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POND SOILS AT HANFORD

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SOIL WASHING RESULTS FOR MIXED WASTE POND SOILS AT HANFORD

ABSTRACT

Soil washing technology was assessed as a means for remediating soil contaminated with mixed wastes primarily composed of heavy metals and radionuclides. The soils at the U. S. Department of Energy's Hanford Site are considered suitable for soil washing because of their relatively low quantities of silt and clay. However, in a limited number of soil washing experiments using soils from different locations in the north pond of the 300 Area, the degree of decontamination achieved for the coarse fraction of the soil varied considerably. Part of this variation appears to be due to the presence of a discrete layer of contaminated sediment found in some of the samples.

INTRODUCTION

Soil washing is being considered for remediating soils located at the U.S. Department of Energy's (DOE's) Hanford Site. The Hanford Site encompasses 560 square miles of semiarid desert in South Central Washington and lies in a structural and topographic basin of eastern Washington within the Columbia Plateau. The site is bordered to the north and east by the Columbia River and is adjacent to the northern boundary of the city of Richland, Washington. Located on this site are a number of government facilities which were operated to produce plutonium for the Department of Defense and conduct nuclear research for the DOE. As a result of these operations, over 1000 inactive waste disposal and unplanned release sites were generated ranging in size from minor spills to burial grounds of 100 acres. The soils at these sites are primarily contaminated with both heavy metals and radionuclides. In support of cleanup efforts at Hanford, the effectiveness of soil washing in treating contaminated soils was assessed. A limited number of soil washing tests were conducted using soils obtained from a waste disposal pond located in the 300 Area of the Hanford Site.

SOIL WASHING PRINCIPLES

Successful soil washing largely depends on matching the type of contamination and soil characteristics with specific operations that can perform well under those conditions. In general, there are three main types of soil contamination: contaminants dissolved in the water in the soil, contaminants chemically fixed as solid compounds, and contaminants adsorbed onto the surfaces of the various solids in the soil. The majority of the near-surface contamination in the north pond is expected to be in the form of sediments comprised of precipitates disposed with the wastes and chemically fixed solids resulting from interactions between dissolved solids in the waste and certain minerals present in the soil. Principal soil minerals of concern are carbonates, sulfides, phosphates, and hydrous metal oxides containing manganese or aluminum. (1)

Soil washing as it is currently practiced for chemically fixed heavy metals and radionuclides is accomplished primarily through attrition scrubbing and separation of soil fractions by size. In some instances, surfactants are added to facilitate separation of fine and coarse particles by neutralizing the charge associated with the particles. The soil is separated into two fractions. The coarse fraction of the soil has a much lower surface area per unit weight and a corresponding lower amount of contamination than a comparable mass of very fine particles. Ideally this fraction of the soil can be returned to the site. The fine soil fraction is composed of very fine sand, silt, and clay and has a much larger surface area for chemically fixing dissolved solids and precipitates. It also includes discrete particles of precipitate. After washing, this fraction of the soil, which is usually in the form of a sludge, is contaminated and requires further treatment or off-site disposal. As a general rule, soil containing less than 25% silt and clay can be washed economically.

In actual practice, the contaminants do not always partition sufficiently to the fine fraction of the soil. This is particularly true for radionuclides whose maximum allowable levels are very low. Some of the contaminants become solubilized or dispersed in the water phase and must eventually be removed. Also, depending on the method of separation, both the fine and coarse fractions contain a small portion of the other soil fraction. In addition, some of the contaminants remain on the coarse particles. In either case, residual contamination may preclude returning the coarse fraction to the site without further treatment, and it may be necessary to solubilize the contaminants by adjusting the pH or by using chelating or complexing agents.

