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Reuse of Waste Cutting Sand at Lawrence Livermore National Laboratory

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ABSTRACT

Lawrence Livermore National Laboratory (LLNL) examined the waste stream from a water jet cutting operation, to evaluate the possible reuse of waste garnet sand. The sand is a cutting agent used to shape a variety of materials, including metals. Nearly 70,000 pounds of waste sand is generated annually by the cutting operation. The Environmental Protection Department evaluated two potential reuses for the spent garnet sand: backfill in utility trenches; and as a concrete constituent. In both applications, garnet waste would replace the sand formerly purchased by LLNL for these purposes. Findings supported the reuse of waste garnet sand in concrete, but disqualified its proposed application as trench backfill. Waste sand stabilized in a concrete matrix appeared to present no metals-leaching hazard; however, unconsolidated sand in trenches could potentially leach metals in concentrations high enough to threaten ground water quality. A technical report submitted to the San Francisco Bay Regional Water Quality Control Board was reviewed and accepted by that body. Reuse of waste garnet cutting sand as a constituent in concrete poured to form walkways and patios at LLNL was approved.

INTRODUCTION

Lawrence Livermore National Laboratory is a premier applied-science national security laboratory operated by the University of California for the United States Department of Energy. Its primary mission is to ensure that the nation's nuclear weapons remain safe, secure, and reliable, and to prevent the spread and use of nuclear weapons worldwide. This mission enables programs in applied defense technologies, energy security and supply, environmental assessment and management, bioscience research, applied technologies, and the fundamental sciences.

As part of its environmental assessment and protection program, LLNL pursues an aggressive waste minimization program. LLNL eliminates waste where possible, segregating and finding markets for recyclable materials and beneficially reusing wastes as appropriate. Environmental Protection Department personnel tentatively identified waste garnet cutting sand as an appropriate substitute for product sand in concrete mixed for Laboratory construction. This paper discusses the process by which waste sand became an approved constituent of concrete at LLNL.

This evaluation of the reuse of waste sand in concrete relied on previous research on using concrete to stabilize waste, conducted by Boy[1,2], Stegemann and Cote[3], and MacPhee and Glasser[4]. LLNL's proposal deviates from that earlier work by proposing the use of nonhazardous waste. To evaluate the potential ground water impacts of the land application of waste sand in concrete, LLNL used Jon Marshack's Designated Level Methodology[5]. Because

LLNL plans to use the concrete containing waste sand solely in non-structural applications, we did not perform any materials testing of the physical properties of the finished concrete. Materials testing would be required, should the concrete be used in structural applications.

WATER JET CUTTING PROCESS

The water jet cutting process employs a jet spray containing garnet abrasive (sand) to cut a variety of metal, ceramic, rubber, and plastic parts in sizes up to 4-by-8-foot sheets. **Table 1** lists the materials cut with the water jet at LLNL[6]. Bold text indicates the most frequently-cut materials. Radioactive materials are not approved for use in the facility holding this apparatus, and are therefore never cut with the water jet.) The jet spray uses approximately 0.75 gallons of water per minute for a maximum of four hours per day[7].

A multi-stage separator separates particulates from the wastewater. The first stage, a cyclone separator, removes particulates greater than 50 microns. A series of filters then traps particulates as small as 5 microns, ultimately capturing them in a drum. When wastewater is discharged, approximately 20 gallons per cycle are released to the sanitary sewer under LLNL's site-wide Wastewater Discharge /Chemical Storage Permit. The remaining wastewater is pumped back into the water jet for reuse[7].

