CONF-8406205--1

CONF-8406205--1

DE85 001278

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Publication No. 2359

Research Sponsored by the Office of Defense Waste and By-Product Management, U. S. Department of Energy

Date Published - March 1984

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
for the
U.S. Department of Energy
under Contract No. DE-AC05-84OR21400

GROUTING OF URANIUM MILL TAILINGS PILES

W. J. Boegly, Jr.,[1] T. Tamura,[1], and J. D. Williams[2]

ABSTRACT

A program of remedial action was initiated for a number of inactive uranium mill tailings piles. These piles result from mining and processing of uranium ores to meet the nation's defense and nuclear power needs and represent a potential hazard to health and the environment. Possible remedial actions include the application of covers to reduce radon emissions and airborne transport of the tailings, liners to prevent groundwater contamination by leachates from the piles, physical or chemical stabilization of the tailings, or moving the piles to remote locations.

Conventional installation of liners would require excavation of the piles to emplace the liner; however, utilization of grouting techniques, such as those used in civil engineering to stabilize soils, might be a potential method of producing a liner without excavation.

Laboratory studies on groutability of uranium mill tailings were conducted using samples from three abandoned piles and employing a number of particulate and chemical grouts. These studies indicate that it is possible to alter the permeability of the tailings from ambient values of 10^{-3} cm/s to values approaching 10^{-7} cm/s using silicate grouts and to 10^{-8} cm/s using acrylamide and acrylate grouts. An evaluation of grouting techniques, equipment required, and costs associated with grouting were also conducted and are presented.

INTRODUCTION

Passage in 1978 of the Uranium Mill Tailings Radiation Control Act (UMTRCA) initiated a program of remedial action for inactive mill tailings piles produced as a part of the nation's defense and nuclear power programs (10). To carry out the objectives of the Act, the U.S. Department of Energy (DOE) formed the Uranium Mill Tailings Remedial Action Program (UMTRAP) (7). The presence of these piles (containing approximately 2.5 x 10^7 Mg of tailings) poses significant health and environmental contamination concerns. Initially, 22 inactive tailings piles were included in UMTRCA; however, two additional sites have been included, bringing the total to 24 (2).

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Major research and development effort in UMTRAP has been directed toward liners and covers. Covers that can retain radon for a sufficient time period to allow radioactive decay will eliminate concern with exposure of the population and can prevent spreading of the tailings by wind and water erosion. Single- and multiple-layer covers of earthen and synthetic materials have all shown promise in reducing radon emissions (3). Liners (natural earth or synthetic) can be used to prevent groundwater pollution by leachates. Liners are most applicable to piles that must be moved, because the liner must be emplaced prior to replacement of the tailings pile. Removal of radium and other radionuclides from the tailings will require excavation, treatment, and replacement of the tailings. The UMTRAP has investigated various chemical and physical modifications to the tailings such as thermal treatment, acid extraction of radium, and chemical stabilization (6). Because some of the piles are located in remote areas, it is possible that recontouring of the piles, fencing, and general area cleanup are all that will be required.

An alternative that may meet the remedial objectives of UMTRAP is grouting of the piles using techniques conventionally employed in civil engineering for improving soil-bearing capacities and minimizing water flow in permeable formations. Application of these techniques would not require that the piles be moved or that large amounts of earth be excavated for use as cover. The sequence of grout application can only be speculated at this time; however, it appears that a lower liner might be grouted first, then the sides and top of the pile. If considered necessary, the entire pile could be grouted to completely isolate contaminants and provide structural stability to the pile.

TYPES OF GROUTS

Grouts can be described by the materials used to produce the grout (e.g., cement-based or chemical) or by the physical characteristics of the grout (particulate, colloidal, or solution). Cement-based grouts were used as early as 1902 to repair bridge foundations and seal mine shafts and tunnels; however, their application is limited by the size of the voids in the material being grouted. The most common types of chemical grouts are sodium silicate, lignosulfonates, acrylamides, phenoplasts, and aminoplasts (5). The first two types are classified as colloidal grouts and the last three are solution-type grouts. Chemical grouts are more expensive than the colloidal or particulate grouts; however, their low viscosity and lack of particulates increases their penetrating ability in fine-grained formations.

Each grout type and formulation has special properties and problems associated with its application. It has been suggested that grout selection be made on the basis of permanence, penetrability, strength, gel-time control, compatibility, toxicity, and economics (4). In the case of mill tailings, it appears that permanence, penetrability, and compatibility are the primary characteristics to be considered, with toxicity and economics of secondary importance; strict control of gel time and strength do not appear to be major concerns.

GROUTING EQUIPMENT AND TECHNIQUES

The basic equipment required to perform a grout injection consists of a solids and liquid storage and measurement system, a source of water, a mixer, and a pump. Depending on the size of the operation, a small portable unit containing all of this equipment or skid- or truck-mounted units may be all that is required. Most of the grouting service companies have developed mobile equipment for performing grout injections. Of special interest for its potential application to mill tailings are mobile injection probes used to inject lime/fly ash slurries into landfills and near-surface formations for soil stabilization. This type of equipment does not require predrilling of injection wells at fixed intervals and should minimize the cost of injection for a given grout.