SITE DESCRIPTION

The surface soil at Hanford is characterized by a layer of light brown, fine, slightly silty, wind-deposited sand typically varying from less than 0.3 m to over 4.5 m in depth. Surface soil samples from two separate locations near the 300 Area contained 69% to 97% sand, 1% to 26% silt, and 1% to 5% clay. (2)

Underlying the surface soil are poorly sorted, unconsolidated glacio-fluvial sediments informally referred to as the Pasco gravels of the Hanford Formation. These sediments were deposited during catastrophic flooding episodes associated with failures of the Lake Missoula ice dam during the late Pleistocene epoch. (3) The last major flood occurred approximately 13 thousand years ago. (4) The Pasco gravels of the Hanford Formation consist of a variable mixture of boulders, cobbles, gravel, sand, and silt; however, most of the sediments can be classified as a silty sandy gravel consisting of 50% gravel, 40% sand, and 10% silt. (5) The uppermost aquifer beneath Hanford consists of an unconfined system ranging in depth from less than 0.3 m near the Columbia River to over 90 m. (6)

The bench-scale treatability tests reported in this paper were conducted using soil samples from the north process pond in the 300 Area located in the

southeast corner of the Hanford site approximately 5 km north of Richland and approximately 90 m west of the Columbia River. In the vicinity of the pond, the surface soils are thin and the Pasco gravels are about 15 to 18 m thick.

The north pond area consists of six small settling basins and one large infiltration basin, as shown in Fig. 1, separated by 3.7-m-wide dikes. The entire 10 acre area is surrounded by a dike 4.5 m wide and approximately 3 m high.

From 1949 to 1974 the pond was one of two unlined surface impoundments that received low-level radionuclide liquid wastes and cooling water from facilities located in the 300 Area. The pond was dredged periodically to increase infiltration rate. Since closure, several of the dikes between basins were removed and uncontaminated material from the dikes was placed on the bottom of the basins. The pond has since dried out.

The estimated inventory of nonradiological chemicals known to be disposed in the pond is listed in Table I. Previous analyses⁽⁷⁾ of soil samples taken from the site indicate low levels of both the sodium and nitrate ions, suggesting that they were fairly mobile species.

RESULTS OF BENCH-SCALE SOIL WASHING TESTS AT HANFORD

Bench-Scale Experimental System and Procedures

Fig. 2 shows a procedure flow diagram for the bench-scale soil washing system. Soil samples ranging in size from about 100 g up to 500 g were used in each experiment. A portion of each sample was retained for comparison with the cleaned soil fractions. The soil samples were dried, weighed, and mixed with water in a 3.8-L polystyrene bottle. The water-to-soil weight ratio ranged from 1:1 to 10:1. The bottle was then placed on a reciprocating shaker for a period ranging from 30 min to 1 h and shaken at a stroke length and frequency of 4.57 cm and 4 Hz, respectively.

The soil-water slurry was then poured into the top of a Gilson Wet-Vac Model WV-3. The Wet-Vac contains three screens and filter paper to collect the various soil fractions. After the wash solution was separated, rinse water was added to the Wet-Vac and recirculated. The solids retained on each screen were collected, dried, weighed, and submitted for analysis. The wash water and the recycle water were also submitted for analysis. Analysis of the original sample and each washed fraction was performed using U.S. EPA SW846 methods.

Samples Tested

The sample numbers shown in Fig. 1 correspond to the samples used in the tests. Soil samples taken from the ponds show that the soil is quite sandy with a lot of gravel and boulders. The particle size distribution for some of the samples is given in Table II. Rocks and gravel that could not pass a 1.27-cm screen were not included in the samples.

Experimental Results

Nine soil washing tests were performed to gain experience with the soil washing apparatus and to explore some of the parameters known to be important to the process.

Table III shows the concentrations of a number of constituents in the whole soil before washing and in the different fractions following soil washing for a soil sample obtained from location A03. This test used a wash water/soil ratio of 5:1 and a total washing time of 1 h. Also shown in Table III for comparison are the average concentrations of these elements for soil samples obtained at depths ranging from 0 to 3.3 m from a location in the 300 Area which is believed to be representative of uncontaminated soil.⁽⁷⁾ It can be seen from the data that there is a definite partitioning of the major contaminants to the smaller fractions. In addition, very little of the contamination partitioned to the wash water.