WASTE STREAM DESCRIPTION

Waste stream constituents vary, due to the range of materials cut with the water jet. In general, LLNL manages the waste stream as nonhazardous, collecting the spent sand in 55-gallon drums. When regulated metals are cut, samples of the waste are collected and analyzed for soluble metals, using the California Waste Extraction Test (WET) method[8]. When regulated metals have not been cut, analysis is not required and generator knowledge is used to characterize the waste as nonhazardous[9]. WET results dictate disposal when regulated metals are in the waste stream. Analytical data collected from February through August 1995 suggest that when copper is cut, the waste sand usually exceeds the soluble threshold limit concentration (STLC) for copper. Therefore, whenever copper is cut, this waste stream is segregated and handled as hazardous waste. **Table 2** presents soluble metals analytical results for the full 1995 testing period[7].

CONCRETE WASTE STABILIZATION

Considerable research has been conducted regarding the stabilization of hazardous waste in concrete. Cementitious materials were among the first used to chemically fix hazardous wastes and remain widely used[2]. The curing process physically stabilizes waste materials within the matrix of the concrete and chemically binds them in a less soluble form[4].

The concentrations of metals in the LLNL waste sand are significantly lower than those evaluated in the research referenced above; however, the stabilization process is similar. LLNL will beneficially reuse a waste material containing concentrations of metals below the hazardous criteria. The waste garnet sand will become a component of LLNL concrete, in place of commercially produced and purchased sand.

LLNL's evaluation tested a batch of waste sand, and the concrete formed from it, using the WET method. This method mills the cured, solid material to pass it through a 2-micron filter. The milled concrete is then subjected to the WET extraction solution (sodium citrate with a pH of 5.0 + 0.1) and vigorously agitated for 48 hours. (This test method simulates conditions encountered within a landfill.) The resulting extract is then filtered and analyzed for its metals content[8]. The conditions to which the LLNL concrete containing waste sand will be exposed are significantly less aggressive to the material than the WET method simulation. Therefore, it is expected that even less metal would leach from the solid concrete paths and patios than is indicated by the testing protocol.

CONCRETE ANALYTICAL METHODOLOGY AND RESULTS

Six samples from an existing batch of waste garnet sand were collected and analyzed for soluble metals. **Table 3** presents the soluble metals concentration found in this waste garnet sand. A portion of this batch of sand was then formed into concrete. LLNL collected samples of the wastewater slurry from the concrete as it was being mixed, and from the cured concrete. Separate tests were performed on the water and on the solid fraction of the slurry. **Table 4** enumerates the soluble and total metals analytical results from the concrete and concrete slurry samples. **Table 5** summarizes average, maximum, and minimum soluble metals concentrations for the sample batch of waste garnet sand, as well as the concentrations of metals detected by the WET test performed on the concrete formed with this sand. For comparison STLC values are also listed.

From the data collected by LLNL, it appears that concrete stabilizes low concentrations of the metals in the waste garnet sand. Three metals detected in the WET leaching procedure performed on the concrete were not present in, or occur at lower concentrations in, the waste garnet sand. We believe that these metals—arsenic, barium, and vanadium—are present in the cement added to make the concrete, not in the waste sand. Iron and manganese were detected in the concrete, but were not analytes in the sand tested, as they had not been cut with that batch of sand.

GROUND WATER IMPACTS

The waste sand presents a potential impact to ground water if metals can leach from the application site into the soil and eventually into the ground water. LLNL utilizes the Designated Level Methodology (DLM) developed by Jon Marshack of the Central Valley Regional Water Quality Control Board to evaluate the transport of contaminants from the surface into ground water[5]. To support the reuse of soils, LLNL applied DLM limits to develop *de minimis* concentrations that, if exceeded, may affect ground water.

Review of the existing analytical data from the waste sand eliminated the potential for the waste sand to be reused as backfill, since the metals leached readily from the unconsolidated sand. The concentrations of metals detected in the leachate would pose a threat to ground water quality if applied directly to land.

These *de minimis* concentrations may be applied to the proposed concrete, with the qualification that they were developed for the reuse of soil, an unconsolidated medium. As a solid mass, concrete is less likely to release its chemical constituents when exposed to the same environmental conditions.

