATED SOILS AT A FORMER OPEN BURNING PROPELLANT DISPOSAL SITE

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ABSTRACT

Lead-contaminated surface soils at an eleven-acre former open-burning propellant disposal site at the Badger Army Ammunition Plant were scheduled for remediation by phosphate-addition soil stabilization and soil cover construction. Laboratory treatability tests performed to select an effective mix of stabilization compounds suggested that native soils (a 5 - 7 foot thick loess deposit) underlying the contaminated topsoil had a high capacity to immobilize/attenuate lead naturally, without the addition of artificial chemical stabilizers. This initial testing showed that over 99% of dissolved lead content was removed from leachates contacted with the underlying soils, up to a leachate lead content of over 10,000 μg/l. Before further studies were undertaken to support remediation through natural attenuation for this site, soil borings were installed on a 100' grid to establish the presence of the attenuating loess layer across the entire site. Then, leachates created from contaminated site soils through the Synthetic Precipitation Leaching Procedure (SPLP) were contacted with underlying attenuating soil. Pre-contact and post-contact leachate lead concentrations were tracked to determine the level of attenuation achieved. The SPLP leachates, which characteristically had a low dissolved lead content, were also spiked with higher concentrations of lead (up to 10,000 μg/l). Using these spiked leachates, the soil's attenuation capacity at higher lead levels was evaluated. The results showed that the underlying soils had over 20,000 times more capacity to attenuate dissolved lead than the contaminated soils had capacity to generate dissolved lead. Securing approval from regulators to forego chemical stabilization/soil cover in favor of natural attenuation/soil cover was a rigorous process. Like most military installations, remedial activities at Badger AAP are closely scrutinized by regulators and a local environmental group. Therefore, regulatory personnel were very cautious about granting this approval which represented a significant change from the soil stabilization plan previously approved. Documentation of laboratory and field studies described above was submitted as well as long-term groundwater data showing no indication of lead impact from overlying soils, and detailed soil analysis confirming that the lead contamination had been naturally immobilized in the upper six inches of top

soil. Approval was granted on the condition that two small collection lysimeters be installed under the contaminated soils to confirm that infiltrating precipitation is not leaching detrimental amounts of lead from the attenuating soils. Our ability to obtain approval of the "natural attenuation" alternative for these contaminated soils not only represents a savings of taxpayer dollars on this particular project due to the elimination of stabilization costs, but also sets a precedent for regulatory consideration of practical alternatives to expensive remedial technologies proposed for contaminated sites state-wide.

1. INTRODUCTION

Natural attenuation of contaminants in soils and groundwater is at the forefront of emerging remedial technologies. Whereas natural attenuation used to be regarded as the equivalent of a "no action" alternative, it is now realized that nature's physical and chemical processes can go far to moderate the effects of anthropogenic contaminants. When natural attenuation can be proven and used as the remedial action for a contaminated site, savings in funding expenditures can be realized without compromising protection of human health and the environment. At this early stage of the development of natural attenuation as a remedial method, regulators are often hesitant to approve natural attenuation remedial actions. This paper details the investigation and documentation that were necessary to successfully secure regulatory approval for the natural attenuation of lead in surface soils at a former open burning disposal site.

1.1 INSTALLATION HISTORY AND BACKGROUND

The Badger Army Ammunition Plant (BAAP) is situated on 7354 acres, 30 miles north of Madison, Wisconsin. Site boundaries include U. S. Highway 12 on the west, Devil's Lake State Park on the north, and farmland on the south and east.

1.1.1 Installation Activities and Regulatory Environment

During World War II, and the Korean and Vietnam Conflicts, BAAP produced rocket and small arms propellants and propellant intermediates such as nitroglycerine, nitric acid, and sulfuric acid. Badger has been in "stand-by" status since 1975 when the focus of operations changed from propellant production to the investigation and remediation of soils and groundwater contaminated by production activities. These remedial investigations and actions are monitored by the Wisconsin Department of Natural Resources (WDNR) and the United States Environmental Protection Agency, with the WDNR taking the regulatory lead.

1.2 RACETRACK AREA BACKGROUND

The subject site for this paper is a portion of the Propellant Burning Ground in the southwest quarter of the installation, one of several solid waste management units on the facility. The Propellant Burning Ground contains four separate sites requiring remediation. We will focus on the Racetrack Area site, named for the oval gravel road that dominates the site topography.

1.2.1 Racetrack Area Activities

The eleven-acre Racetrack Area of the Propellant Burning Ground at BAAP was the site of open burning disposal of off-specification propellants and propellant wastes including nitrocellulose, BALL POWDER®, nitroglycerine-containing compounds and waste propellant paste. Initially, wastes were spread and burned directly on the ground surface. Later, open steel dishes and gas-fired grills were installed to perform burning disposal operations.

1.2.2 Contaminants and Contaminant Source Locations

Within the Racetrack Area there are several separate sources of contaminants: burning pads on the western side of the gravel oval, burning plates on the eastern side of the gravel oval, three small refuse pits adjacent to the southeast corner of the gravel oval, and the open burning on bare ground over most of the eleven-acre area.