Both the elemental and overall material balances between the total soil and the sum of individual fractions and wash water recovered are shown in Table III. These balances are expressed as a percent of the soil sample values before washing. The amount of material accounted for in the balance is not very good for several of the elements. This trend was observed for all of the tests performed. The poor elemental balances can be attributed only partially to loss of material. The remaining discrepancies are attributed to analytical error including the method of selecting samples for analysis and the variability introduced by analyzing small (1-g) quantities of material. This is particularly important where single grains of soil account for a significant portion of the sample analyzed and individual grains of contaminants can account for a significant portion of the concentrations measured.

Table IV shows the degree to which contaminants were partitioned to the -2 mm/+250 μ m fraction for four soil washing tests performed using a water/soil ratio of 5:1 and 30 min of washing. There is considerable variation in the partitioning of individual contaminants for soil samples obtained from different locations. These results are significant because this fraction alone represents anywhere from approximately 50% to as much as 90% of the soil passing a 1.27-cm screen. Technical feasibility of soil washing will depend on adequate cleaning of this fraction.

The results obtained for tests using a soil sample collected from the N-6-2 location in the pond are particularly noteworthy. This sample was collected at a point close to where other samples were collected. However, inspection of the sample as it was washed and observations during collection at the site indicated that it contained a substantial quantity of a relatively hard, light green sediment. Earlier analysis of this sediment⁽⁷⁾ showed that the green material in the sediment consisted mostly of copper. Preliminary analysis also indicated gross alpha levels about four times higher in the blue-green sediment than in the whole soil. Soil washing tests showed that the sediment was not readily attrited during washing. The poor partitioning results for this fraction suggest that a significant portion of the

contamination is associated with the blue-green sediment and that simple washing does not partition the sediments to the smaller size fractions.

Three additional tests were performed with soil samples obtained from the N-6-2 site. Two tests were performed with HCl and H₂SO₄, respectively, added to the wash water to obtain an initial pH of 2. In both cases the acid caused foaming during washing and the final pH was increased to about 5.5, which is the same value obtained for all previous tests. In both cases partitioning improved only marginally for the -2 mm/+250 μm fraction. For example, HCl and H₂SO₄ achieved residual copper concentrations in the -2 mm/+250 μm fraction that were 109% and 69%, respectively, of the bulk soil concentrations. The third test was performed using a ball mill roller instead of the shaker in order to impart a tumbling action to the soil. Even though there was no obvious increase in the amount of fines due to attrition, the results did indicate that the -2 mm/+250 μm fraction was decontaminated moderately. For example, the residual concentration of copper was about 48% of that in the bulk soil.

CONCLUSIONS

Based on the limited number of experiments conducted to date, it is not possible to draw any firm conclusions regarding the feasibility of using soil washing to remediate contaminated soils at the Hanford Site. However, the following conclusions can be made about the character of the contaminated soil in the north pond of the 300 Area and its behavior during soil washing:

- The soil in the 300 Area ponds is, as expected, primarily sand. Typically 80 to 90% of the soil has a particle size greater than 250 μm.
- The primary hazardous contaminant present is copper, and the primary radionuclide present is uranium.
- Initially, the contamination is distributed throughout the range of particle sizes, but after washing, the contamination is partitioned preferentially to the fine fraction (<250 μm) of the soil.
- After washing, the coarse fraction still contains significant levels of contamination, which appears in the form of discrete particles and as a coating on the sand particles. The amount of decontamination achieved for this fraction also varies significantly between soils from different locations in the pond.
- Very little of the contamination is water soluble, indicating that high water recycle ratios can be used.
- Additional unit operations, such as attrition scrubbing, will be necessary to further reduce the contamination for the coarse fraction.

