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TECHNOLOGY TRANSFER REPORT ON RECYCLING SPENT SANDBLASTING GRIT INTO ASPHALTIC CONCRETE

by

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EXECUTIVE SUMMARY

The recycling of spent sandblasting grit, commonly referred to as spent abrasive blast material (ABM), into asphaltic concrete has been investigated by the U.S. Navy as an alternative to disposing the spent ABM in a landfill. This technology transfer report discusses issues related to the technical feasibility and regulatory acceptability of this concept and relates lessons learned from two U.S. Navy ABM-to-asphalt recycling projects, one at Construction Battalion Center (CBC), Port Hueneme in southern California, and the other at Naval Station Treasure Island, Hunters Point Annex (HPA) in northern California. The critical issues include sampling and chemical characterization of the spent ABM, asphalt mix design criteria, the development of a work plan for the recycling project, regulatory compliance considerations, and cost. The advantages and disadvantages of recycling spent ABM into asphalt are discussed. The merits of recycling versus some other option should be evaluated on a case-by-case basis.

ACRONYMS AND ABBREVIATIONS

ABR	approximate bitumen ratio
ABM	abrasive blast material
ARRA	Asphalt Recycling and Reclaiming Association
ASTM	American Society for Testing and Materials
BDAT	Best Demonstrated Available Technology
BTEX	benzene, toluene, ethylbenzene, and xylenes
CBC	Construction Battalion Center
CFR	<i>Code of Federal Regulations</i>
CKE	centrifuge kerosene equivalent
CLP	Contract Laboratory Program
DTSC	(California) Department of Toxic Substances Control
EPA	Environmental Protection Agency
EP Tox	extraction procedure toxicity
FR	Federal Register
HPA	Hunters Point Annex
HSWA	Hazardous and Solid Waste Act
NFESC	Naval Facilities Engineering Service Center
PCBs	polychlorinated biphenyls
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
S/S	solidification/stabilization
SAE	Society of Automotive Engineers
SARA	Superfund Amendments and Reauthorization Act
SSPC	Steel Structures Painting Council
STLC	(California) Soluble Threshold Limit Concentration
TBT	tributyltin
TCLP	Toxicity Characteristic Leaching Procedure
TOC	total organic carbon
TTLC	(California) Total Threshold Limit Concentration
UCD	use constituting disposal
WET	(California) Waste Extraction Test

RECYCLING SPENT SANDBLASTING GRIT INTO ASPHALTIC CONCRETE

1.0 INTRODUCTION

1.1 Background

Numerous terms have been used to refer to spent sandblasting grit, including blasting sand, blast media, and abrasive blast material (ABM). The term ABM has been adopted for the purposes of this volume and will be used throughout to refer to any material that is used for sandblasting.

The U.S. Navy generates spent ABM as a result of its ship-cleaning operations. The spent ABM generally contains low concentrations of metals from the paints, antifouling compounds, and other coatings that are applied to ship hulls. In the past, much of this spent ABM has been disposed of in landfills of two types: nonhazardous waste landfills for spent ABM having very low metal concentrations, and hazardous landfills for spent ABM containing relatively high metal contents. However, landfill disposal is being scrutinized by waste generators and regulators because of rising disposal costs, land ban restrictions imposed by the Resource Conservation and Recovery Act (RCRA), and the growing emphasis on waste minimization. Spent ABM appears to be a good candidate for recycling into asphaltic concrete or similar composites because the ABM has textural characteristics similar to the conventional raw materials used in the composites. Also, it was shown in a previous study that certain spent ABM does not respond well to stabilization/solidification technology to immobilize the metal contaminants (Means et al., 1991) (see Section 1.4.2).

1.2 Types of Abrasive Blast Material (ABM)

Numerous types of ABM are produced from a variety of processes. Steel shot is being used as ABM because it can be reused many times before losing its blasting effectiveness, if the proper equipment for separating the ABM from the blasting dust is used. However, steel shot is not a conventional component of asphaltic concrete. It is dense and subject to swelling upon oxidation, and therefore is not recommended for recycling into asphaltic concrete.

Many types of ABM are used to remove paint, coatings, and/or corrosion from industrial structures. Any ABM used at a U.S. Navy shipyard or at a private shipyard working on U.S. Navy vessels must meet Mil-A-22262b(SH) specifications. Processed coal and metallurgical slags are popular sources for ABM, but natural mineral materials may also be used. Slag blasting media are typically used once in a blasting operation and then discarded, although tougher materials such as garnet can be cleaned and reused.

One widely used type of ABM is made as a by-product of coal combustion. The ABM is a fused ferro-alumino-silicate formed when molten slag from a coal combustion boiler is quenched in water. The water quench cools the slag quickly, resulting in an amorphous, noncrystalline particulate. Thermal shock from the rapid cooling fractures the slag into rough, angular particles. ABM can be produced from the slag particles simply by segregating different particle-size grades using screens (Austin, 1995). Higher quality ABM can be made by performing an initial crushing and screening followed by magnetic separation to remove metal particles. The upgraded slag particulate is then screened to separate size grades. The 11 companies that supply ABM made from coal slag had total volume and sales in 1992 of 442,000 tons (401,000 metric tons) and \$19,500,000, respectively. Reed Minerals, the largest volume

producer supplying about 62% of the sales, makes a product called Black BeautyTM*. Due to the dominance of the Black BeautyTM in the coal slag ABM market, many users incorrectly use the trade name as a generic term for coal slag ABM. Similar materials made by the other companies are marketed under other trade names such as Stan-BlastTM made by Stan-Blast Abrasives (17% of sales) and Black DiamondTM made by Foster Dixianan (10% of sales) (Paumanok, 1992).

ABM is also made from slag produced by pyrometallurgical processing to recover copper or nickel. The metallurgical slags are quenched to produce glassy fragments and then screened in the same manner as the coal slag. As with the coal slag, magnetic separation may be used to remove metal particles.

Copper slag is a mixture of ferrosilicate, ferro-alumino silicate, calcium silicate, magnesium silicate, and silica with trace amounts of antimony, arsenic, copper, and lead. Seven companies supply ABM made from copper slag with total volume and sales in 1992 of 187,000 tons (170,000 metric tons) and \$10,300,000, respectively. The largest suppliers are Kleen-Blast Abrasives (37% of sales volume), Minerals Research and Recovery (29% of sales volume), RDM Multi-Enterprises (21% of sales volume) and MDC Industries (7.5% of sales volume) (Paumanok, 1992). The copper slag materials are marketed under trade names such as Sharp ShotTM, Apache Black HawkTM, and Copper BlastTM. The copper slag ABM product trade-named Kleen BlastTM is imported from Canada.

Nickel slag is a mixture of magnesium ferro-silicate and silica with trace amounts of other metals (Austin, 1995). There are two suppliers of nickel slag ABM in the United States market. Green Diamond Abrasives produces Green DiamondTM nickel slag using slag from a smelter near Riddle, Oregon, with total volume and sales in 1992 of 45,000 tons (40,800 metric tons) and \$3,200,000, respectively. Kayway Industries imports about 5,000 tons/yr (4,540 metric tons/yr) of nickel slag ABM from Canada for sale in the United States (Paumanok, 1992).

Physical and chemical characteristics influence the recyclability of slag ABM. The regulatory status is the single most important factor because waste management practices controlled by RCRA or state hazardous waste regulations reduce the flexibility in selecting and implementing recycling options. Physical properties such as particle size and shape and chemical properties such as total composition also affect the acceptance of spent ABM in commercial applications.

ABM produced from slag may contain elevated background levels of regulated metals. ABM from coal slag will typically contain nickel and vanadium and a variety of other metals depending on the coal that was used as the source of the slag. Copper slag from primary smelters contains elevated copper and barium levels and lower but significant levels of cobalt, trivalent chromium, and nickel. Copper slag from secondary smelters may contain significant levels of lead and arsenic. Nickel slag typically contains elevated concentrations of nickel, copper, and trivalent chromium and lower levels of cobalt and vanadium. Arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver are used to determine leachable metal toxicity by the U.S. Environmental Protection Agency (U.S. EPA) under RCRA. Some states, for example California, consider additional metals and total content as well as leachability in their definition of hazardous waste. It is unlikely but possible that unused ABM will be classified as a hazardous material by virtue of its background soluble or total metal content. A high background metals content in the virgin ABM means that the addition of a relatively small amount of metals-containing dust during blasting may cause the spent ABM to be classified as hazardous.

*Use of trade names does not necessarily constitute endorsement for use.

Most ABM are produced in at least three different particle size grades. In general, the coarser grades are more compatible with recycling as aggregate for portland cement concrete or asphaltic concrete because they mix better. Rounded particles are more suitable for use in portland cement, whereas sharp, angular particles are better for use in asphaltic concrete.

The chemical composition can affect the performance of spent ABM. The dark colors of slag ABM may limit acceptance in products with an appearance function where the slag materials replace lighter colored natural minerals. High chloride concentrations are undesirable in many applications. Sulfate concentrations or high alkali reactivity would make the ABM unsuitable for use as aggregate in portland cement.

Natural minerals such as silica sand, garnet, or staurolite are also used for ABM. Silica sand ABM is typically composed of mostly quartz with some garnet and feldspar and traces of lithic fragments such as hornblende. The fine silica particles produced by blasting with sand create a significant health concern, so use of sand as ABM is declining. Garnet is a general name for a family of complex silicate minerals having similar physical properties and crystal form. The general formula for garnet is $A_3B_2(SiO_4)_3$, where A can be calcium, magnesium, ferrous iron, or manganese and B can be aluminum, ferric iron, chromium, or (in rare cases) titanium. The most common garnet minerals for use as ABM are $Mg_3Al_2(SiO_4)_3$ (pyrope), $Fe_3Al_2(SiO_4)_3$ (almandite), and $Ca_3Fe_2(SiO_4)_3$ (andradite). Almandite and almandite-pyrope solid solutions make the best abrasive grains. Andradite is softer and breaks down more easily. Staurolite is $(Fe^{2+}, Mg, Zn)_2Al_9(Si, Al)_4O_{23}(OH)_2$.

Mineral ABM may be naturally occurring sand or may be manufactured by crushing and size-grading using screens. Sand for abrasive blasting is produced by 48 companies operating 84 mines (Austin, 1995). Silica sand does not meet the requirements of the Mil-A-22262b(SH) specification due to the high free silica content. Ten firms produce garnet ABM with a total volume and sales in 1992 of 25,000 tons (22,700 metric tons) and \$7,800,000, respectively (Paumanok, 1992). DuPont, marketing Starblast™, is the only supplier of staurolite ABM. Unofficial sources estimate the 1992 volume and sales for Starblast™ at 55,000 tons (50,000 metric tons) and \$7,700,000, respectively (Paumanok, 1992). Similar to slag ABM, mineral ABM is available in different particle sizes, with the coarse grades more amenable to recycling into asphalt. However, unlike slag ABM, abrasives made from natural minerals contain low background metals concentrations. The matrix of mineral ABM is unlikely to contribute to total or leachable hazardous metals which can make recycling easier.

A mineral ABM, "Monterey beach sand" from California, is the subject of both ABM-to-asphalt recycling demonstrations discussed in this document (see Photos 1-1 and 1-2). Beach sand ABM typically is composed mostly of quartz with some garnet and feldspar along with traces of lithic fragments such as hornblende. Similar to slag-based ABM, beach sand ABM comes in different particle sizes, with the coarser grades more amenable to recycling into asphalt. However, unlike slag-based ABM, virgin beach sand contains very-low-background metals concentrations, making it more compatible with recycling.

1.3 Examples of Wastes That Can Be Recycled Into Asphaltic Concrete

1.3.1 Reclaimed Asphalt Pavement

The concept of recycling of wastes into asphaltic concrete is not new. For example, blast furnace slag was widely used as construction aggregate in 1989 (Ahmed, 1993). A variety of materials have been substituted successfully for some portion of normal graded aggregate without adverse effects on product quality. The most widespread occurrence of recycling into asphalt is the growing utilization of reclaimed



Photo 1-1. Pile of spent beach sand ABM covered with a tarp to minimize air emissions and wetting. Note debris in the foreground.

asphaltic concrete from previous paving projects. The reclaimed asphalt is crushed and substituted for a portion of the aggregate in both cold-mix and hot-mix asphaltic concrete. According to a press release (ARRA, 1994), more than 12 million tons of asphalt was recycled among 35 asphalt contractors in 1992 alone. The corresponding savings were more than \$600 million in landfill costs and more than \$30 million in materials cost for liquid asphalt and aggregate. In certain situations, the old pavement is recycled into cold- or hot-mix asphalt in place, thereby reducing paving costs and truck traffic to transport the old aggregate back to the contractor's facility (ARRA, 1994).

1.3.2 Glass

Another example of recycling waste materials to make asphaltic concrete is the recently developed concept of recycling waste glass into asphalt. The resulting product has been termed "glassphalt" (Monroe, 1990). Glassphalt uses mixed colored glass that is less desirable than clear glass for remelting to make new glass. Glassphalt containing 10% glass was used in a base coarse lift for the first time on a project in New Jersey. Highway agencies in Connecticut, District of Columbia, New Jersey, and Virginia have been using glassphalt on a trial basis since the late 1980s (Ahmed, 1993).

1.3.3 Rubber

Rubber particulate from ground-up or cryogenically processed tires has been recycled as aggregate in asphaltic concrete. However, field tests of asphalt made with rubber particulate aggregate



Photo 1-2. Spent beach sand ABM from previous photo after screening to remove rocks and debris.

have been inconclusive. In some tests, the rubber aggregate product has lasted twice as long as conventional asphalt, but it has failed rapidly in other tests (Blumenthal, 1993). Testing of asphalt containing recycled tire rubber is continuing.

1.3.4 Spent Abrasives, Soils, and Foundry Sands

Other examples of recent asphalt recycling projects using spent ABM or waste materials similar to spent ABM are as follows:

- Black Beauty™ (derived from coal slag) ABM from ship-cleaning operations at the Bath Iron Works in Bath, Maine has been successfully recycled into hot-mix asphalt since 1990. The mix design includes ABM at a concentration of 5% by weight (Arndt, 1993).
- The incorporation of steel shot ABM from bridge-blasting operations has been the subject of an ongoing demonstration project in North Carolina (Medford, 1989, 1990, and 1992). Recent field test results suggest that the steel shot ABM is not compatible with the asphaltic concrete product and is leading to premature failure due to the oxidation and swelling of the steel particles (Medford, 1992, personal communication).
- Hazardous soil contaminated with zinc and lead from a railcar brake shoe facility in California was recycled into cold-mix asphalt (Testa & Patton, 1992).

- Lead-contaminated foundry sands from brass foundries in Pennsylvania are being recycled into asphalt (Boyd, 1992).
- There are numerous permitted facilities for recycling petroleum-contaminated soils into hot- and cold-mix asphaltic concrete. U.S. EPA (1992) provides a directory of permitted recycling facilities and includes a discussion of the processing equipment that is used.

1.4 Remedial Alternatives for Spent ABM

Numerous options other than recycling into asphaltic concrete exist for the management of metal-contaminated ABM. Although recycling into asphaltic concrete may in many cases be technically feasible, inexpensive, and an easily implementable alternative, the choice of this option over other available options must be based on a careful analysis of the advantages and disadvantages of each option. It is not within the scope of this document to define all the options and discuss the decision-making rationale for technology selection; however, it is useful to list a number of the alternatives so that the reader is broadly aware of the options.

The principal remedial alternatives, other than recycling, for metal-contaminated ABM are (1) disposal in a permitted landfill; (2) treatment by stabilization/solidification; (3) soil washing or heap leaching; and (4) classification or flotation. Landfill disposal and stabilization/solidification are the conventional remedial alternatives that are frequently and successfully implemented. Soil washing and classification technologies are more innovative. These two technologies have not yet been fully demonstrated for ABM materials, but they show promise for the future. A brief description of each of the technologies is provided below.

1.4.1 Disposal in a Permitted Landfill

Disposal in a permitted landfill is easily implemented and does not require the extensive planning and treatability testing that are customarily associated with treatment projects. Principal costs fall into two categories: (1) transportation, which is highly project-specific and dependent on both the distance between the site and the landfill and the mode of transportation (and may range up to hundreds of dollars per ton of material transported for more distant sites); and (2) tipping at the landfill, which varies with the landfill and waste composition, but which typically ranges between \$150 to \$250/ton. Compared with the other remedial and recycling options for sandblasting grit, disposal in a permitted landfill is administratively easy to implement, but very expensive, and is not compatible with U.S. EPA's preference for recycling or treatment over disposal (see Figure 1-1).

1.4.2 Treatment by Stabilization/Solidification

Chemical stabilization, or solidification/stabilization (S/S) as it is frequently called, is a proven technique for immobilizing a wide variety of metals in soil and solid waste. Screened solids can be stabilized directly by mixing the solids with suitable binders that immobilize the metals physically and chemically. Common binders are cement, soluble silicate, fly ash, lime, and kiln dust. Estimated treatment costs typically vary from \$100 to \$200/ton. Smaller projects cost more than larger projects on a per tonnage basis because of fixed costs, such as mobilization and demobilization, and a low tonnage of spent ABM across which to spread these costs.

First Choice (Pollution Prevention):

Reduce/Eliminate Waste Production at the Source

- Design Long-Lived, Low-Impact Products
- Use Less-Hazardous Input Materials
- Minimize Use of Non-Recoverable Input Materials and of Water
- Conserve Energy in Production Operations and Facility Operation
- Improve Process Technology and Practices

Second Choice (Pollution Prevention):

Reuse (Closed-Loop Recycling)

- Recover Chemicals
- Reuse Water
- Recover Waste Heat

Third Choice:

Recycle Off Site

- Ensure Safe Transport to Recycling Operation
- Select Environmentally Sound Recycling Technology

Fourth Choice:

Treat and Dispose of Unavoidable Wastes Safely

- Minimize Volume, Toxicity, and Mobility of Wastes
- Dispose of Safely



Battelle

... Putting Technology To Work

**U.S. Environmental Protection Agency's
Hierarchy of Hazardous Waste
Management**

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HUNTERS POINT PROJECT

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GRAPHICS CORP.