Table 6 presents a comparison of the *de minimis* concentrations developed for soil, and the concentrations of metals leached from the concrete made with waste garnet sand. All of the results obtained from the WET procedure performed on such concrete are below *de minimis* concentrations.

REUSE CONTROLS

In order to ensure that no environmental harm results from the reuse and to ensure that only nonhazardous waste is reused, LLNL agreed to institute a series of controls.

The primary concerns was to ensure proper storage of the waste sand, such that the stored sand did not leach metals into the ground or get washed away during rain events. LLNL had to balance this concern with the need to easily use the sand. Therefore, we fabricated a special storage bin for the waste sand. The custom bin is located in the corporation yard where the concrete is mixed. The storage bin prevents saturation of the sand and runoff into storm water. Further, the bin provides a barrier between the sand and the ground. As designed the bin allows workers to use the waste sand almost as easily as product sand.

Since approval of this reuse is only applicable to nonhazardous waste, LLNL will continue the current controls to prevent the inadvertent reuse of hazardous waste. Operators will segregate waste streams when the materials are likely to produce hazardous waste concentrations. Operational procedures require that the water jet system to be cleaned prior to and immediately after cutting copper, to minimize hazardous wastes. When hazardous waste is generated, process machinery will be cleaned before waste sand is collected for reuse. LLNL will sample the waste sand generated each time regulated metals are cut. This sampling will core each drum of waste sand generated when these metals are cut [9]. To qualify for reuse, metals concentrations in the waste garnet sand must be lower than the hazardous waste criteria under federal and state regulations. Unused waste sand will be disposed in an appropriately permitted landfill, based on the characteristics of the waste. Waste sand characterized as hazardous will not be reused.

The final control is to ensure that the sand is only used in non-structural concrete applications. The spent garnet will replace commercial sand only in concrete mixed on-site at LLNL. Such concrete will be limited to institutional jobs such as buried bond beams, sidewalks and other non-structural applications.

ECONOMICS OF REUSE

LLNL annually disposes of approximately 70,000 pounds of waste sand generated in the water jet cutting process. The estimated cost of handling, transporting and disposing of this material is $1 per pound. Beneficial reuse of this material, when fully implemented will save the institution about $60,000 each year. (Some handling costs are carried over into the reuse.) LLNL also realizes a minimal savings in the reduced purchase of raw sand used to formulate non-structural concrete.

CONCLUSION

LLNL believes that this garnet sand project represents an opportunity to reuse a waste stream, that, with the proposed control measures, does not pose a risk to the environment. Stabilization of the waste results in a useful end-product that LLNL would otherwise have used raw materials to create. This project demonstrates the importance of evaluating thc entire reuse process. Due to the waste constituents care had to be given to the manner in which the material is stored pending reuse to prevent environmental degradation. Further the workers had to be considered in designing the storage method, since the waste material would not be reused if it was significantly more difficult to use than the raw material.

ACKNOWLEDGMENTS

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Table 1. Materials Cut with the Water Jet