While some test results are encouraging, additional tests will be needed to fully assess the applicability of the technology and to resolve some of the issues identified in these preliminary tests.

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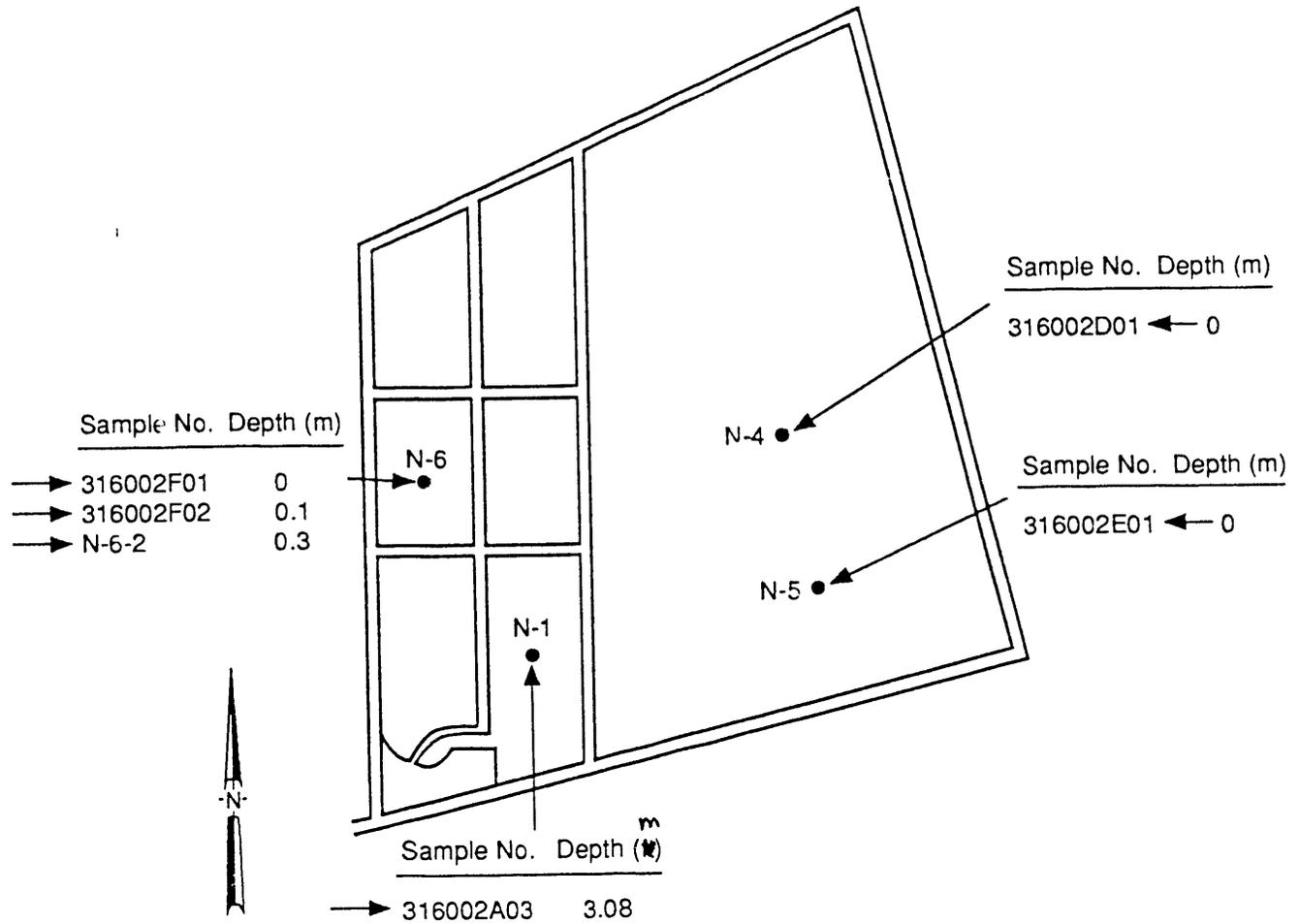