Figure 1-1. U.S. Environmental Protection Agency's Hierarchy of Hazardous Waste Management

S/S technology is consistent with the treatability guidance in the Superfund Amendments and Reauthorization Act (SARA) and has been designated a Best Demonstrated Available Technology (BDAT) for metal-contaminated soils and solid wastes under the Resource Conservation and Recovery Act (RCRA). Portland cement is the most frequently used generic stabilization agent for inorganic wastes. Metals are transformed to less soluble forms (hydroxides and other phases) due to the alkaline nature of the binder. Binder-to-waste ratios vary from 1:10 to 1:1. The process equipment can be mounted on a trailer as a mobile unit, and different variations of the technology are offered by numerous vendors.

Certain ABM products that have been recently introduced to the market incorporate an alkaline cement binding agent, such as cement, lime, or kiln dust, into the granular ABM formulation for purposes of reducing the aqueous solubilities of the contaminant metals and improving the chances that the spent ABM will pass the Toxicity Characteristic Leaching Procedure (TCLP) (or other regulatory) leach test. Example trade names of ABM with built-in chemical stabilizers are StarBlast^{*} and BlastTOX. An important question relating to the use of these materials is whether the metal immobilization that occurs in ABM leads to long-term immobilization of the metals or whether the stabilizers simply allow the spent ABM to pass the TCLP with no long-term immobilization of the metals in a disposal or reuse environment.

1.4.3 Treatment by Soil Washing and Classification

Both soil washing (or heap leaching) and classification show promise as future treatment technologies for spent ABM, either coupled with each other or combined with other technologies; however, neither technology has yet been demonstrated at full scale for this type of material. The soil washing dissolution reaction has not yet been shown to be adequately selective for Pb and other metals; high selectivity is required in order to reduce the soluble Pb content of the soils to levels that will satisfy regulatory criteria. Classification technologies show potential for further reducing the metal content of spent ABM, particularly in view of the fact that most of the contaminant metal content in spent ABM occurs in fine-grained paint dust fragments that should be physically separable from the blast granule matrix. However, as with soil washing, the classification technology for spent ABM has not been adequately demonstrated at full-scale operation. Also, classification technology is somewhat complex, entails numerous steps, and uses large volumes of water that must be decontaminated or disposed of at the conclusion of the project. The Naval Facilities Engineering Service Center (NFESC) currently is studying both technologies — soil washing and classification — for their applicability to the treatment of ABM and similar types of metal-contaminated solids and will report on any significant advances in either technology in the future.

1.5 Other Recycling Alternatives for Spent ABM

Depending on its chemical and physical characteristics, spent ABM is potentially usable as a raw material in the production of a number of different construction materials other than asphaltic concrete. In California, the U.S. Navy has been studying the recycling of spent copper slag ABM in the manufacture of Portland cement. This recycling option takes advantage of the relatively high iron content of copper slag ABM. In Portland cement manufacture, the natural iron content of the quarry rock must almost always be supplemented. This is usually done by purchasing iron ore. Therefore, in this case the spent ABM is a substitute iron ore for the manufacture of Portland cement and provides some additional

^{*}Use of trade names does not necessarily constitute endorsement for use.

silica, which is one of the two major ingredients of Portland cement. The typical percentage of spent ABM in the final cement product is ~0.3 to 2.0%, and the resulting metal content of the cement due to the metal content of the spent ABM is very low. Testing at the cement facility has shown that the metals that are entrained in the Portland cement product become insolubilized due to heating to approximately 2900°F during cement production and that metal emissions from the stack are well within permitted levels.

An additional recycling option for spent ABM is beneficial reuse in the manufacture of structural fired clay products, e.g., bricks. The U.S. Navy, David Taylor Research Center in Annapolis, Maryland, has been studying this alternative for the past several years. The bricks produced using spent ABM meet the specifications for strength and absorption, and the metals are incorporated into chemically stable, complex silicate phases during brick firing. Data collected thus far indicate that metal leachability in the final clay product decreased with increasing particle size of the spent ABM (Thomas, 1992).

A third recycling option for spent ABM has been studied by the University of Texas at Austin in conjunction with the Texas Department of Transportation and involves the incorporation of spent ABM into mortar. The spent ABM is substituted for a portion of the sand ingredient. The mortars thus produced are being used in the production of riprap (Salt, 1993).

A number of recycling options for spent ABM take advantage of the abrasive's physical and/or chemical characteristics. The above discussion is not necessarily comprehensive but is intended to demonstrate the variety of recycling options that have been successfully implemented. The selection of the most suitable recycling option for spent ABM materials depends on a number of different factors, such as the (1) physical and chemical characteristics of the ABM, including its metal concentrations; (2) level of risk that the ABM introduces to either the recycling process or product; (3) local market demand for the spent ABM as a raw material; and (4) regulatory considerations relating to the recycling option.

Most of these factors will vary significantly on a project-by-project basis and, in some cases, for certain ABM products, evaluation of these factors will lead to the conclusion that recycling is not preferred to treatment or disposal.

2.0 CHARACTERIZATION OF THE SPENT ABM

As indicated in the previous section, the applicability of an asphalt recycling option to a given spent abrasive blast material must be evaluated on a case-by-case basis. Spent ABM varies widely in composition and characteristics depending on its source. Therefore, each type of spent ABM must be characterized thoroughly. This section briefly summarizes the types of analyses that are usually required and gives guidance on how to obtain statistically representative samples on an accumulation of spent ABM.

2.1 Chemical Characterization of the Spent ABM

Depending on its source, spent ABM may contain a wide variety of contaminants. It is important to identify these contaminants and their concentrations to determine if the grit is regulated as a hazardous waste and to support the assessment of risks posed to either human or ecological receptors by the recycling process or the product. For example, the California EPA's proposed (now in the process of being finalized) standards for the use of recyclable materials in asphaltic concrete and concrete includes a requirement that recyclable materials must be "free of Se, Be, Cd, Hg, and asbestos in quantities exceeding the concentrations set forth in Section 66699, Title 22, California Code of Regulations." The recyclable material also is supposed to be free of organics, other than hydrocarbons, or the recyclable material must have at least 95% by weight nonhazardous constituents.

The challenge for efficient planning of a characterization project is to select the number of analyses to reliably characterize the waste without conducting an excessive number of analyses, unnecessarily increasing cost. A statistically based random sampling design is needed to ensure the plan includes enough samples to meet data quality objectives (see Photo 2-1) and that the samples are collected from the correct locations. Sampling program design is discussed briefly in Section 2.3 and in detail in Appendix A. If the chemical analyses are required by a regulatory agency, these analyses must be performed by analytical laboratories with the appropriate certifications. Certain states such as California have their own certification programs. For analyses performed by the U.S. EPA, the laboratory should be part of the Contract Laboratory Program (CLP).

In designing the chemical characterization program, all available information on the source of the spent ABM should be carefully considered. For example, if it is known that the ABM was used to blast Pb-based paint, then Pb will be an important analyte; similarly, if there is no plausible way in which the ABM could have come in contact with radionuclides, then there is no need to embark on those expensive and time-consuming analyses.



Photo 2-1. Sampling spent ABM in accordance with a statistically designed sampling plan.

2.1.1 Analyses for Metal Contaminants

In general, the chemical characterization program should include a thorough characterization of total and leachable metals concentrations, because metals normally are the most significant contaminants in paints and coatings. The 19 California Assessment Manual metals and their corresponding EPA analytical methods are listed in Table 2-1. All of these metals are regulated in the State of California. The leachability of eight of these metals is measured as part of the RCRA hazardous waste toxicity characteristic definition:

- arsenic
- chromium
- lead
- selenium
- barium
- cadmium
- mercury
- silver

A given sample of ABM usually contains only a few of these metals in significant concentrations. It is not necessary to analyze for metals that, based on background information or project history, can be shown to be absent.

The types of metal analyses that should be conducted depend on the applicable regulations but usually will include a total metal analysis followed by an analysis of leachable metals. U.S. EPA uses the Toxicity Characteristic Leaching Procedure (TCLP) to make a determination of whether a waste shows a toxicity characteristic and is therefore hazardous. (The EP Toxicity Leaching Procedure which the TCLP replaced is still used in rare instances.) Certain states, such as California, have adopted their own leaching procedures which are more aggressive than the TCLP. In California, the leaching protocol is referred to as the Waste Extraction Test (WET). It is therefore possible for a waste to pass the TCLP but fail the state's leaching test, such that the waste is considered a hazardous waste in that state but not by the U.S. EPA. In addition, the U.S. EPA regulates metal-contaminated waste based on leachable metals concentrations, but not total metals concentrations. In contrast, certain states, including California, regulate on the basis of total metals concentrations in addition to soluble metals concentrations.

Table 2-1. Metals for Chemical Analyses

Metal	Method
Barium	EPA 7080
Antimony	EPA 7040
Arsenic	EPA 7061
Barium	EPA 7080
Beryllium	EPA 7090
Cadmium	EPA 7130
Chromium, Total	EPA 7190
Chromium (VI)	EPA 7196
Cobalt	EPA 7200
Copper	EPA 7210
Lead	EPA 7420
Mercury	EPA 7471
Molybdenum	EPA 7480
Nickel	EPA 7520
Selenium	EPA 7741
Silver	EPA 7760
Thallium	EPA 7840
Vanadium	EPA 7910
Zinc	EPA 7950

Hazardous waste classifications based on total or soluble metals concentrations are made in comparison to preestablished concentration thresholds. Threshold values for the TCLP, the Extraction Procedure Toxicity (EP Tox) test, and the Total Threshold Limit Concentration (TTLC — California's total metals content criteria) and Soluble Threshold Limit Concentration (STLC — California's soluble threshold limit content criteria for the WET test) are provided in Table 2-2.

**Table 2-2. Metal Concentration Threshold Values for TCLP,
EP Tox, TTLC, and STLC Tests**

Element	Metal Concentration		
	TCLP and EP Tox ^(a) (mg/kg)	TTLC ^(b) (mg/L)	STLC ^(c) (mg/L)
Sb	—	500	15
As	5	500	5
Ba	100	10,000	100
Be	—	75	0.75
Cd	1	100	1
Cr (Total)	5	2,500	560
Cr(VI)	—	500	5
Co	—	8,000	80
Cu	—	2,500	25
Pb	5	1,000	5
Hg	0.2	20	0.2
Mo	—	3,500	350
Ni	—	2,000	20
Se	1	100	1
Ag	5	500	5
Tl	—	700	7
V	—	2,400	24
Zn	—	5,000	250

(a) U.S. EPA Toxicity Characteristic Leaching Procedure, Method 1311

U.S. EPA Extraction Procedure Toxicity Test, Method 1310

(b) From California Code of Regulations, Title 22, Section 66262.24(a)(2)(A).

TTLC = Total Threshold Limit Concentration.

(c) From California Code of Regulations, Title 22, Section 66262.24(a)(2)(A).

STLC = Soluble Threshold Limit Concentration.

When analyzing metals, it generally is most cost-effective to conduct the total metal analyses first, and then to analyze for just those leachable metals whose total concentrations are high enough to allow the leachable metals concentration to exceed the limit after accounting for the dilution factor of the leaching test. For example, if the average total Pb content of spent ABM sample is 50 mg/kg, then the maximum corresponding TCLP Pb concentration is 2.5 mg/L, because the TCLP test involves a 20-fold dilution of the waste with extractant. Therefore, it is physically impossible for the TCLP Pb content of the ABM to exceed the TCLP threshold of 5 mg/L, and it is a useless expenditure of project funding to conduct the TCLP Pb analysis in this situation. The same logic applies to the California WET test, except the WET involves a 10x dilution factor rather than 20x.

2.1.2 Analysis for Other Types of Contaminants

Although metals usually are the principal contaminants of concern, there may be a need to analyze the spent ABM for other possible contaminants or unusual forms of metallic contaminants that might pose special hazards. For example, depending on the source and storage conditions of the spent ABM, analyses for the following may be warranted:

- U.S. EPA organic priority pollutants, such as semivolatile organics (EPA Method 8270), volatile organics (Method 8240), and/or organo-chlorine pesticides and polychlorinated biphenyls (PCBs) (Method 8080)
- Petroleum hydrocarbons; benzene, toluene, ethylbenzene, and xylene (BTEX); and/or oil and grease
- Asbestos
- Radionuclides

An example of a special form of a metal that may be present in spent ABM from ship-cleaning operations is tributyltin (TBT). This compound was widely used for several decades as a coating on lower ship hulls to inhibit biological growth. The use of TBT was discontinued when it was found that it is acutely toxic to numerous species of marine biota and is persistent in the environment. Thus, it is not unusual to find TBT or other organo-tin compounds in spent ABM from older ships. Note that many of these analyses are relatively expensive (i.e., up to several hundred dollars per analysis) and, with the exception of TBT cited above, there is no reason to suspect their presence in normal spent ABM. Only in those special instances where there is likelihood of the substances being present should the analyses be conducted.

2.1.3 Noncontaminant Chemical Characterization

As indicated in Section 1.0, information on the bulk chemical composition of the spent ABM will aid in the evaluation of the most viable recycling option. For example, an ABM with high Fe content and very fine particle size will probably be a better candidate for recycling into Portland cement than into asphalt. However, if the same ABM contains elevated Mg, then it may be a poor choice for recycling into Portland cement, because Mg is an undesirable constituent in the product. Therefore, information is needed on the bulk chemical composition of the spent abrasive. Because most abrasives are predominantly composed of silica and/or metal silicates, then the following analyses would be expected:

- | | | | |
|----------------------------------|---------------------|--------------------|----------------------------------|
| • SiO ₂ | • CaO | • K ₂ O | • Fe ₂ O ₃ |
| • Al ₂ O ₃ | • Na ₂ O | • MgO | |

However, depending on the source of the ABM, it may also be advisable to analyze for other anions such as chloride or sulfate, or metallic iron, which are undesirable in asphaltic concrete because they can lead to swelling and premature cracking.

2.2 Physical Characterization of the Spent ABM

Basic information about the physical characteristics of the spent abrasive is needed to evaluate the feasibility of recycling as aggregate. The most important physical properties when considering reusing spent ABM as aggregate in asphaltic concrete are:

1. *Particle size or gradation characteristics.* This affects mix design and determines the percentage of spent ABM that can be tolerated in the mix. Gradation analyses such as a sieve test or Los Angeles Rattler test can be readily obtained from materials testing laboratories.

2. *Specific gravity.* Specific gravity should be factored into the densitometer readings that are made at the paving site to determine when optimal compaction has been achieved.
3. *Moisture content.* Excessively wet ABM will need to be dewatered prior to recycling into asphaltic concrete.
4. *Volume of ABM to be recycled.* This information along with the percentage of ABM in the mix design will determine the amount of asphaltic concrete that must be produced in order to recycle the entire amount of ABM.
5. *Presence of debris.* Spent ABM frequently contains debris such as cloth, wood, or pieces of ceramic or metal. Debris usually can be removed easily prior to recycling by screening.

2.3 Sampling Procedures

Obtaining representative and statistically valid chemical characterization data on a large and heterogeneous accumulation of spent ABM can be challenging. The sampling program must be statistically designed. Appropriate sampling procedures must be used to avoid contamination. The key elements to consider when planning any spent ABM sampling and analysis program are:

- Statistical design of sampling locations and sampling frequency
- Sampling equipment and operation
- Sample collection and preservation
- Personal protective equipment and decontamination
- Sample custody, labeling, packaging, and transportation
- Sample quality assurance and quality control.

Guidance on these and related issues is provided in the attached example Sampling and Analysis Plan (Appendix A), which was prepared for the characterization of several piles of spent ABM at the Mare Island Naval Shipyard in Vallejo, California (Photo 2-2).



Photo 2-2. Using a hand auger to sample spent ABM.

3.0 REGULATORY CONSIDERATIONS

3.1 Introduction

Depending on applicable state codes, regulations, and policies, spent ABM will fall into one of three categories:

Category 1: Nonhazardous and unregulated by either state or U.S. EPA regulations.

Category 2: Special waste or hazardous by state code or local code, but nonhazardous by U.S. EPA regulation (note, not all states have special waste or state-only hazardous waste definitions).

Category 3: Hazardous by virtue of both state and U.S. EPA regulations.

If the ABM is nonhazardous by both the state and U.S. EPA code and does not fall into any special waste categories, then it is unregulated and there are no regulatory compliance issues pertaining to the asphalt recycling option. However, it is always advisable to discuss the intent to recycle the spent ABM with the purchaser of the asphalt, whether it be a private party or an entity of a state department of highways or transportation. If the spent ABM falls in the second category above, i.e., regulated by the state but not by the U.S. EPA, then a number of state regulatory agencies may have cognizance over the recycling project. If the ABM falls into the third category, then both state regulatory agencies in addition to the appropriate U.S. EPA regional office will need to be contacted.

For category 2 and 3 materials, the following regulatory agencies may have cognizance:

- State air board or air quality management district
- State water board
- State environmental protection agency (or department of environmental protection)
- County department of public health (or similar agency, if applicable)
- City department of public health (or similar agency, if applicable)
- Regional office of the U.S. EPA.