ABS/Polycarbonate	**Inconel**	**Sapphire**
Acrylic	Invar	Selenium
Adaprene	Indium	Silica
Alinico	Iridium	Silicon
Alumina (Aluminum oxide)	Iron	Silicone
Aluminum	Kel-F	**Silicon Carbide**
Aluminum 2024	Kevlar	Silicon Nitride
Aluminum 5052	**Kovar**	Silver
Aluminum 6061	Lava	Slate
Aluminum 7075	Limestone	Soapstone
Amzerc	**Lucite**	Soda Lime
Antimony	**Magnesium**	Sodium Aluminum Borosilicate
Armco	Manganese	Sodium Barium Borosilicate
Asbestos	Marble	Stainless Steel
Bakelike (phenolic)	Meehanite	Stainless Steel 302
Bismuth	**Mica**	Stainless Steel 303
Boron Carbide	**Micarta (non-asbestos)**	**Stainless Steel 304**
Boron Nitride	Mock HE (w/o soluble barium)	**Stainless Steel 316**
Borosilicate	Mock HE (w/ soluble barium)	**Starrett Stock**
Brass	**Molybdenum**	**Steel**
Brass 260	Monel	Steel 1009 HR
Bronze	Mullite	**Steel 1018 CR**
Bronze, oil impregnated	Mumet	**Steel 1018 HR**
Cadmium	Muntzmetal	Steel 1095 CR
Cast Iron	**Mylar**	**Steel 4135**
Coal	Nickel and alloys	**Steel 4140**
Concrete	Neoprene	Steel 4340
Copper	**Nylon**	Steel HY-80
Copper (oxygen free)	Palladium	Steel HY-90
Copper 172	Paraffin	**Styrofoam**
Copper 310	**Permaloy**	Synthane (non-asbestos)
Dolomite	Platinum	**Tantalum**
Emery	Platinum/Iridium	Tellurium
Epoxy	**Plexiglas**	Thallium
Epoxy/Fiberglass	Porcelain	Tin
Ethafoam	Polyamide	Titanium
Europium	Polybutadiene	**Tool Steel**
Ferrite	Polyester	Transite
Fiberglass	**Polyethylene**	**Tungsten**
Formica	Polymethylpentene	**Tungsten Carbide**
Geranium	**Polypropylene**	Tungsten/Nickel/Iron Alloy
Glass	**Polystyrene**	Tygon
Glass Reinforced Plastics	Polytetrafluorethylene	Vanadium
Gold	Polyvinyl chloride	**Viton**
Graphite	Polyurethane	Wax
Graphite (synthetic)	Polyvinylidene	**Wood**
Granite	Prophyllite	Zirconia
Gypsum	Quartz	Zirconium
Hafnia	Rhodium	Yttrium
Hastelloy	**RTV–Silastic**	Zinc
Hycar	Salt (Sodium Chloride)	
Hymu	Sandstone	

Note: **Bold text** indicates materials that are frequently cut

Table 2. 1995 Soluble Metals Analytical Results mg/L

Analyte	2/7/95	2/7/95	2/7/95	2/7/95	2/7/95	2/7/95	2/7/95	2/7/95	2/7/95	4/14/95
Antimony	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Barium	0.43	0.37	0.35	0.27	0.31	0.40	0.31	0.41	0.38	ND
Beryllium	0.007	ND	ND	ND	ND	ND	ND	0.003	ND	ND
Cadmium	ND	ND	0.3	ND	ND	ND	ND	0.02	ND	ND
Chromium	3.1	2.1	1.0	2.2	1.6	1.7	1.1	**8.1**	1.7	0.573
Cobalt	0.06	0.03	0.05	0.05	0.03	0.05	0.03	0.1	0.03	ND
Copper	**44**	15	**41**	**37**	**26**	**120**	**36**	18	22	**30.9**
Iron	NA	NA	NA	NA	NA	NA	NA	NA	NA	547
Lead	0.2	0.05	0.79	ND	ND	0.08	ND	0.1	0.04	ND
Mercury	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND
Molybdenum	0.80	0.47	4.0	0.60	0.36	0.37	0.27	2.2	0.40	1.4
Nickel	0.70	0.47	0.51	0.50	0.4	0.46	0.3	1.4	0.4	1.11
Selenium	0.2	0.1	ND	ND	0.1	0.1	0.1	ND	0.1	ND
Silver	0.05	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vanadium	0.2	0.05	0.09	0.05	ND	0.09	ND	0.07	ND	ND
Zinc	63	9.7	25	16	12	51	15	30	8.6	17.5

Note: **Bold text** indicates sample concentration exceeds STLC.