Figure 1. Diagram of 300 Area North Pond

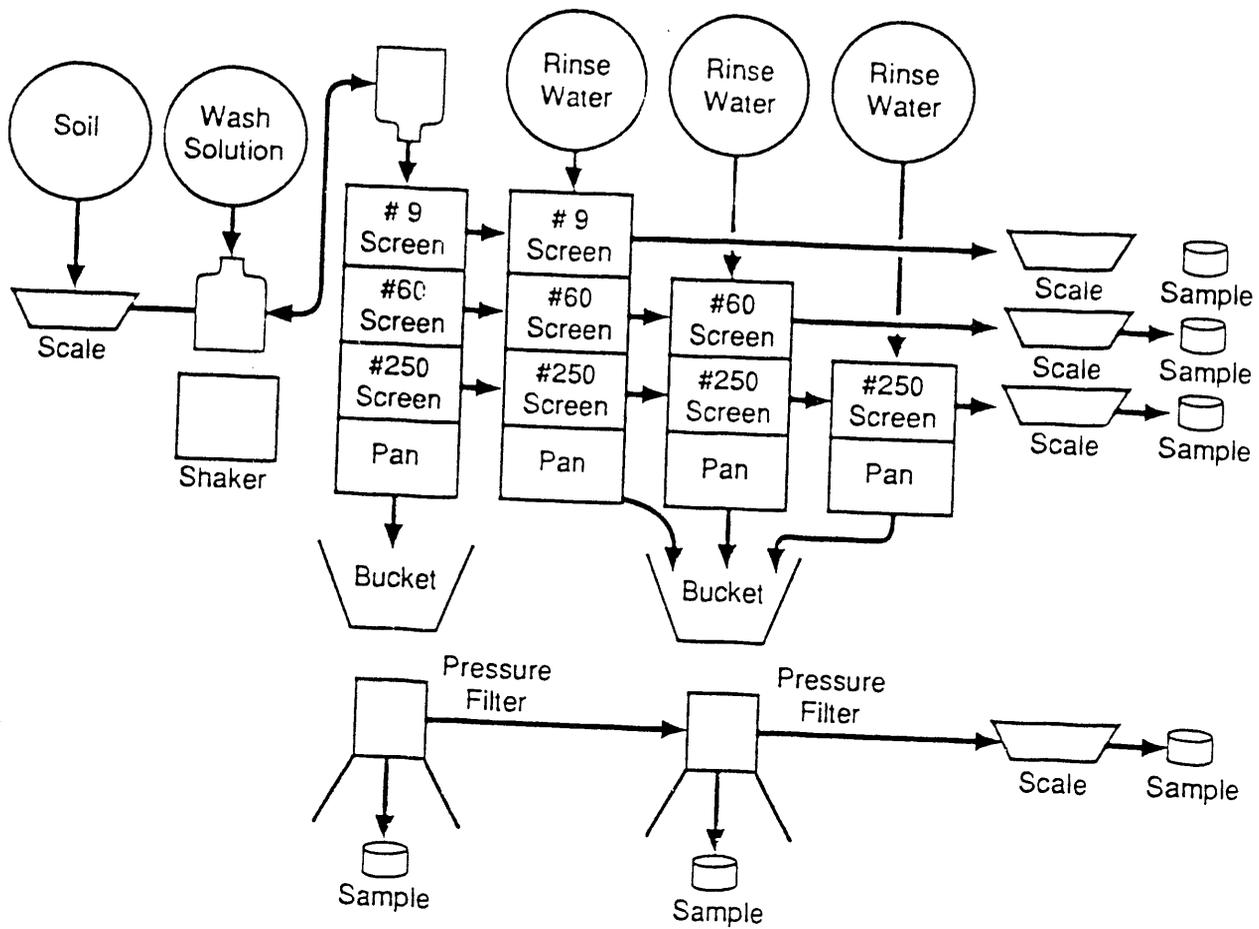


Figure 2. Schematic of Bench-Scale Soil Washing System

Table I. Estimated Nonradiological Chemical Waste Inventory for the North Process Pond