The names of these organizations may vary widely from region to region, and the above list is not necessarily complete. A list of addresses and phone numbers of state environmental regulatory agencies and a list of U.S. EPA information hotlines and other sources of regulatory information pertaining to recycling are provided in Appendix B (SSPC, 1992).

Regulations pertaining to recycling vary widely from state to state; in addition, the prevailing attitude on the part of the regulator toward recycling will vary based on a number of factors, such as previous track record, perceived risk and public perception, and other factors. It is not possible here to define or predict the compliance issues that may be encountered on a project-by-project basis. The remainder of this chapter summarizes U.S. EPA and state regulations (using California as an example) that pertain to the recycling of spent ABM. The discussion of state regulations and policy pertains specifically to California code only, but may provide some generic perspective on the types of compliance issues that may be encountered in other states as well.

3.2 Overview of RCRA Recycling Regulations

The Resource Conservation and Recovery Act (RCRA) of 1976, as amended by the Hazardous and Solid Waste Act (HSWA) of 1984, is the primary legislation that regulates recycling of hazardous waste materials.

Rules issued by U.S. EPA on January 4, 1985 (50 FR 614) acknowledged the need to encourage safe recycling of hazardous wastes — particularly when recycling clearly reduces resource use or pollution — while at the same time assuring the abatement of pollution and the prevention of harm to human health and the environment (see Photo 3-1).

For a secondary material to be regulated under RCRA Subtitle C, the material must first meet the definition of a “solid waste.” Section 1004(27) of RCRA defines solid waste as:

any garbage, refuse, sludge, ... and other discarded material, including solid, liquid, semi-solid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations and from community activities.

A central element of this definition is that wastes are “discarded.” In 1985, the U.S. EPA revised the definition of solid waste to further clarify when a recycled secondary material should be considered a solid waste. Under the regulatory definition of solid waste, found in 40 CFR Section 261.2(a-f), a secondary material is defined as a solid waste if:



Photo 3-1. Wetting down the grit pile during screening operations to control fugitive emissions, protecting human health and the environment.

- It is abandoned
- It is recycled in certain ways, or
- It has been defined as “inherently wastelike.”

The term “secondary material” refers to spent materials, sludges, by-products, commercial chemical products, and scrap metals, as defined below:

Spent material — a material that has been used, which as a result of contamination can no longer serve the purpose for which it was produced without further processing.

Sludge — any solid, semisolid, or liquid waste generated from a municipal, commercial, or industrial water or air pollution control facility (exclusive of the effluent from a wastewater treatment plant).

By-product — a material, excluding a co-product, that is not one of the primary products of a production process and is not solely or separately produced by the production process (e.g., process residues such as slags or distillation column bottoms).

Commercial chemical products — a category that specifically includes unused commercial chemical products listed in Section 261.33 but is interpreted to include additional unused products that exhibit a hazardous waste characteristic.

Scrap metal — bits and pieces of metal parts such as bars, turnings, rods, sheets, or wire, or metal pieces that may be combined with bolts or soldering (radiators, scrap automobiles, railroad boxcars) and that, when worn, can be recycled.

The U.S. EPA distinguishes between recycling that is regulated as waste management and recycling that is exempt from regulation, depending on the type of secondary material and the manner in which it is being managed. Unless they are covered by an exception, secondary materials are solid wastes, and thus are subject to regulation, when they are recycled using any of the following four methods:

- Used in a manner constituting disposal (i.e., applied to the land or used to produce a product that is placed on the land).
- Burned for energy recovery (including used to produce a fuel).
- Reclaimed (processed to recover a usable product or component or regenerated), or
- Accumulated speculatively (material stored with less than 75% recycled within one calendar year).

Some combinations of types of secondary material and regulated recycling methods are exempt from solid waste regulation. The four primary exceptions are:

Characteristic sludges being reclaimed
 Characteristic by-products being reclaimed
 Commercial chemical products being reclaimed, or
 Commercial chemical products being speculatively accumulated.

Characteristic sludges and by-products used in any of the remaining three ways (i.e., placed on the land, burned for energy recovery, or accumulated too long before recycling) are solid wastes. Commercial chemical products that are placed on the land or burned for energy recovery also are solid wastes, unless that is their ordinary use.

In addition to the exclusions discussed above, the U.S. EPA recognized other situations that closely resemble production processes and, therefore, are excluded from regulation under the RCRA program. Materials are not solid wastes when legitimately recycled by being:

- Used or reused as an ingredient in an industrial process to make a product, provided the materials are not first reclaimed

- Used or reused as effective substitutes for commercial products provided they have not been reclaimed, or

- Returned to the original process from which they are generated without first being reclaimed (material must be used as a substitute for raw material feedstock).

The burden of proof that a particular material is not a solid waste and is, therefore, exempt from regulation lies with the person making the claim. This person must be able to demonstrate that there is a market for the material and that the specific use/reuse meets the condition of the exclusion. Closed-loop recycling processes also are excluded from regulation (40 CFR 261.4).

In addition, three case-by-case variances can be granted by the Regional EPA Administrator to exclude a material from classification as a "solid waste," two of which involve recycling:

- A material is reclaimed and then reused as a feedstock within the original primary production process in which the material was generated if the reclamation operation is an essential part of the production process, or

- A material has been reclaimed but must be reclaimed further before recovery is complete if, after initial reclamation, the resulting material is commodity-like.

The U.S. EPA has also established a policy identifying criteria that may indicate sham recycling that is actually a surrogate for hazardous waste treatment or disposal. If a person uses a secondary material as is (in a production process), that person must be able to show that the secondary material is as effective as the raw material it is replacing. Also, if the material does not contribute any necessary or significant element to a product of the production process, the recycling may be a sham. Other indicators of sham recycling are use of a secondary material in excess of the amount necessary for a particular process and the handling of a secondary material without regard to economic loss. The burden of proof for the legitimacy of a claimed regulatory exemption rests solely on the recycler.

For secondary materials subject to regulation as a solid waste and potentially as a hazardous waste, specific standards exist for some types of hazardous waste reuse or reclamation activities. Generators and transporters of recyclable materials (hazardous wastes that will be recycled) generally are subject to 40 CFR Parts 262 (generator requirements) and 263 (transporter requirements) of Subtitle C, as well as notification requirements of Section 3010 of RCRA. Additionally, recycling facilities that store recyclable materials prior to recycling are subject to notification requirements and Subtitle C hazardous waste storage requirements. However, in general, the recycling process itself currently is exempt from regulation under Subtitle C. Recycling facilities that do not store recyclable materials before recycling are subject only to Subtitle C notification and manifest requirements.

Some particular recyclable materials are not subject to the full generator, transportation, and storage requirements of Subtitle C, but are only subject to the limited provisions of Part 266 (again, the actual recycling process is not regulated; only the storage prior to recycling is subject to full Subtitle C regulation). Recyclable materials regulated under Part 266 include:

- Hazardous waste burned for energy recovery
- Precious metal reclamation
- Spent lead-acid batteries
- Recyclable materials used in a manner constituting disposal.

3.3 Summary of California EPA Policy Regarding "Use in a Manner Constituting Disposal"

California is one of a handful of states that have promulgated policy pertaining to recycling hazardous wastes into construction materials and specifying acceptance criteria for the types of wastes or by-products that may be recycled. On August 18, 1995, the California EPA, Department of Toxic Substances Control (DTSC), Alternative Technology Division in Sacramento issued a management memo dated August 1995 for "Use Constituting Disposal or UCD" (Appendix C). The purpose of this policy is to encourage the recycling of suitable wastes into construction materials and to establish conditions to assure that the recycling occurs safely and can be monitored as necessary to prevent abuses. Several of these conditions, which are described more fully in Appendix C, are as follows:

1. Policy applies only to non-RCRA (California-only) hazardous wastes.
2. For wastes failing the California WET test (California version of the TCLP leach test), the contaminant in the resulting construction material needs to be "chemically bound." The effect of contaminant dilution by other ingredients in the construction materials needs to be accounted for by increasing the measured leachable concentration by the dilution factor so that the component of immobilization due to chemical binding can be assessed. The WET soluble metal content of the asphalt-treated ABM must adhere to STLC standards after accounting for the effect of dilution.
3. Recyclable materials should add no significant hazard to public health or the environment, either in the recycling process or in the final product.
4. The recyclable materials must be used beneficially; that is, the material must meet accepted performance standards such as Caltrans (California Department of Transportation) specifications and must be made for commercial use.

Clearly, compliance with these criteria will involve some testing and evaluation. Demonstrating compliance with the metals leaching criteria will require laboratory or field treatability tests to evaluate the extent of metals immobilization due to asphaltic binder ingredients. Compliance with the criteria pertaining to hazards posed by the recycling process or product may require the performance of a quantitative risk assessment.

3.4 California Hazardous Waste Management Compliance Issues

The regulations summarized in Sections 3.2 and 3.3 specify when a hazardous by-product is recyclable. Once that recyclability is demonstrated, for category 2 and 3 wastes, it will still be necessary to manage that recycling project in compliance with applicable state, local, and/or U.S. EPA waste management regulations.

As in the previous sections, it is not possible to define these regulations and policies for every region, as they will vary significantly from region to region. However, it is instructive to indicate the types of compliance issues that may exist, using California as an example.

In California, hazardous waste control requirements are set forth in the California Health and Safety Code, Division 20, Chapter 6.5, Section 25100 et seq. and regulations adopted to implement this section of the statutory code. Recyclable materials are subject to these requirements unless a variance is issued by the California DTSC or unless the material is excluded or exempted from classification as a waste under Section 25143.2(b), (c), or (d) or California's hazardous waste management regulations (adopted pursuant to Sections 25150 and 25151).

Materials exempted or excluded under Section 25143.2, subdivisions (b) or (d), must be managed in accordance with the requirements for management of a recyclable material specified in 25143.9. Under 25143.9(a), if a material is held in a container or tank, the container or tank must be labeled, marked, and placarded in accordance with DTSC hazardous waste labeling, marking, and placarding requirements applicable to hazardous waste generators, except that the container or tank would be labeled or marked clearly with the words "Excluded Recyclable Material" instead of the words "Hazardous Waste," and manifest document numbers would not be applicable.

Under 25143.9(b), the owner or operator of the business where the material is located must have plans that meet the California requirements given in Section 25504, including but not limited to emergency response plans and procedures, as described in subdivision (b) of Section 25504, which specifically address the material meeting the DTSC's emergency response and contingency requirements that are applicable to generators of hazardous waste.

Section 25143.9(c) requires that the recyclable material be stored and handled in accordance with all local ordinances and codes, including but not limited to fire codes, governing the storage and handling of the hazardous material. If a local jurisdiction does not have an ordinance or code requiring secondary containment for hazardous material storage areas, then the material must be stored in tanks, waste piles, or containers meeting the DTSC's interim status regulations establishing design standards applicable to tanks, waste piles, or containers storing hazardous waste. Finally, under Section 25143.9(d), there are additional requirements if the material is being exported to a foreign country.

Although recyclable materials are not required to comply with the same regulations applied to hazardous waste generators, there is a statutory provision that affects the length of time that recyclable materials can be stored. Under Section 25413.2(e), materials that are speculatively accumulated do not qualify for the exemptions under Section 25143.2. Because California has not specified a definition of speculative accumulation, the definition established by the U.S. EPA in 40 CFR 261.1(c)(8) applies. Under this definition, a recyclable material is not accumulated speculatively if the person accumulating it can show that the material is potentially recyclable and has a feasible means of being recycled; and that during the calendar year (commencing on January 1), the amount of material that is recycled or transferred to a different site for recycling equals at least 75% by weight or volume of the amount of that material accumulated at the beginning of the period.

Persons recycling more than 100 kilograms per month of recyclable material are required to provide reports to the local health officer or other local public officer authorized to implement the statute (see Section 25143.10). The following information is required to be provided in writing every 2 years:

1. The name, site address, mailing address, and telephone number of the owner or operator of any facility that recycles the material.
2. The name and address of the generator of the recyclable material.
3. Documentation that the requirements of any exemptions or exclusions pursuant to Section 25143.2 are met includes, but is not limited to, both of the following:
 - A. A person who recycles a material generated by someone else must document that there is a market for the recyclable material and any products manufactured from the recyclable material.
 - B. Recyclable material that is excluded based on use or reuse to make a product or as a substitute for a commercial product requires the following documentation:
 - a general description of the material and products
 - identification of the constituents or group of constituents and their concentrations
 - an estimate of constituent concentrations that would cause the material or product to be designated hazardous, if it were a waste
 - the means by which the material is beneficially used.

If the exclusion of the recyclable material is questioned and the regulatory authority brings action against the owner or operator using the recyclable material, the burden of proof that the exclusion is valid lies with the owner or operator, not with the agency. The owner or operator would be required to provide information on the management of the material and to maintain adequate records to demonstrate that there is a market for disposition of the material (Section 25143.2, subdivision (f)).

3.5 Public Information and Involvement

Support of the people in the area where the asphalt will be used is an important aspect to gaining acceptance of the recycling option. Public support can be fostered by providing information in precise but nontechnical language early in the project. Example news releases for a general audience are provided in Appendix D.

4.0 MIX DESIGN TESTING

Before commencing the full-scale production of asphaltic concrete using spent ABM as an additive, it is advisable and sometimes necessary to conduct some mix design tests in the laboratory to prepare some ABM-containing asphaltic concrete specimens for subsequent testing. There are three principal reasons for conducting these mix design tests:

- To optimize the mix design in terms of relative proportions of aggregate, asphalt bitumen, and spent ABM.
- To demonstrate that the resulting ABM-containing asphaltic concrete product possesses structural integrity and will meet the physical properties requirements for demonstrating long-term durability under the anticipated traffic load.
- To verify that the chemical characteristics of the ABM-containing asphaltic concrete adhere to any regulatory criteria, such as the California UCD criteria for immobilization of soluble metals content described in Section 3.3.

Some additional detail on these three aspects of mix design testing are presented below.

4.1 Optimizing the Mix Design

Generally an asphalt plant has several standard mix designs for their asphaltic concrete products. Incorporating the spent ABM usually is not very difficult in that it can be readily substituted for a portion of the normal sand/dust or fines fraction. Alternatively, spent ABM can be used as mineral filler, which is allowed by many states at a concentration up to ~15% in the final asphaltic concrete product. Note that, even with metal contaminants from the paint chips, spent ABM often will have a total metal content similar to the metal content of natural mineral fillers such as soil, sand, or crushed rock. A tabulation of the trace element concentrations commonly found in soils is provided in Table 4-1 to give a basis for comparing the spent ABM to the composition of natural soils.

Spent ABM typically is added to asphaltic concrete in substitution for a portion of the fine fraction, usually at a concentration ranging from 5 to 10 wt % in the final asphalt product. However, theoretically the entire fine size fraction in the asphaltic concrete, up to 25 to 35% depending on mix design, could be comprised of spent abrasive.

Usually the spent ABM will have physical characteristics so similar to the normal fine aggregate constituents for which it is being substituted that further modification of the mix design is not necessary. However, if this is not the case, and there is concern that the optimal asphalt (oil) content of the asphaltic concrete needs to be modified in order to accommodate the spent ABM, the Centrifuge Kerosene Equivalent (CKE) test (ASTM D 5148-90) can be conducted. The CKE test consists of saturating with kerosene all aggregates of the mixture that pass the No. 4 sieve (considered as the fine aggregate fraction) and then centrifuging at 400 g. The 3/8 inch to No. 4 size aggregate, considered to be the coarse fraction, is saturated with lubricating oil (SAE No. 10 oil or Shell Tellus No. 100 oil) and allowed to drain for 15 minutes at 140°F. Various K factors, K_c (for coarse fraction) and K_f (for fine fraction), are determined from the weight of the kerosene and oil retained in the aggregates. From the K factors, the approximate bitumen ratio (ABR) or the optimum asphalt content is read from several plots found in the ASTM standard.

Table 4-1. Trace Elements Commonly Found in Native Soils (mg/kg)

Trace Elements	Common Ranges	Average Concentrations
Antimony	2 - 10	NA
Arsenic	1 - 50	5
Barium	100 - 3,000	430
Beryllium	0.1 - 40	6
Cadmium	0.01 - 0.7	0.06
Chromium	1 - 1,000	100
Cobalt	1 - 40	8
Copper	2 - 100	30
Lead	2 - 200	10
Manganese	20 - 3,000	600
Mercury	0.01 - 0.3	0.03
Molybdenum	0.02 - 5	2
Nickel	5 - 500	40
Selenium	0.1 - 2	0.3
Silver	0.01 - 5	0.05
Strontium	50 - 1,000	200
Thallium	NA	NA
Vanadium	20 - 500	100
Zinc	10 - 300	50

Source: U.S. Environmental Protection Agency, 1983, SW-874.

4.2 Physical Properties Testing

After the optimal mix design is determined, asphaltic concrete pellet specimens are produced in the laboratory and subjected to physical testing to determine whether the asphaltic concrete will meet paving standards. The physical properties test most commonly used is the Hveem Method (ASTM D 1560-81). Data collected according to the Hveem Method include (1) bitumen or asphalt content, (2) stabilimeter value, (3) cohesiometer value, (4) test temperature, (5) density of asphalt-treated grit mixture, and (6) air voids ratio.

The Hveem Method or something very similar is currently adopted by most state highway departments and involves two principal tests. The first test, the stabilimeter test, is a type of triaxial test that determines the resistance to deformation of compacted asphalt mixtures by measuring the lateral pressure developed when applying a vertical load using the Hveem stabilimeter. The second test, the cohesiometer test, determines the cohesion of the compacted asphalt mixtures by measuring the force required to break or bend the sample as a cantilever beam using the Hveem cohesiometer. Other information obtained from the cohesiometer test are the density and air void properties of the asphalt-treated grit mixture.