A review of the literature indicates that there are no universally acceptable procedures for performing a grouting operation; rather, the grouter uses whatever methods he considers acceptable for the job. The most common procedure appears to be drilling injection wells on a grid pattern with the holes spaced at equal distances along parallel lines. The holes located in alternate lines may be displaced by one-half the spacing of the previous line, or a true rectangular grid may be employed. Spacing between injection wells can be calculated, using the properties of the grout (viscosity, particle size, gel time, etc.), the properties of the formation being treated (porosity and permeability), and engineering features such as the diameter of the injection pipe and an assumed limitation on injection pressures (4). Although it is possible to calculate a theoretical spacing for the wells, it appears that the spacings utilized in practice are tempered by engineering judgment based on past experience with similar grouts and formations rather than on a theoretical basis. In practice it appears that if acceptable penetration of the formation does not occur at the selected spacing, additional holes are drilled for more injections.

LABORATORY STUDIES

Samples of tailings from the Salt Lake City, Shiprock, and Durango piles were obtained for chemical and physical analysis and compatibility studies. Chemical analysis indicated that the tailings contained elevated levels of arsenic, chromium, copper, manganese, mercury, selenium, molybdenum, zinc, and uranium (9). Laboratory leaching studies showed that some of these elements could be released in concentrations that could cause localized groundwater contamination. Physical property measurements on the tailings samples indicate hydraulic conductivities ranging from 3×10^{-3} to 6×10^{-3} cm/s and effective particle sizes (diameter of soil particle such that the weight of 10% of all particles is less than this size) ranging from 0.046 to 0.065 mm. These values appear to rule out the use of particulate grouts, which generally require an effective particle size greater than 0.5 mm (9).

Based on the measured physical properties of the tailings specimens, it was decided to evaluate the use of polyacrylamide, polyacrylate, resorcinol, urea-formaldehyde, urethane, bentonite, and sodium silicate as candidate grouts. Compatibility of the grout and tailings was based on observed changes in hydraulic conductivity. Glass columns 10 cm long by 2.5 cm diam were packed with the tailings, the initial hydraulic conductivity was measured, and grout was added and allowed to infiltrate the tailings by gravity flow until the entire column was filled. The grout was allowed to set and the hydraulic conductivity redetermined. Results of these tests are shown in Table 1, and indicate that the best performance was obtained with polyacrylamide and sodium silicate formulations. Resorcinol failed to perform well for two tailings samples, perhaps because these samples were more acidic than the Durango sample. The apparent low conductivities shown by the bentonite grout were due to surface plugging of the column.

ECONOMICS

Costs of grouting are site dependent and include the cost of raw materials, labor, injection wells if required, and injection equipment costs (purchase or rental). The larger the amount of grout injected the lower the unit cost. A rough estimate of the amount of grout required can be calculated if the porosity of the formation is known. Based on vendors' prices for grout chemicals and the porosity of the mill tailings samples, the estimated cost ranges from $103/m^3 of tailings

TABLE 1. HYDRAULIC CONDUCTIVITIES OF GROUTED MATERIALS
URANIUM MILL TAILINGS

GROUT	SHIPROCK	SALT LAKE CITY	DURANGO	QUARTZ SAND
		(cm/s)		
NONE	5.5×10^{-3}	3.8×10^{-3}	4.1×10^{-3}	3.9×10^{-2}
POLYACRYLAMIDE (10%)	5.4×10^{-5}	$\leq 2.6 \times 10^{-7}$	$\leq 2.6 \times 10^{-7}$	$\leq 2.6 \times 10^{-7}$
POLYACRYLATE (10%)	$\leq 2.6 \times 10^{-7}$	$\leq 2.6 \times 10^{-7}$	$\leq 2.6 \times 10^{-7}$	$\leq 2.6 \times 10^{-7}$
BENTONITE (5%)[a]	$\leq 2.6 \times 10^{-7}$	$\leq 2.6 \times 10^{-7}$	$\leq 2.6 \times 10^{-7}$	$\leq 2.6 \times 10^{-7}$
RESORCINOL-FORMALDEHYDE (10%)	1.1×10^{-3}	8.7×10^{-4}	$\leq 2.6 \times 10^{-7}$	$\leq 2.6 \times 10^{-7}$
UREA-FORMALDEHYDE (20%)	3.4×10^{-3}	1.4×10^{-3}	2.5×10^{-3}	2.6×10^{-2}
SODIUM SILICATE (15%)	1.4×10^{-6}	7.0×10^{-7}	5.2×10^{-4}	2.6×10^{-4}
URETHANE (5%)	9.4×10^{-4}	8.0×10^{-6}	$\leq 2.6 \times 10^{-7}$	$\leq 2.6 \times 10^{-7}$