<u>Chemical</u>	<u>Quantity (kg)</u>
Beryllium	30
Cadmium	60
Chromium	3,000
Copper	50,000
Fluoride	5,000
Lead	2,000
Mercury	40
Nickel	8,000
Nitrate	800,000
Nitrite	700,000
Nitric Acid	900,000
Silver	900
Sodium	1,000,000
Sodium Aluminate	2,000,000
Sodium Hydroxide	800,000
Sodium Silicate	90,000
Trichloroethylene	100,000
Uranium	30,000
Zinc	3,000
Total volume of Liquids Disposed:	
	10,000,000,000 L

Table II. North Pond Wet Sieving Results

<u>Sieve Size</u> <u>U.S. STD.</u>	<u>Soil Type</u>	<u>Sample Number</u>					
		<u>A03</u>	<u>F01</u>	<u>F02</u>	<u>N-6-2</u>	<u>F03</u>	<u>D01</u>
-12.7 mm/ +2 mm	coarse sand/ fine gravel	2.6	35.3	26.1	28.8	15.8	38.2
-2 mm/+250 μ m	medium/fine sand	90.0	46.5	52.9	56.1	76.3	47.9
-250 μ m/ +63 μ m	coarse silt/ very fine sand	3.8	7.5	13.4	7.8	3.2	4.6
-63 μ m	clay/silt	3.7	10.3	7.8	6.1	4.6	9.4

Table III. Soil Washing Results for A03 Soil Sample Obtained from North Pond

	Analysis Values in $\mu\text{g}/\text{g}$ ($\mu\text{g}/\text{L}$ for water)							Material Balance (%) (a)
	Background Soil	Bulk Soil (282 g)	2 mm to 12.5 mm (6.92 g)	250 μm to 2 mm (236.3 g)	63 μm to 250 μm (9.9 g)	Less Than 63 μm (9.7 g)	Wash Water (1.56 L)	
Chromium	9.8	286	23	110	690	2,180	0.23	67
Copper	18.4	12,500	1,560	8,000	22,900	69,000	0.34	79
Lead	5.1	92	0.0	60	250	425	0.0	80
Nickel	7.6	191	40	140	1,430	820	0.0	103
Uranium	---	65	5	24	117	316	0.0	55

(a) The sum of the soil fraction quantities was 93% of the quantity of the bulk soil.

Table IV. Comparison of Soil Washing Results for Soils Obtained from Different Locations in the North Pond (analysis values in $\mu\text{g/g}$)

	Bulk Soil	A03		F01		M6-2-1		D01				
		Soil 2mm/250 μm	% Bulk Value	Bulk Soil	Soil 2mm/250 μm	% Bulk Value	Bulk Soil	Soil 2mm/250 μm	% Bulk Value	Bulk Soil	Soil 2mm/250 μm	% Bulk Value
Weight (g)	263	236	89.8	128	59.6	46.5	324	193	59.4	288	137	47.8
Chromium	286	110	38.5	766	296	38.6	645	800	124	75	40	53.3
Copper	12,500	8,000	64.0	12,400	4,830	39.0	9,070	12,000	132	2,070	1,260	60.9
Lead	92.0	60.0	65.2	50.0	69.0	138	NA	NA	NA	NA	NA	NA
Nickel	191	140	73.3	369	156	42.3	325	405	125	150	150	100
Uranium	65	25	38.5	NA	NA	NA	10.0	20.1	201	220	40.0	18.2

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