The physical properties requirements for asphaltic concrete for paving projects will vary according to the state, type of paving project, and the traffic load or maximum weight load that the pavement is expected to incur. Although the mix design specifications will be highly project-specific, typical test limit criteria are as follows:

- Hveem stabilimeter value of 35 for medium traffic applications
- minimum cohesiometer value of 50
- maximum swell value of 0.030 inch
- percent voids range of 4 to 8%.

4.3 Metals Analysis of the Asphalt Test Specimens

As described in Section 3.3, certain states (California being the example cited) have defined limits on the metals content of the asphaltic concrete product and/or have specifications requiring a certain degree of reduction in the leachable metals content of the asphaltic concrete due to immobilization by binder ingredients. Using the U.S. Navy's ABM-to-asphalt recycling project at Hunters Point Annex (HPA), California, and the metal Pb as an example, Table 4-2 shows how to determine compliance with STLC criteria in the asphalt product after subtracting out the effect of dilution. The average WET (leachable) Pb content of the spent ABM was 19 mg/L compared to an STLC of 5 mg/L. Therefore, the asphalt binder ingredients would need to immobilize the Pb by a factor of about four to bring the WET Pb content of the spent ABM in the asphaltic concrete to below 5 mg/L. Based on core samples of asphalt test strips laid at HPA, the average WET Pb content of the ABM-containing asphaltic concrete was 0.13 mg/L, versus 0.07 mg/L for control asphaltic concrete specimens containing the same aggregate and oil contents, but no ABM, thus indicating a WET Pb content of 0.06 mg/L attributable to the ABM component of the asphalt. Asphaltic concrete was 5.0%, indicating a dilution factor of 20 which, when multiplied by the background-corrected WET Pb content of the asphaltic concrete, yields 1.2 mg/L Pb. This value is well below the STLC criterion of 5 mg/L, thus indicating compliance with the criterion and an immobilization factor of slightly greater than 15.

Table 4-2. Calculations for Pb in Asphalt Test Strips Containing Hunters Point ABM

Mean Total Pb Content of Spent ABM	204 mg/kg
Mean WET Pb Content of Spent ABM	19 mg/L
A) WET Pb Content of Asphalt Test Samples (average of 4 values)	0.13 mg/L
B) WET Pb Content of Control Asphalt Test Samples (average of 4 values)	0.07 mg/L
C) Background-Corrected WET Pb Content of Asphalt Test Samples (A – B)	0.06 mg/L
D) Dilution Factor – Untreated Test Strips	20 ^(a)
E) Dilution-Corrected WET Pb Content of Asphalt Test Samples (C x D)	1.2 mg/L
F) STLC for Pb	5.0 mg/L

(a) ABM content of the asphalt content was 5.0 wt %.

5.0 DEVELOPMENT OF A WORK PLAN

A work plan, management plan, business plan, or similar written documentation of the planned ABM-to-asphalt recycling project may be a regulatory requirement. Even if it is not required, a succinct and specific work plan is a good management tool for ensuring that all of the participants understand their responsibilities.

The size and content of the Work Plan will vary, depending on the magnitude of the project, its duration, and other factors. An example of an outline for a typical ABM-to-asphalt recycling project is provided in Table 5-1. Sample text for the Sampling and Analysis Plan, Transportation Plan, Health and Safety Plan, and QA/QC Plan portions of the Work Plan are provided in Appendices A, E, F, and G, respectively.

Table 5-1. Brief Annotated Outline of an Example Work Plan for an ABM-to-Asphalt Recycling Project

1.0	INTRODUCTION
	• purpose of work plan • describe site and spent ABM • overview of proposed project • identify stakeholders and participants • applicable regulatory requirements and performance objectives
2.0	ABM CHARACTERIZATION (see Appendix A, Example Sampling and Analysis Plan)
2.1	Sampling Plan
2.1.1	Overview
	• sampling objectives • general description of the sampling project
2.1.2	Statistical design
	• randomized statistical approach • number of samples • sample locations
2.1.3	Sample collection and preservation
	• composite vs. grab samples • sample preparation, e.g., screening • chemical additives, refrigeration, etc. • type of sample containers
2.1.4	Sample handling
	• chain of custody • labeling and recordkeeping • packaging • storage • shipping
2.1.5	Sampling equipment and operation
2.1.6	Personnel protective equipment and decontamination
2.2	Analysis Plan
	• What samples are analyzed for which parameters • U.S. EPA method numbers or other procedural documentation

**Table 5-1. Brief Annotated Outline of an Example Work Plan for
an ABM-to-Asphalt Recycling Project (continued)**

2.3 Sample QA/QC 2.3.1 Rinsate blanks (equipment washes) 2.3.2 Laboratory quality control • matrix spike analysis • matrix spike duplicates • method blank tests • holding times 2.3.3 Laboratory certification requirements
3.0 MIX DESIGN 3.1 Mix Design Optimization 3.2 Test Design • number of samples/replicates • bitumen content • aggregate content, aggregate grade • ABM content 3.3 Chemical Analyses • total metals • soluble metals (TCLP and/or WET) 3.4 Physical Properties Analyses • HVEEM test • other physical properties measurements
4.0 PLAN FOR ABM USE IN COMMERCIAL PAVING OPERATION 4.1 Site Selection • hot plant location • paving location • permits, variances, or other approvals 4.2 ABM Pretreatment • screening, if necessary • dewatering, if necessary 4.3 Transportation to the Hot-Mix Asphalt Plant • route • timing 4.4 Storage at the Hot-Mix Asphalt Plant • labeling, worker notification • need for containers, liners, tarpaulins, etc. 4.5 Full-Scale Production of ABM-Containing Asphalt • mix design • go/no go indicators 4.6 Sampling and Analysis of the ABM-Containing Asphalt • sampling frequency • statistical design • chemical analyses 4.7 Contingency Plans 4.8 Recordkeeping • rate of ABM recycling • paving locations • deviations from work plan

**Table 5-1. Brief Annotated Outline of an Example Work Plan for
an ABM-to-Asphalt Recycling Project (continued)**

5.0 TRANSPORTATION PLAN 5.1 Driver Training 5.2 Storage at Hot-Mix Asphalt Plant 5.3 Decontamination of Trucks
6.0 HEALTH AND SAFETY PLAN 6.1 Facility Background 6.2 Key Personnel and Responsibilities 6.3 Job Hazard Analysis 6.4 Risk Assessment Summary 6.5 Exposure Monitoring Plan 6.6 Personal Protective Equipment 6.7 Work Zones and Security Measures 6.8 Decontamination Measures 6.9 General Safe Work Practices 6.10 Sanitation 6.11 Standard Operating Procedures 6.12 Contingency Plans 6.13 Training Requirements 6.14 Medical Surveillance Program 6.15 Recordkeeping
7.0 QA/QC PLAN 7.1 Roles and Responsibilities 7.2 Sampling Procedures 7.3 Sample Custody 7.4 Calibration 7.5 Analytical Procedures 7.6 Data Reduction and Reporting 7.7 Internal Quality Control Checks 7.8 Performance of System Audits 7.9 Preventative Maintenance 7.10 Procedures to Assess Data
8.0 PROPOSED SCHEDULE AND MILESTONES

6.0 CONTRACTING PROCEDURES

The recycling contract can consist of either a single contract issued directly to the asphalt plant or one or more contracts issued to both the hot-mix asphalt plant and a third-party consultant whose function is to coordinate the project, oversee sampling, interface with regulatory agencies, and prepare written documentation. A Statement of Work is attached (Appendix H) from the U.S. Navy ABM-to-asphalt demonstration at Hunters Point Annex (HPA) California, which serves as an example of a contract issued to a third-party firm who then subcontracted various elements of the project (chemical analysis, ABM pretreatment, transportation, debris disposal, and asphalt production) to suitably qualified contractors. Note that this Statement of Work included several tests and analyses specific to the HPA project that would not necessarily be included in a routine recycling project, namely (1) a roadgrinding operation on test strips laid at HPA to determine the metals content of dust emissions (Photo 6-1); (2) core sampling of the same test strips to determine physical and chemical properties (Photo 6-2); (3) a milling operation on a pile of treated grit to reduce its particle size for recycling; (4) air monitoring during grit screening and milling (Photo 6-3); and (5) the preparation of a technology transfer report and slide show to facilitate future ABM-to-asphalt recycling projects.

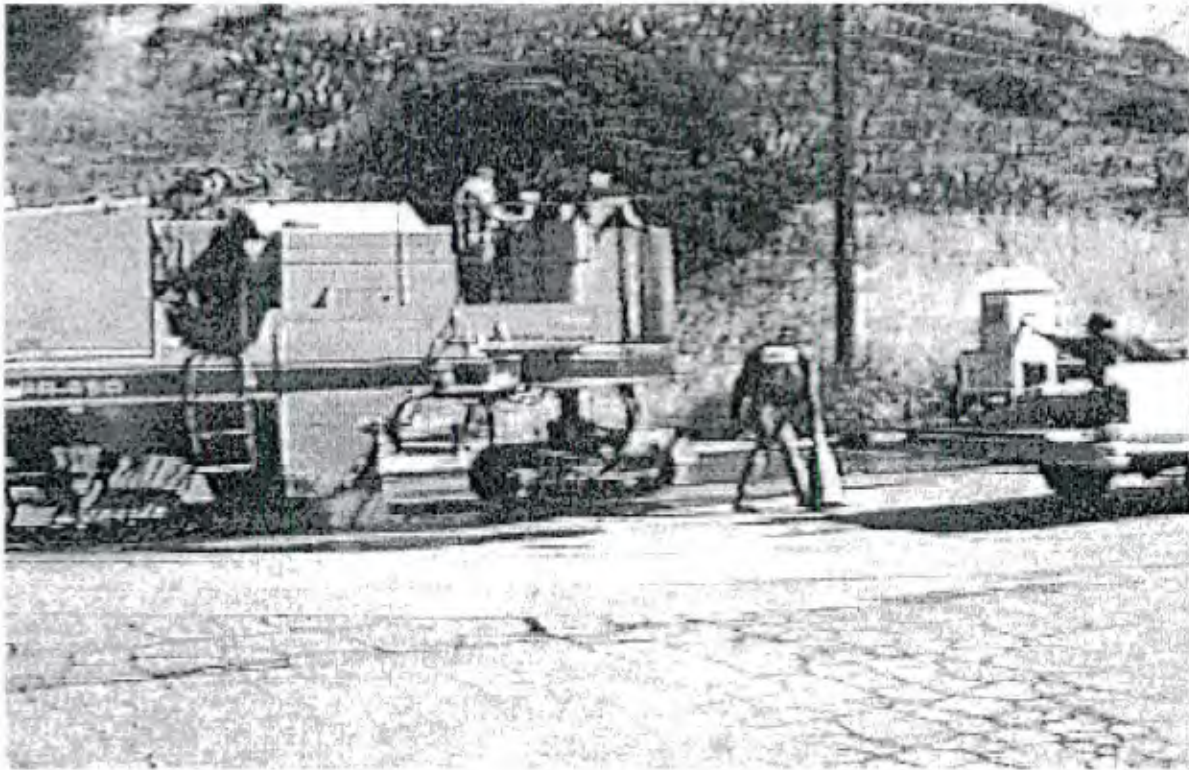


Photo 6-1. Roadgrinding operations being performed on a test strip of ABM-containing asphalt.



Photo 6-2. Core sampling of an asphalt test strip.



Photo 6-3. Installing air monitoring equipment prior to grit screening operations.

7.0 COST

The cost of an ABM-to-asphalt recycling project depends on a number of factors, particularly:

- the tippage rate charged by the asphalt plant
- the distance between the generator and the asphalt plant
- the required amount of planning, regulatory interactions, reporting, and program management.

and to a lesser extent:

- the analytical fees for chemical and physical analyses (typical unit costs are provided in Table 7-1)
- the costs for grit pretreatment such as screening and debris disposal.

In the simplest case, where planning, reporting, and regulatory interactions may be held to a minimum, the primary cost elements will be transportation and tippage (see Photo 7-1). Assuming that there are 1,000 tons of spent ABM at a tippage fee of \$20/ton and that the hot plant is near the generator (<20 miles), with associated loading and transportation costs of ~\$6/ton, then the recycling project could be conducted for ~\$26/ton, rounded upwards to about \$35/ton, including chemical analysis and project coordination. However, this is a rather ideal case, and the example of the HPA project in Table 7-2 is more realistic. The average cost for the HPA project comes to approximately \$140/ton, which despite significant costs for planning, management, and regulatory interactions, is still quite favorable compared to the typical cost range of disposal in a RCRA-permitted landfill of \$300 to \$600 (or more)/ton.

Another important factor affecting cost is the total amount of spent ABM to be recycled. When the amount of spent ABM is less than several hundred tons, it probably will be difficult to identify an asphalt plant that is willing to participate, because the small tippage fee will not be worth the time that must be invested in developing a suitable mix design and in coordinating the project. Larger volumes are clearly preferred, but not so large as to exceed the asphalt plant's ability to recycle it. Assuming a medium-size plant produces 1,000 tons of asphaltic concrete per day, 5 days a week, for a 6-month paving season, and the asphaltic concrete contains an average of 5% by weight spent ABM, then 6,000 tons of spent ABM could be recycled in a single paving season. Obviously, this amount can be more or less depending on the size of the hot plant, the business climate, and the percentage of spent ABM in the asphaltic concrete.

Recycling costs generally will decrease on a per tonnage basis with increasing amounts of ABM. Some of the cost elements involved in ABM recycling are independent of ABM volume, whereas others are more or less directly proportional to the amount of ABM to be recycled. For example, planning, reporting, and project management will be relatively independent of ABM volume, whereas the pretreatment, hauling, and tippage cost will depend on the ABM volume. However, the generator often can negotiate a lower tippage rate per ton if there is large and continuous source of the spent ABM.

**Table 7-1. Costs of Typical Analytical Tests
Spent ABM and Asphaltic Concrete**

Analysis	Unit Cost ^(a) , \$
<u>Physical</u>	
Sieve analysis	55-70
Los Angeles Rattler test	130-140
Hveem stability	85-100
Compacted unit weight	20-25
Cohesion	55-65
As-received unit weight	25-30
Swell	100-110
Maximum theoretical unit weight	65-75
Extraction of bitumen	80-90
Gradation of aggregates	90-100
<u>Chemical</u>	
PH	10-20
Oxidation reduction potential	75
Total organic carbon (TOC)	40-55
Oil and grease	110-135
Alkalinity	20-40
As	30-50 ^(b)
Se	30-50 ^(b)
Hg	20-25
As, Ag, Ba, Cd, Cr, Pb, or Se	10-20/each ^(c)
<u>Leach Tests</u>	
Extraction, TCLP	75-100
Extraction, Cal WET	95-145
As	30-50 ^{(b)(d)}
Se	30-50 ^{(b)(d)}
Hg	20-25 ^(d)
As, Ag, Ba, Cd, Cr, Cu, Pb, Se, or Zn	10-20/each ^{(c)(d)}

(a) 1995 costs. May vary considerably among various laboratories. Approximate ranges are given based on quoted prices. There may be some savings of scale if a large number of samples are being analyzed.

(b) Furnace atomic absorption spectroscopy.

(c) Inductively coupled plasma atomic emission spectroscopy.

(d) Cost for analysis performed on TCLP or WET extract.

Following is our estimate of reasonable cost ranges for different amounts of ABM:

<u>Amount ABM (tons)</u>	<u>Estimated Cost of Recycling (per ton)</u>
500-1,500	\$125-175
1,500-3,000	\$100-150
3,000-6,000	\$50-100

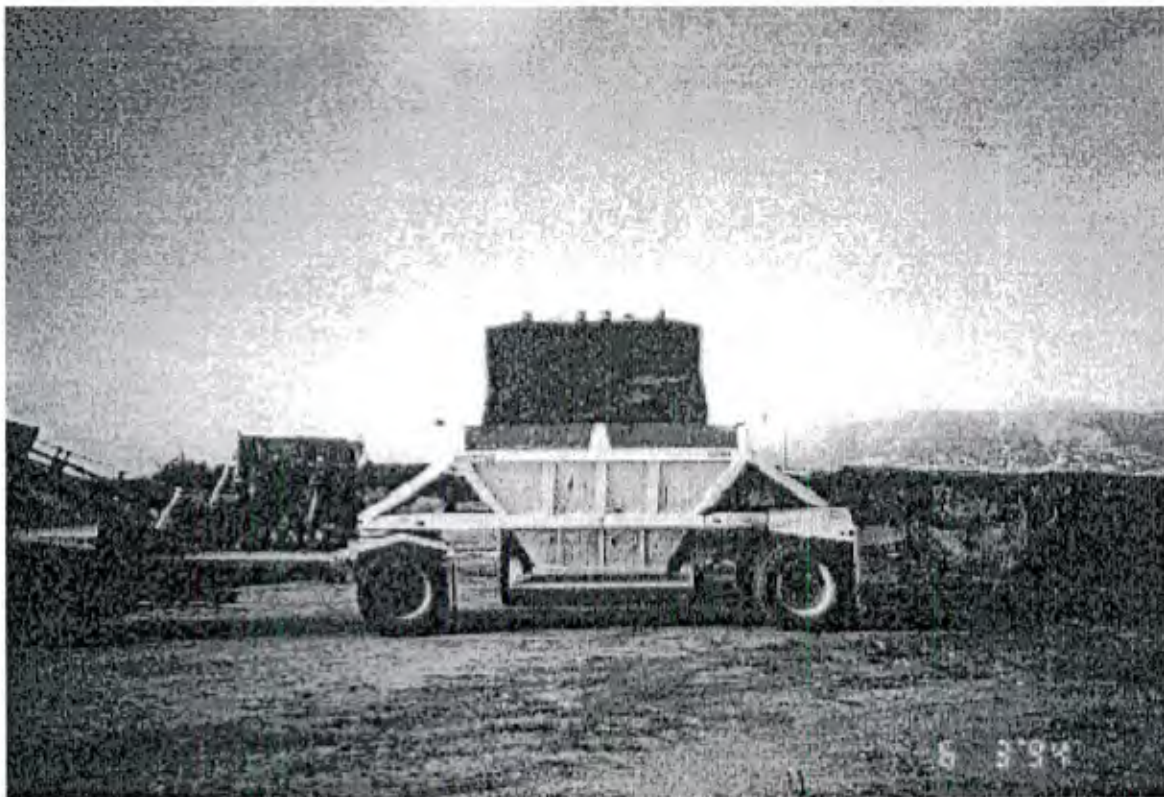


Photo 7-1. Transportation costs will include the costs of loading and transporting the ASM material.