[a]IN ALL CASES, BENTONITE FAILED TO INFILTRATE THE SOIL COLUMNS, AND THE REPORTED LOW CONDUCTIVITIES ARE THE RESULT OF SURFACE PLUGGING

grouted for sodium silicate to $259/m^3 for acrylate. To these figures must be added the site-specific costs for injection of the grout. For comparison purposes, Herndon and Lenahan (4) reported chemical grouting costs in 1976 of $52 to $250/m^3. Escalating these costs to 1982 indicates that costs ranging from $85 to $400/m^3 can be anticipated (9). Although these costs may appear high, other pile stabilization alternatives are also expensive. It is estimated that the cost of moving the Salt Lake City Vitro Chemical Company pile will cost in excess of $31/m^3, versus in situ stabilization at $10/m^3 (1). It should be noted that for lining a pile only a small fraction of the total pile must be grouted, depending on the thickness of the liner and the height of the pile.

CONCLUSIONS

Based on the limited exploratory studies performed at ORNL, it appears that grouting is a potential alternative to liners or covers as a method of remedial action for inactive uranium mill tailings piles. Grouts are available that are compatible with the tailings, that can reduce the permeability to very low values, and that appear to provide the permanence (at least as well as other types of liners) required. Particle size analysis and permeability tests using samples provided by UMTRAP indicate that many of the grouts tested can provide the necessary penetration and reduction in permeability required to seal the piles. An evaluation of the equipment currently used for grouting indicates that no special problems exist that would require research and development; in fact, many of the grouting service companies have developed mobile equipment that can provide the necessary flexibility for operations on mill tailings piles. Rough cost estimates indicate that the costs of this type of remedial action are probably excessive unless isolation of the entire pile is warranted. However, if only a liner is needed, then grouting may provide this remedial action at a lower cost than relocating the pile.

The technology reported in this paper is also applicable to the treatment of any waste material such as blast furnace slags, mining wastes, combustion ash/slags, etc., which are normally placed in piles for disposal. Although only limited field testing has been conducted, the use of chemical grouts to fill voids in low-level waste burial trenches has been successful in minimizing contact of buried waste with groundwater (8). The major requirement is to select a grout formulation that is chemically compatible with and is capable of penetrating the waste.

ACKNOWLEDGMENTS

The authors would like to express their appreciation to B. P. Spalding, I. Munro, H. W. Wilson, Jr., and A. F. Iglar for guidance and assistance in preparing this paper. Research sponsored by the U.S. Department of Energy (Nuclear Waste Programs) under Contract No. DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc. Publication No. 2359, Environmental Sciences Division, ORNL.

APPENDIX

1. "Draft Environmental Impact Statement on Remedial Actions at the Former Vitro Chemical Company Site, South Salt Lake, Salt Lake County, Utah," DOE/EIS-0099-D, U.S. Department of Energy, Washington, D.C., 1983.

2. Groelsema, D. H., "The Management of Uranium Mill Tailings in the United States," IAEA-SM-262/20, Management of Wastes from Uranium Mining and Milling, IAEA, Vienna, Austria, 1982.

3. Hartley, J. N., et al., "Uranium Mill Tailings Remedial Action Project (UMTRAP): Cover and Liner Technology Development Program," IAEA-SM-262/39, Management of Wastes from Uranium Mining and Milling, IAEA, Vienna, Austria, 1982.

4. Herndon, J., and Lenahan, T., "Grouting of Soils: Vol. 1, Design and Operations Manual," FHWA-RD-76-26, U.S. Department of Transportation, Washington, D.C., 1976.

5. Karol, R. H., "Chemical Grouts and their Properties," Grouting in Geotechnical Engineering, American Society of Civil Engineers, New York, N.Y., 1982, pp. 359-377.

6. Macbeth, P. J., et al., "Laboratory Research on Tailings Stabilization Methods and their Effectiveness in Radiation Containment," GJT-1, Ford, Bacon, and Davis Utah, Inc., Salt Lake City, Utah, 1978.

7. Matthews, M. L., "The Technology Development Effort of the Uranium Mill Tailings Remedial Action Project," IAEA-SM-262/42, Management of Wastes from Uranium Mining and Milling, IAEA, Vienna, Austria, 1982.

8. Spalding, B. P., Hyder, L. K., and Munro, I. L., "Grouting as a Remedial Technique for Problem Shallow Land Burial Trenches of Low-Level Radioactive Solid Wastes," ORNL/NFW-83/14, Oak Ridge National Laboratory, Oak Ridge, Tenn., July 1983.

9. Tamura, T., and Boegly, Jr., W. J., "In Situ Grouting of Uranium Mill Tailings Piles: An Assessment," ORNL/TM-8539, Oak Ridge National Laboratory, Oak Ridge, Tenn., May 1983.

10. "Uranium Mill Tailings Radiation Control Act of 1978," U.S. Government, Public Law 95-604, 95th Congress, 1978.