Table 2 continued. 1995 Soluble Metals Analytical Results mg/L

Analyte	5/31/95	5/31/95	5/31/95	5/31/95	5/31/95	6/20/95	6/20/95	6/20/95	6/20/95
Antimony	ND	ND	ND	ND	ND	ND	0.324	ND	ND
Arsenic	ND	ND	ND	ND	ND	ND	ND	ND	ND
Barium	0.06	ND	ND	0.05	0.09	ND	ND	ND	ND
Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	ND	ND	ND	ND	ND	0.045	0.055	0.654	ND
Chromium	0.6	0.3	0.1	0.4	0.5	0.602	0.814	2.01	0.407
Cobalt	0.02	ND	ND	ND	0.03	ND	ND	ND	ND
Copper	2.1	0.8	1.0	4.5	ND	6.27	3.68	3.35	3.8
Iron	NA	NA	NA	NA	NA	367	461	1030	219
Lead	0.02	ND	ND	0.03	ND	ND	ND	ND	ND
Mercury	ND	ND	ND	ND	ND	ND	ND	ND	ND
Molybdenum	0.82	0.16	0.22	1.9	0.45	5.51	6.42	12.9	3.92
Nickel	0.7	0.1	0.1	0.5	0.6	0.68	1.31	2.24	0.674
Selenium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silver	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vanadium	0.3	ND	0.1	0.7	0.1	0.777	1.15	1.92	1.12
Zinc	1.9	0.3	0.4	4.7	2.1	3.27	4.76	8.64	3.28

Notes: **Bold text** indicates sample concentration exceeds STLC.
ND = not detected at or above the detection limit
NA = not analyzed

Table 2 continued. 1995 Soluble Metals Analytical Results mg/L

Analyte	6/20/95	7/31/95	7/31/95	7/31/95	7/31/95	7/11/95	7/11/95	8/30/95	8/29/95
Antimony	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	ND	ND	ND	ND	ND	ND	ND	ND	ND
Barium	ND	ND	ND	ND	ND	ND	ND	0.05	0.07
Beryllium	ND	ND	ND	ND	ND	0.218	ND	ND	ND
Cadmium	ND	ND	ND	ND	ND	0.0364	ND	ND	ND
Chromium	0.829	0.834	0.604	1.71	0.507	2.12	0.575	0.5	0.7
Cobalt	ND	ND	ND	ND	ND	ND	ND	ND	0.02
Copper	2.61	2.14	5.37	3.4	5.24	23	148	0.4	1.7
Iron	445	249	211	146	160	420	98	NA	NA
Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mercury	ND	ND	ND	ND	ND	ND	0.0021	ND	ND
Molybdenum	6.66	ND	ND	ND	ND	3.21	ND	0.79	0.42
Nickel	1.42	0.387	0.347	0.225	0.308	0.738	0.256	12	6.2
Selenium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silver	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vanadium	1.05	ND	ND	ND	ND	0.557	ND	ND	ND
Zinc	5.64	3.23	4.31	1.68	3.09	21.5	1.9	0.8	0.6

Notes: **Bold text** indicates sample concentration exceeds STLC.
ND = not detected at or above the detection limit
NA = not analyzed

Table 3. Soluble Metals Concentrations in Waste Garnet Sand mg/L

Analyte	Results					
Antimony	ND	ND	ND	ND	ND	ND
Arsenic	ND	ND	ND	ND	ND	ND
Barium	0.25	0.23	0.26	0.24	0.23	0.25
Beryllium	ND	ND	ND	ND	ND	ND
Cadmium	ND	ND	ND	ND	ND	ND
Chromium	1.1	0.48	0.59	0.81	0.63	0.69
Cobalt	0.02	0.02	ND	0.01	ND	ND
Copper	2.7	1.1	1.8	3.2	1.4	1.4
Lead	ND	ND	ND	ND	ND	ND
Molybdenum	0.07	0.04	0.05	0.04	0.03	0.04
Nickel	0.2	0.1	0.2	0.1	0.2	0.1
Selenium	ND	ND	0.1	0.1	0.1	0.1
Silver	ND	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND	ND
Vanadium	0.05	ND	ND	0.06	0.04	0.05
Zinc	4.3	1.1	2.1	6.9	1.7	1.8

Notes: ND = not detected at or above the reporting limit.
NA = not analyzed.