**Table 7-2. Principal Cost Elements of the Hunters Point Annex
ABM-to-Asphalt Recycling Project**

	Est. Cost (\$K)
Sampling and analysis — Spent ABM	20
Screening and milling	25
Hazardous debris disposal (40 tons)	12
Transportation to the hot plant, including loading and dust suppression ^(a)	130
Tippage — hot plant ^(b)	142
Sampling and analysis — ABM-containing asphalt	15
Permits and variances, planning, meetings, reporting, project management	100
Total = \$139/ton for 3,200 tons	446

(a) Approximately 22¢ per ton per mile plus loading and dust depression.

(b) Approximately \$44/ton.

8.0 ADVANTAGES AND DISADVANTAGES OF RECYCLING SPENT ABM INTO ASPHALTIC CONCRETE

Asphaltic concrete recycling can be an effective and relatively inexpensive (compared to treatment and/or disposal) option for managing hazardous spent ABM, as long as there is a well thought-out plan for the recycling operation and the project is conducted in full compliance with relevant regulations, codes, and/or policies. There is a fairly extensive track record for the ABM-to-asphalt recycling option, including a considerable number of projects in California (e.g., the two performed by the U.S. Navy discussed in this report), and several projects in states including Maine, North Carolina, and Ohio. The process also has elicited interest from the U.S. Department of Defense and state departments of transportation or highways in numerous states. The following is a brief discussion of advantages, disadvantages, and several cautions pertaining to recycling.

8.1 Advantages

1. The cost of recycling spent ABM into asphaltic concrete is usually much lower than the cost of disposal (see Section 7.0).
2. The recycling and reuse option is higher in the hierarchy of hazardous waste management than disposal with or without treatment options (Figure 1-1). Furthermore, waste minimization credit may be given to the generator of the spent ABM because the spent ABM is not manifested as hazardous waste when it is transported to the asphalt plant for recycling.
3. The recycling option does not consume valuable landfill space, which can be reserved for higher-level hazardous wastes. Most spent ABM contains relatively low metal concentrations and poses negligible risk.

8.2 Disadvantages

1. If the spent ABM is hazardous, the material needs to be handled as a hazardous material (although not as a hazardous waste) and must comply with cognizant transportation, storage, handling, and reporting regulations. Also, regulatory requirements must be satisfied or a permit or variance may be required.
2. Bench-scale treatability testing is required for each combination of ABM, aggregate, and bitumen. Different types of spent ABM have different physical and chemical characteristics that affect leaching resistance and physical performance, so testing is needed to ensure regulatory compliance and to optimize the mix design.
3. Certain constituents will interfere with the production of high-quality asphalt. For example, high organic content (such as from paint chips and other organic coatings) can reduce the strength of the asphaltic concrete. A high concentration of sulfate or metallic iron may cause swelling upon contact with water.
4. If bench-scale testing is performed to design a mix, it is important that the feeder sand/aggregate used in the bench-scale tests be the same as that used in the full-scale operation at the asphalt plant. Otherwise, the bench-scale test will not provide a true representation of the full-scale process. Feeder sand and aggregate frequently are purchased

on the open market and physical characteristics such as particle size, shape, and density can vary significantly from batch to batch.

8.3 Cautions

Finally, the following list of cautions is offered for anyone who may be considering an ABM recycling option who has not had prior experience with it:

1. Grit characterization must include analysis for metals that may be present in paint chips. Pigments may include lead, chromium, or cadmium chemicals. Antifouling additives may include butyltin or copper chemicals.
2. Soluble and total metal concentrations in the ABM form the basis for whether it will be classified as hazardous, nonhazardous, or special waste. Know your relevant hazardous waste classification definitions, and be aware that certain virgin ABM materials such as metal slag possess elevated metals concentrations from the slagging process. Also, organic priority pollutants, asbestos, tributyltin, radionuclides, and/or other high-hazard substances should not be present.
3. Extremely fine-grained spent abrasive may mix poorly and/or adds little to the structural integrity of the asphaltic concrete. Steel grit should not be recycled into asphaltic concrete because it may expand and lead to cracking upon oxidation.
4. Depending on the region, there may be significant regulatory compliance issues pertaining to ABM recycling. These should be clearly understood at the onset of the project, and the participants should make full disclosure of their intent to recycle to both cognizant regulatory agencies and the clients for the paving projects where the ABM is to be used.
5. The relative merits of recycling spent ABM as aggregate should be weighed against the merits of other recycling approaches, prior to the decision to proceed with the aggregate recycling approach. Certain types of ABM are better candidates for recycling into Portland cement, bricks, mortar, or concrete, based on factors such as the chemical composition and particle-size characteristics of the ABM, local demand for certain types of construction materials, regulatory preferences, and other factors.

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APPENDIX A

Example Sampling and Analysis Plan

DRAFT REPORT

**SAMPLING AND ANALYTICAL PROCEDURES FOR
SPENT ABRASIVE BLAST MATERIAL**

to

MARE ISLAND NAVAL SHIPYARD

February 25, 1992

by

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DRAFT REPORT
FOR
SAMPLING AND ANALYTICAL PROCEDURES FOR
SPENT ABRASIVE BLAST MATERIAL
TO
MARE ISLAND NAVAL SHIPYARD

1.0 INTRODUCTION

Mare Island Naval Shipyard performs abrasive blast cleaning of the hulls of Naval submarines undergoing overhauling. For this operation, the Shipyard usually uses a copper slag abrasive medium. The spent abrasive is collected and stored on-site until sampling is conducted to determine the concentration of contaminants in the abrasive.

The primary objective of this sampling plan is to provide a written document which details the individual tasks and indicates how these tasks will be performed in order to properly sample spent abrasive at Mare Island Naval Shipyard. A brief overview of the project scope will first be presented, followed by the sampling program, statistical analyses, and methods for sample collection. This plan is intended to apply to the existing accumulation of spent abrasive south of Building A 215 as well as generically to future accumulations of spent abrasive.

2.0 PROJECT SCOPE

The existing spent abrasive consists of three accumulated piles of material situated on pavement in an approximately rectangular shape (Figure 2-1). Approximate estimates of the dimensions of the piles are: Pile 1: 43 ft by 27 ft and 2 ft deep; Pile 2: 53 ft by 38 ft and 2 to 2.5 ft deep; and Pile 3: 53 ft by 20 ft 3 ft deep.

A preliminary sampling of the spent abrasive was conducted by Battelle to obtain an estimate of the number of contaminants of concern as well as the concentrations. In addition, previous sampling by Mare Island Naval Shipyard staff of other spent abrasive which had been collected in rolloff boxes and stored in the parking area south of Building A 215 was analyzed in order to obtain a better estimate of the contaminants likely to be found in the piles. Copper and lead were the primary contaminants from both sampling surveys. Average concentrations of copper and lead from the rolloff boxes and piles are shown in Tables 2-1, 2-2, and 2-3. These preliminary measurements of the metal concentrations were used to design the sampling program.

The spent abrasive tends to be fairly uniform in consistency throughout, but possible variations in metal concentrations require that samples be collected at varying locations, both spatially and as a function of depth. Specific details of the sampling design are discussed in the following section.

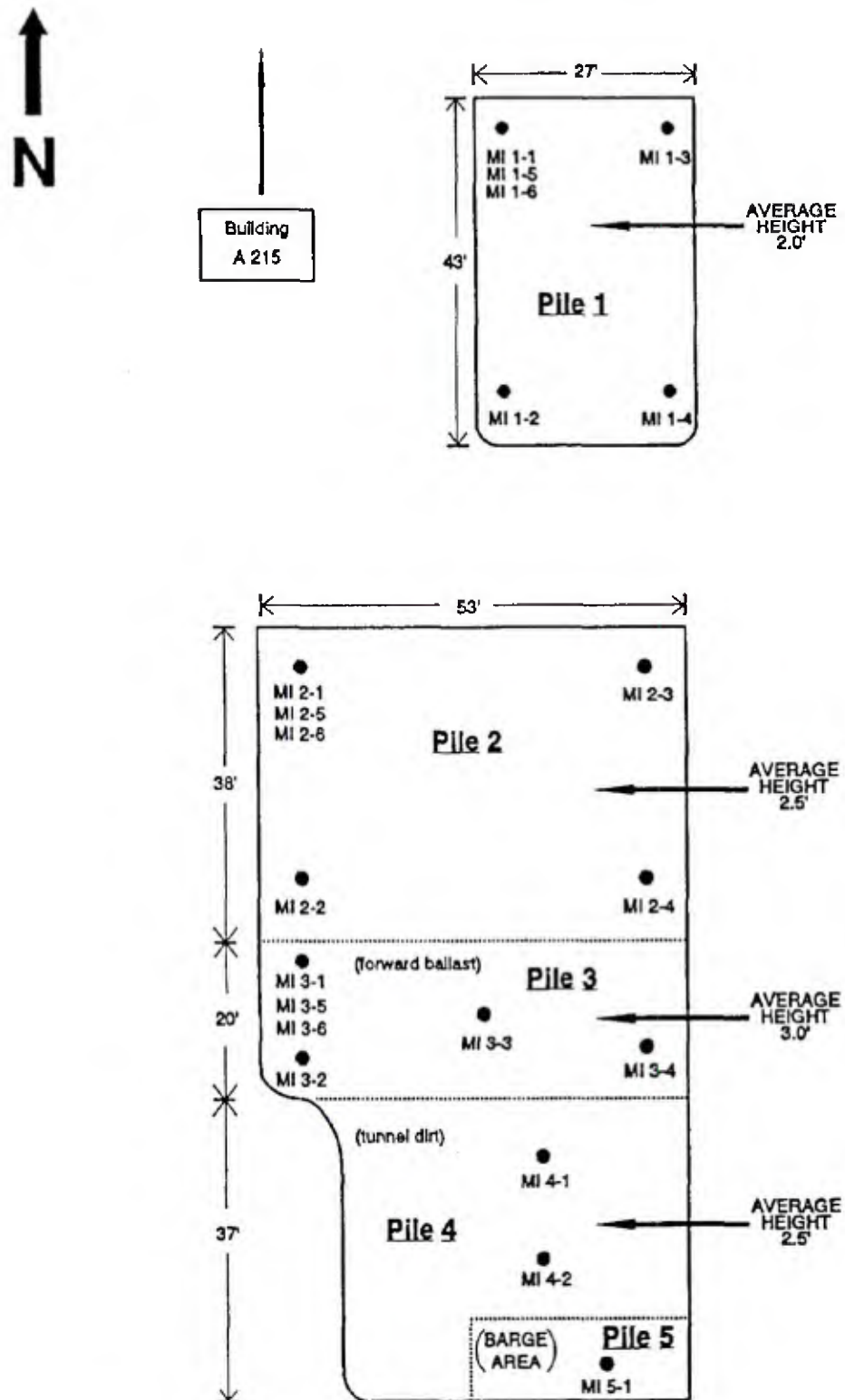


FIGURE 2-1. SCHEMATIC DIAGRAM OF SPENT ABRASIVE WASTE PILES

TABLE 2-1. SUMMARY OF COPPER AND LEAD LEVELS IN ROLLOFF BOXES

Results by Analytical Methods	Copper	Lead
STLC		
Regulatory Threshold (mg/L)	25	5.0
Mean (mg/L) ¹	35	2.2
Coefficient of Variation	0.97	0.43
TTLC		
Regulatory Threshold (mg/kg)	2500	1000
Mean (mg/kg) ¹	3240	28
Coefficient of Variation	0.33	0.40

¹ - Samples which contained nondetectable concentrations were used in calculations as the mean between 0 and the detection limit.

TABLE 2-2. SUMMARY OF COPPER LEVELS IN MARE ISLAND WASTE PILES

Results by Analytical Methods	Pile #		
	1	2	3
STLC			
Regulatory Threshold (mg/L)	25		
Mean (mg/L) ¹	45	79	31
Coefficient of Variation	0.33	0.91	0.85
TTLC			
Regulatory Threshold (mg/kg)	2500		
Mean (mg/kg) ¹	2550	3080	2600
Coefficient of Variation	0.14	0.27	0.11

¹ - Average of four samples.

TABLE 2-3. SUMMARY OF LEAD LEVELS IN MARE ISLAND WASTE PILES

Results by Analytical Methods	Pile #		
	1	2	3
STLC			
Regulatory Threshold (mg/L)	5.0		
Mean (mg/L) ¹	3.0	2.0	2.4
Coefficient of Variation	0.23	0.26	0.33
TTLC			
Regulatory Threshold (mg/kg)	1000		
Mean (mg/kg) ¹	66	58	64
Coefficient of Variation	0.21	0.11	0.05

¹ - Average of four samples.

3.0 SAMPLING PROGRAM

The sampling design will be of a random grid layout. Piles 1 and 3 will be gridded into equal surface areas by marking a coordinate every 3 ft, both horizontally and laterally. Due to the variation in size between piles, this will result in approximately 130 grids for Pile 1 and approximately 120 grids for Pile 3. Each grid will have a surface area of 9 square ft. Pile 2 will be gridded into equal surface areas by marking a coordinate every 4 ft, both horizontally and laterally. This will result in approximately 125 grids. Each grid will have a surface area of 16 square ft. The grid areas will be numbered consecutively so that sample locations may be referenced.

Six different samples will be collected along with two blind replicates for each pile. Location of the sampling points will be selected for each of the sampling locations from a random number table (see Section 5.2.3).

Trained technicians will be required to collect samples of abrasive from the piles using the techniques described in Sections 5.0 through 10.0. Composite samples will be collected from each randomly selected grid. Composite sampling will consist of collecting five subsamples from each of two different depths in the randomly selected grid for a total of ten subsamples. The depths will be 0.5 ft from the surface of the pile and approximately 0.5 ft from the pavement. Subsamples will be collected from four corners of the grid in addition to one subsample from the center. The subsamples will then be composited in a tray and mixed using a stainless steel or Teflon spoon. The composited sample will be split and placed into two or three precleaned polyethylene bottles for analysis as follows:

- 500 cc from all sampling points. These samples will be sent to the primary analytical laboratory.
- 1000 cc from all sampling points. These samples will be archived in the event that additional analyses are required.
- 500 cc from 1 out of 10 sampling points. These samples will be sent to a separate analytical laboratory to verify results from the primary laboratory.

This type of sampling versus a single grab sample will provide a better estimate of the mean concentration of the contaminants within the sampling grid and, correspondingly, a better estimate of the mean concentration of the contaminants in the waste pile.

4.0 ANALYSIS PROGRAM

One sample from each pile will be analyzed for the seventeen California Assessment Manual (CAM) metals plus Cr (VI). Total metal concentration is to be compared to California Total Threshold Limit Concentrations (TTLCs) for the seventeen metals plus Cr (VI) using appropriate methods as found in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods", SW-846, 3rd Edition. The remaining samples need be analyzed for only total copper and lead since previous testing has shown these to be the major metals. The spent abrasive will be analyzed for soluble metals using the following two methods:

- The Toxicity Characteristic Leaching Procedure (TCLP) will be carried out on 1 out of 5 samples in future sampling programs to ensure the spent abrasive is not a RCRA waste. The waste piles which are now undergoing analyses have already been tested by this method.
- Soluble metal concentrations using the California Title 22 Waste Extraction Test (WET), to be compared with the California Soluble Threshold Limit Concentrations (STLCs) standards for these metals.

The total metal analyses (all 17 metals plus Cr(VI)) are conducted first and are conducted to determine major metals for subsequent analysis. A major metal is one whose total concentration is ten times above the STLC for that metal. Then all the remaining samples are analyzed for total metals content for just the major metals. Finally, any sample whose total metal concentration is $\geq$ ten times its STLC should be analyzed by the WET to determine any STLC exceedances. The approach to analysis described in this paragraph is relatively simple, quick, and cost-effective.

It is important to inform the analytical laboratory to use as large a sample volume as possible for analyses in order to obtain the most accurate representation of the metal concentrations in each sample. A minimum of 100 g of sample should be used for the WET and a minimum of 5 g of sample should be used for acid digestion.

The analytical laboratory should meet the following quality control and quality assurance standards:

- The minimum acceptable detection limit is 100 times lower than TTLCs for total metals analysis and 10 times lower than STLCs for WET analysis.

- Results from spike analyses should be provided to demonstrate the accuracy and reproducibility of laboratory methods. An error of $\pm 20\%$ is acceptable.

Also, in future sampling programs we recommend that approximately one out of ten samples be analyzed for total metal concentrations of all 17 CAM metals plus Cr(VI). It is not necessary or cost-effective to analyze every sample for all 17 metals. However, a representative fraction of the samples used to be completely characterized in order to determine the major metals present.

Additional details on the statistical design of the sampling program are provided in Section 5.0. Sampling equipment and operation, sample collection and preservation, personal protective equipment and decontamination, and quality assurance and quality control are discussed in the Sections 6.0 through 10.0.