As a result of propellant and propellant-waste burning activities at these Racetrack sites, surface soils contained propellant residues (2,4 and 2,6-dinitrotoluene) and elevated levels of lead. Lead contamination was the primary concern, with dinitrotoluene presenting a concern limited to the burning pad area. Soils were impacted to a depth of approximately six inches.

1.2.3 Site Geology and Hydrogeology

Immediately beneath the six inches of contaminated surface soils a five to seven foot thick layer of lean clay exists. This clay was deposited as loess at the base of the terminal moraine to just to the east of the Propellant Burning Ground. (This is the terminal moraine of the Green Bay Lobe of the Lake Michigan Glacier which last advanced during the Wisconsin Stage of glaciation.) Beneath the clay, outwash sands and gravels are found to a depth of 250 feet below ground surface where Eau Claire Formation bedrock is encountered. In this area, the Eau Claire Formation is a limey sandstone with thinly bedded shale. Groundwater occurs in the outwash at approximately 85 feet below ground surface.

1.3 RACETRACK REMEDIATION

Remediation of contaminated surface soils at the Racetrack took place in two phases.

Phase I included the removal of the most highly contaminated soils. Phase II addressed the remaining soils with lower levels of contamination.

1.3.1 Development of Clean-Up Standards

Clean-up goals for the lead-contaminated soils were developed based upon regional background lead levels. 30 mg/kg was determined to be the average background lead concentration for the area and that concentration became the clean-up goal. Because regulatory agencies felt that an in-situ remedial technique (soil stabilization) should be used at the site, a performance standard was also developed. Leachate from post-action/post-treatment soils remaining on the site was to contain no more than 15 μg/l lead when subjected to the Synthetic Precipitation Leaching Procedure (SPLP). 15 μg/l is the Wisconsin Enforcement Standard for lead in groundwater; concentrations below this level are considered protective of human health and the environment.

1.3.2 Phase I Remedial Action

Phase I of the remedial action involved the removal and decontamination of one burning dish and removal of the two concrete burning pads. After these items were decommissioned, soils containing 2,4 and 2,6-dinitrotoluene and having lead levels exceeding TCLP maximums were excavated. These soils were located on the western side of the gravel oval where burning pads had been located.

1.3.3 Phase II Remedial Action - Initial Plan

The remainder of the soils containing elevated lead levels, were to be remediated through phosphate-addition soil stabilization to immobilize lead followed by the construction of a 30-inch soil cover over the stabilized soils to provide a barrier between stabilized soils and ecological receptors, particularly burrowing animals. This action was named as the preferred alternative in the feasibility study for the site and was subsequently approved by regulators as the remedial action that would be performed.

1.4 TREATABILITY TESTING AND SUPPORT FOR NATURAL ATTENUATION

Treatability tests were performed to develop an effective chemical stabilization mixture for the affected soils. Results of these initial studies suggested that attenuation/immobilization of lead was occurring naturally in soils at the site. Further testing verified the conclusions of the initial study and a document supporting modification of the remedial method from soil stabilization/soil cover to natural attenuation/soil cover was compiled and submitted to regulators for approval.

1.4.1 Initial Treatability Study

The initial treatability study was designed to develop the chemical mix to be used to stabilized the remaining lead-contaminated soils. Results from a portion of this study indicated that the five to seven foot layer of lean clay directly under the contaminated soils was able to naturally immobilize lead without the addition of chemical stabilizers. SPLP leachates were created from lead-contaminated site soils, and these leachates were spiked with up to 10,000 μg/l dissolved lead. These spiked leachates were then contacted with uncontaminated material from the lean clay layer. Contact with the lean clay removed over 99% of the dissolved lead from those spiked leachates. (See Table 1.)

TABLE 1. INITIAL TREATABILITY TEST SPIKED LEAD ATTENUATION RESULTS

Sample	Initial Lead Concentration	Attenuation Test Results (After Contact with Lean Clay)	
		Lead Concentration	Percent Removal
+ 1,000 μg/l lead	1,031 μg/l	8.7 μg/l	99.2
+5,000 μg/l lead	5,031 μg/l	44 μg/l	99.1
+10,000 μg/l lead	10,031 μg/l	28 μg/l	99.7

1.4.2 Support for Further Investigation of the Natural Attenuation Alternative

Three separate lines of evidence suggested that we take a close look at the possibility of utilizing natural attenuation at this site. First, results from the initial treatability study described above showed that native site soils could immobilize high levels of dissolved lead in infiltrating precipitation. Second, extensive soil data collected during the remedial investigation showed that lead from the surface had not migrated significantly; contamination was confined to the top six inches of the soil column. Finally, groundwater quality data collected for the area beneath the site over a period of eight years also showed no lead impacts.