Table 4. Soluble and Total Metals Analytical Results for Concrete

Analyte	Concrete Slurry Liquid Fraction (mg/L)	Concrete Slurry Solid Fraction (mg/kg)	Concrete Block Total Metals (mg/kg)	Concrete Block Soluble Metals (mg/L)
Antimony	ND	ND	ND	ND
Arsenic	ND	ND	2.8	0.080
Barium	3.6	120	49	1.1
Beryllium	ND	0.3	ND	ND
Boron	NA	NA	NA	ND
Cadmium	ND	ND	ND	ND
Chromium	0.6	140	160	ND
Cobalt	0.1	4	6.5	ND
Copper	0.9	18	22	ND
Iron	NA	NA	NA	37
Lead	ND	7	ND	ND
Manganese	NA	NA	NA	1.2
Mercury	NA	NA	ND	ND
Molybdenum	ND	3	ND	ND
Nickel	ND	88	86	ND
Selenium	ND	ND	ND	ND
Silver	ND	ND	ND	ND
Thallium	ND	ND	25	ND
Vanadium	ND	20	26	0.71
Zinc	0.5	53	5.0	ND

Notes: ND = not detected at or above the reporting limit.
NA = not analyzed.

Table 5. Summary of Soluble Metal Results for Waste Garnet Sand and Concrete mg/L

Analyte	STLC	Waste Garnet Sand Batch				
		Average	Maximum	Minimum	Number of Detections	Concrete Block with Waste Sand
Antimony	15	ND	ND	ND	0	ND
Arsenic	5.0	ND	ND	ND	0	0.080
Barium	100	0.24	0.26	0.23	6	1.1
Beryllium	0.75	ND	ND	ND	0	ND
Boron	NL	NA	NA	NA	–	ND
Cadmium	1.0	ND	ND	ND	0	ND
Chromium	5	0.72	1.1	0.48	6	ND
Cobalt	80	0.02	0.02	0.01	3	ND
Copper	25	1.93	3.2	1.1	6	ND
Iron	NL	NA	NA	NA	–	37
Lead	5.0	ND	ND	ND	0	ND
Manganese	NL	NA	NA	NA	–	1.2
Mercury	0.2	NA	NA	NA	–	ND
Molybdenum	350	0.05	0.07	0.03	6	ND
Nickel	20	0.15	0.2	0.1	6	ND
Selenium	1.0	0.1	0.1	0.1	4	ND
Silver	5	ND	ND	ND	0	ND
Thallium	7.0	ND	ND	ND	0	ND
Vanadium	24	0.05	0.06	0.04	4	0.71
Zinc	250	2.98	6.9	1.1	6	ND

Notes: Averages calculated in data sets containing non detects by averaging the ND as one-half the detection.
* Actual detected concentrations
ND = not detected at or above the reporting limit.
NL = no regulatory limit
NA = not analyzed.

Table 6. Comparison of *De Minimis* Concentrations with Soluble Concrete Results mg/L

Analyte	***De Minimis* Concentration**	**Concrete Block with Waste Sand**
Antimony	0.06	ND
Arsenic	0.5	0.080
Barium	10	1.1
Beryllium	0.04	ND
Cadmium	0.05	ND
Chromium	0.5	ND
Cobalt	50	ND
Copper	100	ND
Lead	5	ND
Mercury	0.02	ND
Molybdenum	0.5	ND
Nickel	1	ND
Selenium	0.5	ND
Silver	1	ND
Thallium	0.02	ND
Vanadium	10	0.71
Zinc	500	ND

Notes: ND = not detected at or above the reporting limit.

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