5.0 STATISTICAL DESIGN

An overview of the sampling effort will be discussed first followed by details on each aspect of the sampling design. The overview is intended to provide a general understanding of how the spent abrasive will be sampled. The details which follow the overview will include information on how the number of samples and grid sizes were selected, as well as detailing the method for selection of the grids and the sampling method within a grid.

5.1 Overview

Each waste pile will first be subdivided into either 3 ft by 3 ft grids (Piles 1 and 3) or 4 ft by 4 ft grids (Pile 2). Random sampling will then be used to select six grids for sampling. Within each of these grids, ten samples will be taken and composited, five samples from each of two levels.

The key elements which must be defined for this type of sampling design include: 1) the number of samples; 2) the grids (spatial area) to be sampled; 3) the selection of the grids; 4) the sampling method within a grid; and 5) the estimators used to characterize the population.

5.2 Approach

5.2.1 NUMBER OF SAMPLES PER PILE OF ABRASIVE

Factors affecting the number of samples which should be collected are the homogeneity of the contaminant in the spent abrasive, the desired confidence interval, and the cost per sample. Based on previous sampling at the Mare Island Naval Shipyard (Tables 2-1 - 2-3), an estimate of the number of samples which would provide statistical confidence in the results may be determined.

In order to provide a basis for the determination of the number of samples to acquire per pile, a table was generated which compares the coefficient of variation of a sample set (standard deviation/mean) versus K, which is a ratio of the mean of the sample set to the regulatory threshold (Table 5-1). In order to generate this table, the sample mean, standard deviation, and sample size are related to determine an upper bound, T_U , which represents the highest value for the

TABLE 5-1. SAMPLE SIZE¹ REQUIRED TO DEMONSTRATE COMPLIANCE WITH REGULATORY THRESHOLD (RT) AS A FUNCTION OF ANTICIPATED AVERAGE CONTAMINATION LEVEL (X) AND COEFFICIENT OF VARIATION

CV	K = 100X/RT				
	10	30	50	70	90
80% CONFIDENCE LEVEL					
0.1	1	1	1	1	1
0.5	1	1	1	2	15
0.9	1	1	1	4	38
1.3	1	1	2	6	63
1.7	1	1	2	8	87
2.0	1	1	3	9	103
90% CONFIDENCE LEVEL					
0.1	1	1	1	1	2
0.5	1	1	1	3	34
0.9	1	1	3	8	108
1.3	1	2	4	13	147
1.7	1	2	5	18	202
2.0	1	2	6	21	239
95% CONFIDENCE LEVEL					
0.1	1	1	1	1	3
0.5	1	1	2	5	55
0.9	1	2	4	13	145
1.3	1	3	6	22	242
1.7	1	3	8	29	332
2.0	1	4	10	35	393

¹ - These sample sizes correspond to a statistical power of 50% at a contamination level x, and were calculated assuming a lognormal probability distribution for the metal concentrations, along with assumptions that the standard deviation of the measurements is known, and that spatial correlation effects are not important.

concentration that is plausible based on the samples taken. If T_U is found to be below the regulatory threshold, then it is decided that the true average concentration is also below that threshold. From an environmental point of view, the use of T_U is probably most defensible because it requires that an area be demonstrated free of contaminants at the regulated levels.

T_U is calculated from the statistical formula shown below:

$$\ln(T_U) = m + g_1 - \frac{\sigma}{\sqrt{n}} + \frac{\sigma^2}{2} \quad (5.1)$$

where m is the mean of the log-transformed metal concentrations:

$$m = \frac{\sum_{i=1}^n t(x_i)}{n} \quad (5.2)$$

where: $t(x_i)$ = the log-transformed metal concentrations
 n = sample number
 $g_{1-\alpha}$ = the $(1-\alpha)$ percentile point of the standard normal distribution
 σ = the standard deviation of the log-transformed metal concentrations

The sample sizes shown in Table 5-1 have been generated by assuming an average metal concentration (x), a standard deviation (σ), and a desired T_U to give a range of CVs (σ/x) and Ks ($100x/RT$). In order to use Table 5-1, it is necessary to either assume an expected x and CV or a small preliminary group of samples should be taken to provide an estimate of x and the CV. These values can then be used to select an appropriate sample size. The mean and standard deviation of the sample set may be calculated in the standard method as shown. The mean of a sample set may be calculated as follows:

$$x = \frac{\sum_{i=1}^n x_i}{n} \quad (5.3)$$

The standard deviation of the sample set may be calculated as follows:

$$s = \sqrt{\frac{\sum_{i=1}^n (y_i - \bar{y})^2}{n - 1}} \quad (5.4)$$

The coefficient of variation (CV) is simply the ratio of the sample standard deviation to the sample mean:

$$CV = \frac{s}{\bar{x}} \quad (5.5)$$

From Table 5-1, one can see that as the K value increases or the coefficient of variation increases, a greater number of samples are required to demonstrate compliance. In other words, as the expected sample mean approaches the regulatory threshold, it will require many more samples to demonstrate that the actual metal concentration in the waste is below the threshold.

As shown by the preliminary sampling (Tables 2-1 - 2-3), the results demonstrated that most of the spent abrasive in the piles contains copper concentrations above the regulatory thresholds for both soluble and total metals content, although a high coefficient of variance was often found with these results. Theoretically, additional sampling of any pile of abrasive might result in finding the metal concentrations to be below the regulatory limits (although this is not recommended for these particular piles because the soluble copper content is too high); however, one must balance the cost of sampling with the likelihood of being able to dispose of the abrasive as nonhazardous.

Although the calculations in Table 5-1 show that in some cases one sample would be sufficient to demonstrate compliance, this would be difficult to justify from a regulatory perspective. From a statistical standpoint, a minimum of six samples per pile (where a pile is equal to 300 yd³ or less) would provide relatively good confidence in the calculated average metal concentration. The number of samples required if, for example, the average metal concentration is expected to be close to the regulatory threshold and the coefficient of variation is high, can be as high as 390 samples, which would clearly be economically unfeasible. Therefore, it is recommended that six samples per pile be taken to determine the average metal concentration. If waste piles generated in the future are significantly larger than those now in question, sample size should increase proportionally.

5.2.2 GRID SIZE

The grid size selected was based upon the area required to collect the samples and a "rule of thumb" that for a sample of size n , there should be $20 \times n$ grids. There are six samples to be taken from each pile, therefore, 120 grids would be adequate. This number of grids indicates a grid size of 3 ft by 3 ft would be appropriate for Piles 1 and 3 (generating approximately 130 and 120 grids, respectively), while a grid size of 4 ft by 4 ft would be appropriate for Pile 2 (generating approximately 125 grids).

For sampling of other piles, the following steps may be followed:

1. Determine the number of samples to be taken as discussed in the previous section.
2. Multiply the number of samples, n , by 20 to determine the number of grids required per strata.
3. Based upon the dimensions of the pile, determine the size of the grids required. For example, to take 5 samples from a pile with dimensions of 40 ft by 50 ft would require 100 grids. Selecting a grid size of 4.5 ft by 4.5 ft would yield approximately 100 grids.

5.2.3 SELECTION OF GRIDS

Grid areas should be numbered consecutively. Selection of the grids for sampling will be done randomly.

5.2.4 SAMPLING METHOD WITHIN A GRID

Spatial composite sampling will be used to characterize the abrasive within a grid. Five subsamples will be taken within each grid from the corners of the grid and the center at a depth of 0.5 ft from the surface. An additional five subsamples will be taken in the same manner from a depth of 0.5 ft from the pavement. These ten subsamples will then be composited via mixing in a lined container into a homogenous sample for the various analyses.

6.0 SAMPLING EQUIPMENT AND OPERATION

The following pieces of equipment will be used to perform sampling of spent abrasive placed in roll-off bins, piles, and the rinsate water. The two main requirements for the sampling equipment are:

- The tool must not contribute any chemical contamination to the sample, and
- The tool must be capable of collecting a representative sample.

Stainless steel equipment is generally the most durable and is often used for sampling sludge, sediments, and soils. The following paragraphs below discuss the pieces of sampling equipment which are recommended for use in sampling the spent abrasive and the rinsate water resulting from decontamination.

6.1 Dipper

A dipper consists of stainless steel, glass, or Teflon beaker constructed with or clamped to the end of a handle (Figure 6-1). Dippers are used for sampling tanks, bins, outfalls, and discharge. The following precautions should be observed:

- A stainless steel dipper should have a riveted handle not a soldered handle, because metals from the solder could leach into and contaminate the sample.
- Use only Teflon, stainless steel, or glass to sample materials containing organic materials.
- When using a beaker clamped to a pole, the handle and clamp should be painted with a 2-part epoxy or other chemically-inert paint when sampling either alkaline or acidic materials.

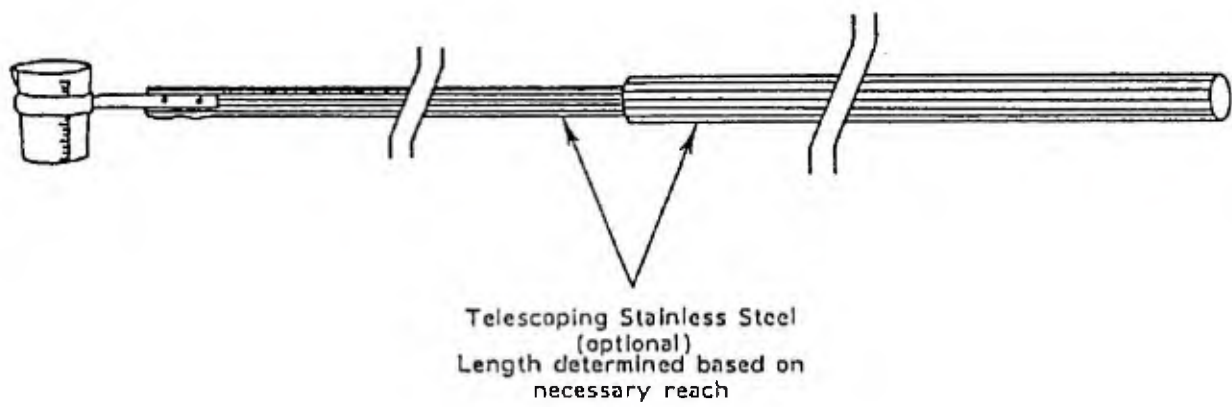


FIGURE 6-1. SCHEMATIC DIAGRAM OF DIPPER

Procedures for Use:

1. Decontaminate the dipper, clamp, and handle (see Section 6.2).
2. In tanks, turn the dipper so the mouth of the dipper faces down and insert it into the waste material. Turn dipper right side up when dipper is at desired depth. Allow dipper to fill completely as shown by the cessation of air bubbles. When sampling drums, submerge the dipper to the desired depth, allow the beaker to fill.
3. Raise dipper and pour the sample material into an appropriate container.
4. Decontaminate the dipper.

6.2 Stainless Steel Spoon or Scoop

A stainless steel spoon or scoop is the simplest, most direct method for collecting soil samples. In general, the procedure is used to sample the first three inches of surface soil. However, samples from greater depths and samples of sludges, sediments and bulk samples may also employ this technique in some situations.

Procedures for use:

1. Collect and composite samples from the top three inches of soil.
2. Mix the samples in a lined container, then deposit in the appropriate container.
3. Wipe sample containers clean of surface contamination.
4. Place in individual plastic bags in an insulated ice chest with freezer packs if refrigeration is necessary.

6.3 Glass Tube Thief

A hollow glass tube is a simple tool which is used to sample liquids from drums (Figure 6-2). The advantages of using a glass tube thief include inexpensive cost, ease of disposal, its availability in variable lengths, and capability to sample a vertical column of waste. The tool consists

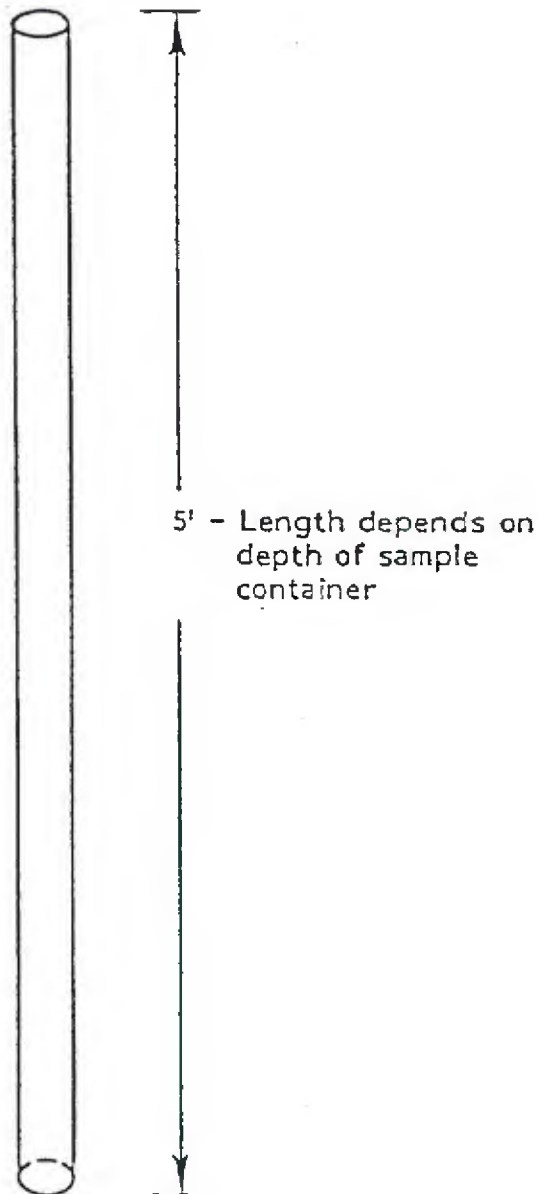


FIGURE 6-2. SCHEMATIC DIAGRAM OF GLASS TUBE THIEF

of a glass tube, typically between 8 and 16 mm in diameter. This device will be used to sample the drums containing rinsate from the decontamination of the dipper.

Procedures for use:

1. Decontaminate the glass tube (see Section 6.2)
2. Slowly insert the tube into the waste container. This should be done at a rate which permits the level of the liquid inside and outside the sampler to remain the same. If the level of waste in the sampler tube is lower inside than outside, the sampling rate is too fast and may yield a non-representative sample.
3. When the tube contacts the bottom of the waste container, place a rubber stopper or attach a squeeze bulb over the exposed end of the sampling tube. The use of a squeeze bulb improves the ability of a glass tube to retain very viscous fluids during sampling. It is important that none of the fluid comes in contact with the rubber squeeze bulb. If using your thumb, ensure your hands are protected by gloves which are resistant to the chemicals sampled. With the end of the tube plugged, slowly draw the tube from the waste container. In order to enable the sampler to retain the fluid in the glass tube, the glass tube may be withdrawn at an angle such that the thumb may be kept over the end of the glass tube.
4. Place the end of the glass tube in the sample container and remove plug from the end of the tube.
5. Repeat steps 2 through 5 until the required amount of sample has been collected.
6. Place the contaminated glass tube in a plastic storage tube for subsequent cleaning, as described in Section 6.2. If used to sample a drum of waste, the glass tube may be disposed in the drum prop to resealing the bung. Notch the glass with a steel file to avoid shattering the glass when breaking long pieces.

6.4 Auger and Thin-Wall Tube Sampler

The system consists of an auger bit, a series of drill rods, a "T" handle, and a thin-wall corer (Figure 6-3). The auger bit is used to bore a hole to the desired sampling depth and is then withdrawn. The auger tip is replaced with the tube corer, lowered down the borehole, and forced into the soil at the completion depth. The corer is then withdrawn and the sample collected.

Alternatively, the sample may be recovered directly from the auger. This technique however, does not provide an "undisturbed" sample as would be collected with a thin-tube sampler.