1.4.3 Obstacles to Regulatory Approval of Natural Attenuation

When regulators were initially approached as to the possibility of obtaining approval for natural attenuation of contaminated soils in lieu of the already-approved chemical soil stabilization, they were pessimistic. As with most federal facilities, BAAP is a high-visibility site with a local environmental group focusing attention on remedial activities on the plant. Specifically, the Racetrack Area was the first remedial action for BAAP that would result in a site closure and , therefore, would be under high scrutiny. A second concern was that, if approved, this site would set a precedent for natural attenuation remediation approvals, resulting in requests for similar approvals across the state. Lastly, although Wisconsin Natural Resources Code did not specifically prohibit natural attenuation as a remedial action alternative, the revisions to the code that would provide for natural attenuation's acceptance was under review by the state legislature, but not yet promulgated. However, the site data was convincing enough to move forward with further natural attenuation studies although regulatory approval did not appear promising.

1.4.4 Natural Attenuation Feasibility Study

Our study focusing on the feasibility of applying natural attenuation to the site had two main goals:

- Confirm the extent of the lean clay soil layer responsible for lead attenuation.
- Quantify the attenuation capacity of the underlying lean clay at locations across the site.

1.4.5 Confirmation of Lean Clay Layer Extent

Before further lab studies were undertaken, the extent of the lean clay soil layer needed to be defined. If the layer did not extend underneath the entire eleven-acre site, then some areas of the site would not be addressed by the attenuative capacity of that layer and we would not obtain approval. The presence of the layer was verified with soil borings performed on a 100-foot grid across the entire site.

1.4.6 Attenuation Capacity Quantification

Once the existence of the clay layer was established, a laboratory study was designed to evaluate the attenuative capacity of both the lean clay layer and underlying outwash sands. Three samples of lean clay were collected from different areas of the site to determine if attenuative capacities were consistent throughout the layer. One sample of underlying outwash sand was collected to check for any additional attenuation capacity it might provide.

These four soil samples were contacted with SPLP leachates prepared from contaminated site soils that were spiked with 1,000 $\mu g/l$ dissolved lead. 1,000$\mu g/l$ was chosen as the spiking concentration purely for quantification of attenuation capacity at worst-case dissolved lead levels. Lead concentrations in SPLP leachates from site soils were much lower, typically under 20$\mu g/l$.

Contact of spiked leachates with lean clay achieved dissolved lead removal rates of 96.8% - 98.0%. Contact with the underlying outwash sand resulted in a removal rate of 98.5%. (See Table 2.)

TABLE 2. NATURAL ATTENUATION FEASIBILITY STUDY RESULTS

Soil Sample	Spiked Lead Concentration Before Contact	Lead Concentration After Contact	% Attenuated
Lean Clay 1	1,000 $\mu g/l$	20 $\mu g/l$	98.0%
Lean Clay 2	1,000 $\mu g/l$	32 $\mu g/l$	96.8%
Lean Clay 3	1,000 $\mu g/l$	24 $\mu g/l$	97.6%
Underlying Sand	1,000 $\mu g/l$	15 $\mu g/l$	98.5%

1.4.7 Natural Attenuation Capacity of the Soil Column

The dissolved lead removal rates from the natural attenuation feasibility study were applied to the soil column to estimate the total attenuation capacity between the contaminated soils and the groundwater at 85 feet below ground surface. Figure 1 provides a summary of the estimates for the lean clay and outwash sand layers. It was estimated that the native soils had approximately 29,400 times more capacity to attenuate lead than contaminated surface soils had to generate dissolved lead.

1.5 DOCUMENTATION SUBMITTAL AND APPROVAL

A document detailing the results of the natural attenuation feasibility study, boring logs for the site's subsurface on a 100' grid, maps depicting residual lead levels, ecological risk assessment information, and a long-term monitoring proposal for site was assembled and submitted to the Wisconsin Department of Natural Resources for approval.

Approval was granted on the condition that two lysimeters be installed under the lean clay layer in areas of highest residual lead levels. These sampling points will monitor the dissolved lead content of any infiltrating precipitation passing through the lean clay layer and confirm the effectiveness of natural attenuation for these soils.

CONCLUSIONS

The reduction in cost and level of remedial effort achieved at this site through the application of natural attenuation of lead-contaminated soils is an example of what can be accomplished through innovative approaches to contaminant problems. Contamination situations that might be resolved with a lower level of effort without comprimising human health or the environment should be actively sought and identified. When these sites are identified, regulators must be approached with innovative

FIGURE 1. NATURAL LEAD ATTENUATION CAPACITY OF SITE SOILS

Soil Description	Soil Depth	Hypothetical Lead Leaching Potential of Surface Soil (mg lead/m^2 soil)	Lead Attenuation Capacity of Soil* (mg lead/m^2 soil)	Comments
Surface Soil	6"	225	NA	
Subsurface soil (lean clay)	5'	NA	>312,000	≈1,400 times the lead leaching potential of surface soil
Underlying soil (sand)	100'	NA	>6,235,000	≈28,000 times the lead leaching potential of surface soil

* For entire soil column of 1 m^2 area.
NA Not applicable.

proposals that provide in full the information and data they need to grant approval for remedial actions with reduced remedial costs.