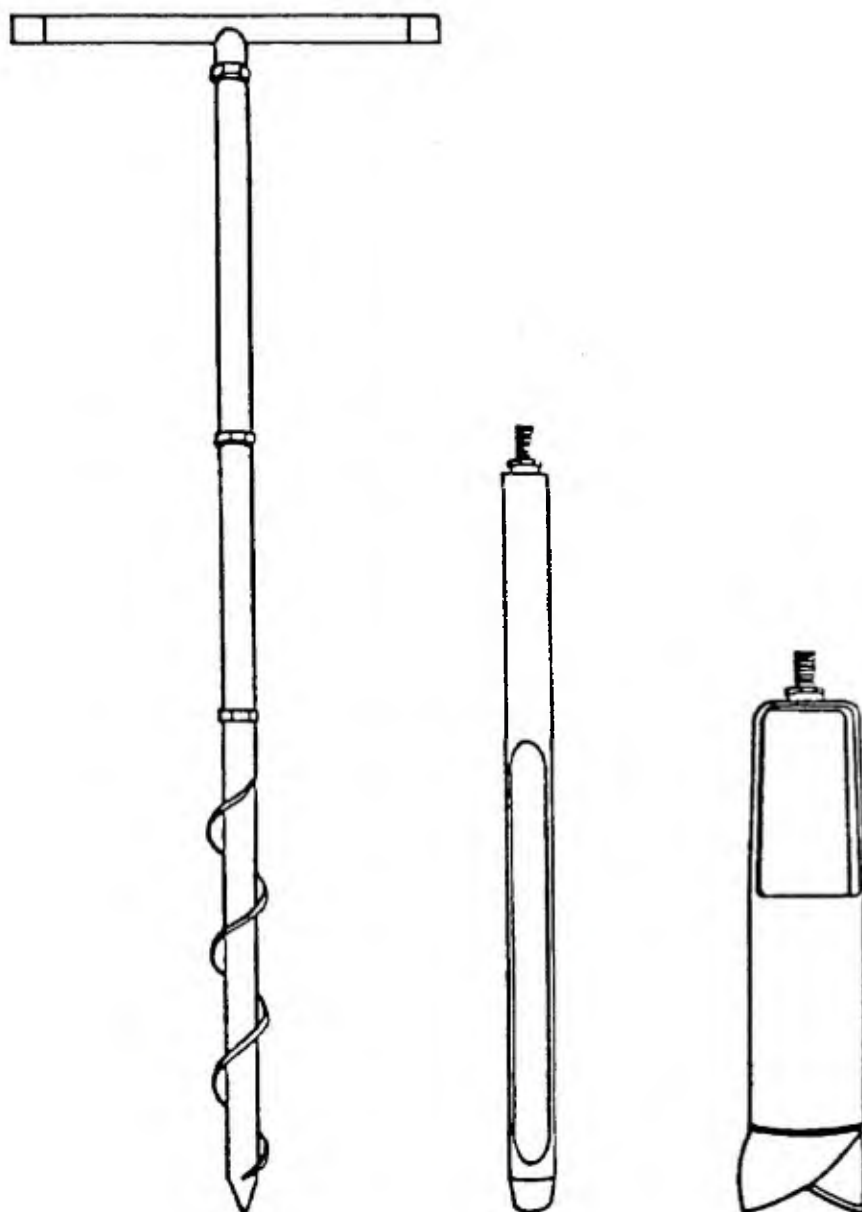


FIGURE 6-3. SCHEMATIC DIAGRAM OF AUGERS AND THIN-WALL TUBE SAMPLER

When the soil is rocky, it may not be possible to force a thin-tube sampler through the soil or sample recovery may be poor. Sampling directly from the auger may be the only viable method. Several auger types are available: bucket type, continuous-flight (screw), and posthole augers. Bucket types are good for direct sample recovery, are fast, and provide a large volume of sample. When continuous flight (screw) augers are used, the sample may be collected directly off the flights, however, this technique will provide a somewhat unrepresentative sample as the exact sample depth will not be known. The continuous-flight augers are satisfactory for use when a composite of the entire soil column is desired. Posthole augers have limited utility for sample acquisition as they are designed more for their ability to cut through fibrous, heavily rooted, swampy areas. In soils where the borehole will not remain open when the tool is removed, a temporary casing may be used until the desired sampling depth is reached.

Procedures for use:

1. Attach the auger bit to a drill rod extension and attach the "T" handle to the drill rod.
2. Clear the area to be sampled of any surface debris (twigs, rocks, litter). It may be advisable to remove the first 8 to 15 cm of surface soil from a 30-cm diameter area around the drilling location.
3. Begin drilling, periodically removing accumulated soils. This prevents accidentally brushing loose material back down the borehole when removing the auger or adding drill rods.
4. After reaching desired depth, slowly and carefully remove auger from boring. (Note: When sampling directly from auger, collect sample after auger is removed from boring and proceed to Step 10).
5. Remove auger top from drill rods and replace with a precleaned thin-wall tube sampler. Install proper cutting tip.
6. Carefully lower corer down borehole. Gradually force corer into soil. Take care to avoid scraping the borehole sides. Do not hammer the drill rods to facilitate coring as the vibrations may cause the boring walls to collapse.
7. Remove corer and unscrew drill rods.
8. Remove cutting tip and remove core from device.

9. Discard top of core (approximately 2.5 cm) which represents material collected by the core before penetrating the layer in question. Place remaining core into sample container.
10. Verify that a Teflon liner is in the cap if required. Secure the cap tightly.
11. Label the sample bottle with the appropriate sample tag. Label the tag carefully and clearly, addressing all the categories or parameters. Complete all chain-of-custody documents and record in the field logbook.

7.0 SAMPLE COLLECTION AND PRESERVATION

7.1 Sample Collection

The following procedures will be followed for sampling spent abrasive from waste piles:

1. Identify the specific pile which will be sampled.
2. Construct the sampling grid as described in Section 5.2.3.
3. Go to the random numbers table (Table 5-2) and select six numbers. Each number represents the grid unit which will be sampled.
4. Use the appropriate instrument to obtain the sample of spent abrasive. Follow the recommended procedures for use as stated in Section 6.0.
5. Collect a composite sample from each randomly selected grid. Composite sampling will consist of collecting five subsamples at two different depths (0.5 ft from the surface and 0.5 ft from the pavement) from each corner of the randomly selected grid in addition to one sample from the center for a total of 10 subsamples. The subsamples will then be composited in a tray and mixed using a stainless steel or Teflon spoon. The composited sample will be placed in precleaned polyethylene bottles for analysis.
6. From each sampling point, split the composite sample into a 500 cc subsample for the analytical laboratory and a 1000 cc subsample to archive. From 1 out of 10 sampling points, reserve 500 cc of the composite sample to send to a separate analytical laboratory. No preservation is required for the spent abrasive samples. Rinsate blanks must be preserved with a solution of nitric acid. This can be provided in the sample jar by the analytical laboratory. Holding time for the samples is 6 months, unless sampling for mercury which has a holding time of 28 days.
7. The collection of the sample does not require filling the sample jar in any special manner.
8. Discard the outer latex gloves after each sample into an appropriate container and then replace them for the next sampling event.
9. For the rinsate blank (which will be required once for every twenty samples of spent abrasive), simply run deionized water over the sampling instrument after it has been decontaminated.

10. The sampler must pay attention while filling the sample bottle for the rinsate blank due to the fact that the sample bottle will have a preservative already in it. If the bottle were to be overfilled during collection, some of the preservative would be lost resulting in insufficient preservative remaining in the bottle and an inaccurate analysis.

7.2 Sample Preservation

No preservatives will be required for the sampling of the spent abrasive itself. Only the rinsate blank (equipment washing) will require a preservative of nitric acid in order to lower the pH of the sample below 2. The analytical laboratory can provide the sample containers containing the appropriate quantities of preservative for this. Caution should be exercised when these samples are collected to prevent accidental exposure by splashing.

8.0 PERSONAL PROTECTIVE EQUIPMENT AND DECONTAMINATION

8.1 Personal Protective Equipment

8.1.1 SAMPLING

The following personal protective equipment shall be worn during the sampling of the spent abrasive:

- Tyvek suit
- Latex gloves (two pairs)
- Dust protector
- Safety glasses with splash shields (only necessary for when rinsate blanks (equipment washes) are collected).

8.1.2 CLEANING OPERATIONS (DECONTAMINATION)

The following personal protective equipment shall be worn during all cleaning operations for sampling equipment:

- Safety glasses with splash shields
- Latex gloves (water decontamination)
- Neoprene or nitrile gloves (when using solvents)
- Tyvek or cloth coveralls

8.2 Decontamination

Decontamination (cleaning) of sampling devices prior to and after use is required. Decontamination is important so that material from a previous sampling event does not contaminate subsequent samples. Decontamination should be performed as follows:

- Scrub the sampling tool with a brush in a laboratory-grade detergent (Alconox, Liquinox, or the equivalent) and tap water solution
- Rinse with water
- Rinse again with deionized water or the equivalent
- If sampling for organic contamination, rinse a final time with pesticide-grade isopropanol or pesticide-grade acetone or methanol (a minimal amount is necessary for rinsing and this should be conducted under a fume hood or in the open, but never in a closed room without adequate ventilation).
- Allow sampling tool to air dry
- Wrap in aluminum foil or other similar protective covering to avoid contamination before the next use
- No eating, smoking, drinking, chewing, or any hand to mouth contact will be permitted during cleaning operations.

The following are cleaning procedures for the glass tube thief:

- Wash thoroughly with laboratory detergent and hot water using a brush to remove any particulate matter or surface film
- Rinse thoroughly with hot tap water
- Rinse with at least a 10 percent nitric acid solution
- Rinse thoroughly with tap water
- Rinse thoroughly with deionized water
- Rinse twice with solvent and allow to air dry for at least 24 hours
- Wrap completely with aluminum foil to prevent contamination during storage

The following are cleaning procedures for stainless steel sampling equipment:

- Wash thoroughly with laboratory detergent and water with a brush
- Rinse thoroughly with tap water
- Rinse thoroughly with deionized water

- If sampling for organic contamination, rinse twice with solvent and allow to air dry
- Wrap completely with aluminum foil
- Rinse with tap water after use in the field.

Decontamination wash waters should be collected and containerized separately from solvent rinses in a 55-gallon drum. Since potentially hazardous wastes are being rinsed from sampling equipment, the collected rinse waters should be handled and sampled for hazardous constituents using a glass tube thief prior to disposal. Shop 07 should have a drum staged for the disposal of rinse waters and one for disposal of solvents. Upon filling the rinse water drum, it should be sampled for metals to determine if it must be disposed of as a hazardous waste or down the industrial drain. The contents of the solvent drum may be recycled.

9.0 SAMPLE CUSTODY, LABELING, PACKAGING, AND TRANSPORTATION

9.1 Sample Custody

The purpose of a sample chain-of-custody is to document the possession of a sample from the time of collection, through all transfers of custody, until it is delivered to the analytical laboratory. This requires that a form (Figure 9-1) be filled out in permanent ink and sent along with the samples to Shop 07. This form will contain the following minimum information:

- Sample number
- Date and time of collection
- Shipyard location
- Waste type
- Signature of collector
- Preservation
- Container type
- Analysis request
- Appropriate notations relative to sample integrity and handling practices
- Signature of all persons involved in the chain of possession
- Inclusive dates and times of possession.

9.2 Sample Labeling

A sample label is applied to a sample container before the sample of waste is collected (Figure 9-2). The label will be completely filled out with permanent ink. It will contain the following information:

[logo]		Specially Cleaned Sample Container	
		LOT NO:	
DATE	TIME	COLLECTED BY	
SAMPLING SITE			
SAMPLE TYPE			
☐ Grab ☐ Composite ☐ Other			
TESTS REQUIRED		PRESERVATIVE	

FIGURE 9-2. SAMPLE LABEL

- Sample number
- Date and hour the sample was taken
- Sampler's initials
- Sampling site
- Tests required, if known
- Preservative used, if any

9.3 Sample Packaging

The laboratory will typically provide all sample containers, preservatives, and packaging for transportation of samples. Proper preparation of sample containers for transport to the laboratory is essential to prevent breakage of containers and spillage of potentially hazardous material. The following steps will be taken during sample packaging:

- Ensure sample container is labeled correctly
- After sampling activities are complete, clean the outer surface of all sample containers
- Wrap each glass container with plastic insulating material (bubble wrap) and enclose in a plastic bag to prevent contact with other sample containers. Plastic containers also should be placed into bags, however, bubble wrap is not needed.
- Place sample containers in thermally-insulated, rigid ice chests which contain ice or reusable ice packs if the temperature must be held at 4°C. If the sample does not need to be held at 4°C, an ice chest is not required. However, an ice chest is a lightweight, rigid, and easily secured container in addition to being thermally efficient.
- Ensure the chain-of-custody forms are filled out and secure the inside the sample chests. Packers should retain one copy.

9.4 Sample Transportation

Transport samples to the laboratory as soon as possible after collection.

10.0 SAMPLE QUALITY ASSURANCE AND QUALITY CONTROL

10.1 Rinsate Blanks (Equipment Washes)

Equipment washes serve as checks of field decontamination procedures. They are obtained after final wash and decontamination of equipment by pouring reagent-grade water into/through/over a decontaminated piece of sampling equipment. The water is collected in appropriate sample containers and transported to the laboratory with other samples. The equipment blanks are analyzed in the same manner as the field samples. Equipment blanks should be collected prior to each sampling event at each sampling site. However, once good equipment decontamination technique (equipment blanks are "clean") has been demonstrated, the frequency of equipment wash samples may be reduced to an occasional basis. Initially, one rinsate blank (equipment wash) will be collected for every twenty samples taken.

10.2 Laboratory Quality Control and Certification

Laboratory quality control procedures are instituted to ensure the reliability of analytical data obtained throughout the sampling effort. Procedures include the analysis of laboratory samples to measure the accuracy and precision of laboratory procedures. A laboratory duplicate should typically be analyzed one time in twenty samples. Any analytical laboratory used should have current certification from the state of California for performing all the necessary chemical analyses.

10.2.1 MATRIX SPIKE ANALYSIS

Matrix spike analyses are performed to assist the accuracy of laboratory methods. Spiked samples are used to determine if chemical interferences are occurring. One spike analysis per sample set is generally adequate.

10.2.2 MATRIX SPIKE DUPLICATES

Matrix spike duplicates are used to evaluate the reproducibility of the analytical procedures. A field sample is analyzed and the results are compared to the original matrix spike sample test results. In general, this is only necessary for large numbers of samples (>30).

10.2.3 METHOD BLANK TESTS

Method blank tests are performed in the laboratory by analyzing distilled, deionized water for all analytical methods employed by the laboratory. Method blanks are analyzed for each matrix to verify that laboratory-induced contaminants are identified and distinguished from environmental contaminants of concern.

APPENDIX B

State Environmental Regulatory Agencies and Other Sources of Information on Recycling

HAZARDOUS WASTE CONTACTS

ALABAMA

Alabama Dept of Environmental Management
Land Division
1751 Federal Drive
Montgomery, AL 36130
334-271-7730

ALASKA

Dept. of Environmental Conservation
410 Willoughby Avenue, Suite 105
Juneau, AK 99801-1795
Program Manager: 907-465-5150
Northern Regional Office (Fairbanks): 907-451-2360
South-Central Regional Office (Juneau): 907-563-6529
Southeast Regional Office (Juneau): 907-465-5350

ARIZONA

Arizona Dept. of Environmental Quality
Waste Programs Bureau
3033 North Central Avenue
Phoenix, AZ 85012
602-207-2300

ARKANSAS

Dept. of Pollution Control and Ecology
Hazardous Waste Division
P.O. Box 8913
8001 National Drive
Little Rock, AR 72219-8913
501-562-7444

CALIFORNIA

California EPA
Dept. of Toxic Substances Control
400 P Street, 4th Floor
P.O. Box 806
Sacramento, CA 95812-0806
916-322-0504

California EPA
State Water Resources Control Board
Water Resources Control Board
P.O. Box 100
Sacramento, CA 95812-0100
916-657-2390

COLORADO

Public and Environment Dept.
Hazardous Materials and Waste Management Division
4300 Cherry Creek Drive South
Denver, CO 80222
303-692-3300

CONNECTICUT

Dept. of Environmental Protection
Waste Management Bureau
Waste Engineering and Enforcement Division
79 Elm Street
Hartford, CT 06106
203-424-3023

Connecticut Resource
Recovery Authority
179 Allyn Street, Suite 603
Professional Building
Hartford, CT 06103
203-549-6390

DELAWARE

Dept. of Natural Resources and Environmental Control
Division of Air and Waste Management
Hazardous Waste Office
89 King's Highway
P.O. Box 1041
Dover, DE 19903
302-739-3689

DISTRICT OF COLUMBIA

Dept. of Consumer and Regulatory Affairs
Environmental Regulation Administration
Pesticides and Hazardous Waste Management Branch
2100 Martin Luther King Avenue, SE, Suite 203
Washington, DC 20020
202-645-6617

FLORIDA

Environmental Protection Dept.
Waste Management Division
Solid and Hazardous Waste Bureau
3900 Commonwealth Boulevard
Tallahassee, FL 32399
904-488-0300

GEORGIA

Georgia Dept. of Natural Resources
Environmental Protection Division
Hazardous Waste Management Branch
Floyd Towers East, Suite 1154
205 Butler Street, SE
Atlanta, GA 30334
404-656-7802

HAWAII

Dept. of Health
Solid and Hazardous Waste Branch
5 Waterfront Plaza, Suite 250
919 Ala Moana Boulevard
Honolulu, HI 96813
808-586-4225

IDAHO

Dept of Health and Welfare
Division of Environmental Quality
280 North 8th Street
Boise, ID 83720
208-334-5840

ILLINOIS

Energy and Natural Resources Dept.
Solid Waste and Renewable Resources Division
325 West Adams Street, Room 300
Springfield, IL 62704
217-785-2800

INDIANA

Dept. of Environmental Management
Office of Solid and Hazardous Waste
100 North Senate Avenue
Indianapolis, IN 46206
317-232-3210

IOWA

Dept. of Natural Resources
Waste Management Assistance Division
Wallace State Office Building
900 East Grand
Des Moines, IA 50319
515-281-8975

KANSAS

Dept. of Health and Environment
Bureau of Waste Management
Forbes Field, Building 740
Topeka, KS 66620
913-296-1612

KENTUCKY

Natural Resources and Environmental Protection Cabinet
Division of Waste Management
18 Reilly Road
Frankfort, KY 40601
502-564-4245

LOUISIANA

Dept. of Environmental Quality
Solid and Hazardous Waste Division
11720 Airline Highway
Baton Rouge, LA 70817
504-765-0249

MAINE

Dept. of Environmental Protection
Bureau of Hazardous Materials and Solid Waste Control
State House Station #17
Augusta, ME 04333
207-289-2651

MARYLAND

Environment Dept.
Waste Management Administration
2500 Broening Highway
Baltimore, MD 21201
410-631-3304

MASSACHUSETTS

Dept. of Environmental Protection
Hazardous Waste Division
One Winter Street, 5th Floor
Boston, MA 02108
617-292-5853

MICHIGAN

Michigan Dept. of Natural Resources
Waste Management Division
P.O. Box 30241
Lansing, MI 48909
517-373-2730

MINNESOTA

Pollution Control Agency
Hazardous Waste Division
520 Lafayette Road North
St. Paul, MN 55155
612-297-8502

MISSISSIPPI

Dept. of Environmental Quality
Division of Solid and Hazardous Waste Management
P.O. Box 10385
Jackson, MS 39289
601-961-5047

MISSOURI

Dept. of Natural Resources
Waste Management Program
P.O. Box 176
Jefferson City, MO 65102
314-751-3176
Missouri Natural Resources Hotline: 800-334-6946

MONTANA

Dept. of Health and Environmental Sciences
Waste Management Division
Cogswell Building, Room B 201
Helena, MT 59620
406-444-1430

NEBRASKA

Environmental Quality Dept.
P.O. Box 98922
Lincoln, NE 68509
402-471-2186

NEVADA

Conservation and Natural Resources Dept.
Division of Environmental Protection
Waste Management Program
123 West Nye
Carson City, NV 89710
702-687-4670

NEW HAMPSHIRE

Dept. of Environmental Services
Waste Management Division
Health and Welfare Building
6 Hazen Drive
Concord, NH 03301
603-271-3406

NEW JERSEY

Dept. of Environmental Protection and Energy
Solid Waste Management
401 East State Street, CN-423
Trenton, NJ 08625
609-530-8591

NEW MEXICO

Environmental Improvement Division
Hazardous Waste Bureau
P.O. Box 26110
Santa Fe, NM 87502
505-827-2775

NEW YORK

Dept. of Environmental Conservation
Division of Hazardous Substances Regulation
50 Wolf Road, Room 229
Albany, NY 12233
518-457-6934
SQG Hotline: 800-462-6553

NORTH CAROLINA

Dept. of Environmental, Health, and Natural Resources
Hazardous Waste Section
P.O. Box 27687
Raleigh, NC 27611
919-715-4140

NORTH DAKOTA

Dept. of Health
Consolidated Laboratories
Division of Waste Management
P.O. Box 5520
1200 Missouri Avenue, Room 302
Bismark, ND 58502
701-328-5166

OHIO

Ohio EPA
Division of Hazardous Waste
P.O. Box 1049
Columbus, OH 43216
614-644-2917

OKLAHOMA

Environmental Quality Dept.
Waste Management Division
1000 NE Tenth Street
Oklahoma City, OK 73117
405-271-7041

OREGON

Dept. of Environmental Quality
Hazardous Waste Division
811 SW Sixth Avenue
Portland, OR 97204
503-229-6585

PENNSYLVANIA

Dept. of Environmental Resources
Bureau of Waste Management
Director's Office
P.O. Box 2063
Harrisburg, PA 17105
717-787-9870

RHODE ISLAND

Dept. of Environmental Management
Division of Air and Hazardous Materials
291 Promenade Street
Providence, RI 02908
401-277-4700

SOUTH CAROLINA

Dept. of Health and Environmental Control
Bureau of Solid and Hazardous Waste Management
2600 Bull Street
Columbia, SC 29201
803-734-5202

SOUTH DAKOTA

Dept. of Environment and Natural Resources
Office of Waste Management
500 East Capital Avenue
Pierre, SD 57501
605-773-3351

TENNESSEE

Environment and Conservation Dept.
Solid Waste Management Division
401 Church Street, 21st Floor
Nashville, TN 37248
615-532-0780

TEXAS

Natural Resource Conservation Commission
Industrial and Hazardous Waste Division
P.O. Box 13087
Capital Station
Austin, TX 78711
512-239-2324

UTAH

Dept. of Environmental Quality
Division of Solid and Hazardous Waste
P.O. Box 144810
Salt Lake City, UT 84114
801-538-6170

VERMONT

Natural Resources Agency
Environmental Conservation Dept.
Hazardous Material Division
103 South Main Street
Waterbury, VT 05676
802-241-3888

VIRGINIA

Natural Resources Office
Environment Quality Dept.
629 East Main Street
Richmond, VA 23219
804-762-4020
Hazardous Waste Hotline: 800-552-2075

WASHINGTON

Dept. of Ecology
Solid and Hazardous Waste Program
P.O. Box 47600, Row 6, Building 4
Olympia, WA 98504
360-407-6103

WEST VIRGINIA

Environmental Protection Bureau
Waste Management Division
1356 Hansford Street
Charleston, WV 25301
304-558-5929

WISCONSIN

Dept. of Natural Resources
Solid and Hazardous Waste Management
P.O. Box 7921
Madison, WI 53707
608-266-1327

WYOMING

Dept. of Environmental Quality
Solid Waste Management Division
Herschler Building
122 West 25th Street
Cheyenne, WY 82002
307-777-7752

**ADDITIONAL SOURCES
OF INFORMATION**

1. Phone & Hotline Information

- RCRA/Superfund Hotline
1-800-424-9346 (in Washington, DC 260-3000)
- EPA Small Business Ombudsman Hotline
1-800-368-5888 (in Washington, DC 557-1938)
- National Response Center
1-800-494-8802 (in Washington, DC 260-2675)
- Transportation of Hazardous Materials
202-366-4488
- Toxic Substance Control Act (TSCA) Assistance Service
202-554-1404
- Center for Hazardous Materials Research (CHMR) Hotline
1-800-334-2467

2. EPA Documents

- EPA/530-SW-86-019, September 1986, *Understanding the Small Quantity Generator, Hazardous Waste Generator.*
- EPA/530-SW-037, November 1986, *Solving the Hazardous Waste Problem — EPA's RCRA Program.*

3. *Journal of Protective Coatings & Linings* (available from Technology Publishing Co., 2300 Wharton St., Suite 310, Pittsburgh, PA 15203 [800-837-8303])

4. Other Publications

- *Bridge Paint Removal, Containment & Disposal*, Synthesis Report 20-05/20-09, 1992. Transportation Research Board, 2101 Constitution Ave., Washington, DC 20418
- *Removal of Lead-Based Bridge Paints*, NCHRP Report 265, December 1983, Transportation Research Board.
- *Industrial Lead Paint Removal Handbook*, SSPC 91-18, November 1991. Available from SSPC, 4400 Fifth Ave., Pittsburgh, PA 15213.

APPENDIX C

California Environmental Protection Agency
Hazardous Waste Management Program
Management Memo EO-95-010-MM
"Use Constituting Disposal"
Dated August 1995

HAZARDOUS WASTE MANAGEMENT PROGRAM MANAGEMENT MEMO

MANAGEMENT MEMO #: EO-95-010-MM

TITLE: USE CONSTITUTING DISPOSAL

AFFECTED PROGRAMS: Hazardous Waste Management Program
Site Mitigation Program

ISSUE:

The Department of Toxic Substances Control (DTSC) is now developing regulations to address the "use constituting disposal" restriction as it pertains to recyclable materials that are non-RCRA hazardous wastes in section 25143.2(e)(2) of the Health and Safety Code (HSC). A "non-RCRA" waste is hazardous waste that is regulated in California but is not a Resource Conservation and Recovery Act (RCRA) waste. A RCRA hazardous waste is any waste identified as a hazardous waste in Part 261, Subchapter I, Chapter 1 of Title 40 of the Code of Federal Regulations (40 CFR). The "use constituting disposal" restriction affects the eligibility of recyclable materials for the exclusions and exemptions provided under HSC section 25143.2. The purpose of this management memo is to provide interim guidance on how to interpret "use constituting disposal," and therefore determine if a waste is subject to regulation pursuant to HSC section 25143.2(e)(2), until the regulations are adopted.

BACKGROUND:

HSC section 25143.2 addresses exclusions and exemptions for recyclable materials that are managed in a specified manner. Note that a recyclable material is defined as a hazardous waste that is capable of being recycled.¹ HSC section 25143.2 also lists conditions under which the recyclable materials must be fully regulated as hazardous wastes, regardless of the exclusions from classification as a waste and the exemptions from facility permitting requirements granted in this section. One such condition is when the materials are "used in a manner constituting disposal." This restriction is addressed separately for RCRA wastes and non-RCRA wastes.

Under California law, there is no definition for "use constituting disposal." The U.S. Environmental Protection Agency (U.S. EPA) has defined "use constituting disposal" to mean placing recyclable materials or products derived from recyclable

¹ Ref. HSC section 25120.5.

materials on the land.² Under federal regulations, recyclable materials that are used in a manner constituting disposal are subject to regulation as solid wastes. At the same time, the U.S. EPA does not currently regulate products containing recyclable materials that are placed on the land if the recyclable materials have undergone a chemical reaction in producing the product so as to be physically inseparable from the product and the product meets the applicable treatment standards (or applicable prohibition levels where no treatment standards have been established) in subpart D, part 268, 40 CFR.

Since 1987, the DTSC has applied a set of criteria to recyclable materials placed on the land in determining whether or not such materials are "used in a manner constituting disposal." If these criteria are met, the recyclable materials are not regulated pursuant to HSC section 25143.2(e)(2) and may be eligible for the exclusions and exemptions under HSC section 25143.2 (b), (c) or (d). **The DTSC's criteria apply only to non-RCRA wastes.** The DTSC is currently writing regulations to address the issue of recyclable materials that are placed on the land ("use constituting disposal"). This management memo clarifies the criteria applied by the DTSC pending adoption of these regulations.

ACTION:

The following, which applies only to non-RCRA wastes, is the DTSC's present interpretation of the "use constituting disposal" restriction, i.e., of which recyclable materials are subject to regulation, in HSC section 25143.2(e)(2). This interpretation applies only until regulations addressing recyclable materials used in a manner constituting disposal or placed on the land are adopted.

A recyclable material that is placed on the land or used to produce a product which is placed on the land is regulated pursuant to HSC section 25143.2(e)(2) unless all applicable criteria listed below are met.

1. This criterion applies to situations where the recyclable material is used as an ingredient in the manufacture of a product. Hazardous constituents in the recyclable material whose concentrations are greater than or equal to the

² Ref. 50 Federal Register 618, January 4, 1985, and 40 CFR 266.20.

regulatory Soluble Threshold Limit Concentrations (STLCs)³ shall have chemically reacted or become physically bound so as not to leach from the product containing the recyclable material. Specifically, the hazardous constituents shall not leach out in concentrations that would exceed the applicable STLC, once the effect of dilution by other ingredients (as explained below) has been taken into account.

In order to meet this requirement, the following procedures must be used to evaluate the recyclable material and the product:

(a) Sampling and analysis:

- (1) Sampling shall be conducted according to the sampling methods described in Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 3rd edition, 1986, or one of the sampling methods listed in Appendix I, Chapter 11, Division 4.5, Title 22, California Code of Regulations (22 CCR); and
- (2) Analysis shall be conducted according to the Waste Extraction Test (WET), Appendix II, Chapter 11, Division 4.5, 22 CCR, or an alternative test method approved pursuant to 22 CCR section 66260.21

- (b) In order to demonstrate that the hazardous constituents in the recyclable material are bound in the product so that they would not exceed the applicable STLC, even when eliminating the effect of dilution by other ingredients, the following calculations must be used.

The concentration of the hazardous constituents in the final product, as determined by the WET, must be multiplied by the dilution factor inherent in combining the recyclable material with other materials. The dilution factor is calculated by dividing the weight of the final product made with the recyclable material by the weight of the recyclable material used in the product, or

³ As set forth in sections 66261.24(a)(2)(A) and (a)(2)(B), Division 4.5, Title 22 of the California Code of Regulations (22 CCR).

$$\frac{\text{weight of final product}}{\text{weight of recyclable material}} = \text{dilution factor}$$

If the ingredients in the product that are not recyclable materials contain the same hazardous constituents present in the recyclable material, the hazardous constituents in the ingredients that are not recyclable materials may be subtracted from the concentration of hazardous constituents in the final product, adjusted for dilution.

The final calculation of the hazardous constituents present in the product, as determined by taking into account the effects of dilution and, where applicable, the effects of hazardous constituents in ingredients that are not recyclable materials, must be less than the applicable STLC.

The following is an example of how these calculations can be done.

A ton of spent sandblast grit, which is hazardous due to a mean soluble lead concentration of 12 mg/L, is combined with nineteen tons of other aggregate and asphalt to produce twenty tons of asphaltic concrete. The dilution factor is thus 20 (twenty tons of final product, including the recyclable material, divided by the original one ton of recyclable material). The asphaltic concrete is then subjected to the WET and yields mean results for lead of 0.05 mg/l. This number is then multiplied by the dilution factor, 20, for a result of 1.00 mg/l. The aggregate that is not a recyclable material was tested with the WET and found to have a concentration of 0.05 mg/l lead. This concentration can be subtracted from 1 mg/l to give you 0.95 mg/l. This final calculation does not exceed the STLC for lead of 5 mg/l and therefore meets the criterion.

2. A recyclable material used as a substitute for a commercial product or a product containing a recyclable material shall not contain constituents that cause the product to exhibit hazardous characteristics pursuant to Chapter 11, Division 4.5, CCR 22, other than those constituents that are also found in the same or greater concentrations in a comparable commercial product. The only exception to this requirement is if the person claiming an exclusion obtains

the DTSC's written concurrence prior to using the recyclable material that:

- (a) the concentrations of hazardous constituents greater than those present in a comparable commercial product improve the quality of the product made from the recyclable material and do not increase the hazards to public health or the environment of that product; or
 - (b) if no comparable commercial product exists, the hazardous constituents in the recyclable material that cause the product to exhibit a characteristic of a hazardous waste are beneficial to the product and do not cause the product to pose a threat to public health or the environment.
3. The recyclable material must be used beneficially, as demonstrated by both of the following conditions:
- (a) Prior to use, the recyclable material and the product containing that material must each be certified by a qualified independent engineer registered in the state of California⁴ to meet the applicable standards or specifications for the intended use of the recyclable material or product of the American Society for Testing and Materials (ASTM), the American Association of State Highway and Transportation Officials (AASHTO), the American National Standards Institute (ANSI), the Uniform Building Code (UBC), or the standards of a government agency having jurisdiction over the construction applications of that recyclable material or product. A nationally recognized industry standard, other than those mentioned, may be used with the prior written approval of the DTSC.
 - (b) There shall be no indications of sham recycling, including, but not limited to, use of the recyclable material or a product containing a recyclable material in excess of what is necessary to accomplish its function, handling of the recyclable material in a manner inconsistent with the economic value of the

⁴ By "qualified independent engineer", we mean an engineer whose registration (e.g., civil, mechanical, structural, etc.) is appropriate for the product she/he is certifying and who is not an employee of the person claiming an exclusion or exemption pursuant to HSC 25143.2.

material, or insufficient use of the recyclable material to accomplish its function.

Non-RCRA hazardous wastes managed according to the applicable criteria above will not be regulated pursuant to HSC 25143.2(e) and may therefore qualify for the exclusions and exemptions in HSC section 25143.2 if the requirements of a specific exclusion or exemption are met and none of the other provisions of subdivision (e) apply.

Examples of recyclable materials used in products placed on the land are spent sandblast grit, contaminated soils, foundry sands, ash, and demolition wastes, which may be used, among other things, as asphalt treated road base, landfill cover material, or aggregate in Portland cement concrete or an asphaltic concrete.

Use of recyclable materials as fertilizer, soil amendment, agricultural mineral, or an auxiliary soil and plant substance, with or without combination with other materials, is not covered by this management memo and is regulated separately.⁵ Used oil is also not covered by this management memo.⁶

This management memo will stay in effect until the promulgation of regulations regarding management requirements for recyclable materials that are placed on the land, i.e., used in a manner constituting disposal, or until it is replaced by a subsequent management memo or DTSC policy.

DISTRIBUTION:

Cal/EPA Access Bulletin Board System
Hazardous Waste Management Program Policy Mailing List

ATTACHMENTS: None

⁵ Ref. Article 8, Chapter 16, 22 CCR.

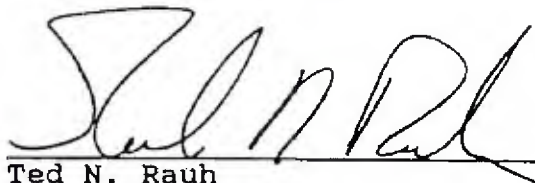
⁶ Ref. Article 13, Chapter 6.5, Division 20 of the Health and Safety Code.

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CONTACT:

Ms. Jessie Schnell
Resource Recovery Section
State Regulatory Program Division
Hazardous Waste Management Program HQ-10
Department of Toxic Substances Control
P.O. Box 806
Sacramento, California 95812-0806
Phone: (916)322-1003/CALNET 492-1003

8/18/95
Date


Ted N. Rauh
Deputy Director

APPENDIX D
Example Transportation Plan

7.0 TRANSPORTATION PLAN

This chapter discusses the plans for complying with transportation requirements of moving the grit on highways in California. Several of the requirements are as follows and discussed in the following sections:

- Each vehicle will have a tarp that is placed over the exposed portion of the grit.
- The grit will be unloaded at ARA directly into the lined storage areas.
- The drivers and hot plant employees will have initial tailgate safety meetings to discuss this project.

7.1 DRIVER TRAINING

All truck drivers will be trained and educated on the material they are handling. The drivers will meet and be provided with a packet of documents that will include the following documents.

- A map with clearly defined instructions on the route of travel
- Material Safety Data Sheets, if available, for copper and lead
- Laboratory result data sheets, if available, for analyses performed on material being carried.

7.2 STORAGE AT R&G

Upon arrival at the hot plant facility, the grit will be offloaded at the designated storage location. The grit storage area will be clearly marked and segregated from other aggregate materials at the plant.

7.3 DECONTAMINATION OF THE TRUCKS

Equipment that comes directly in contact with the grit will be decontaminated with water or wet towels. The washwater will be collected in a drum and chemically analyzed for TTLC metals and, if necessary based on the TTLC data, STLC Cu and Pb to ensure that it is nonhazardous and then dispositioned accordingly.

APPENDIX E
Example Health and Safety Plan

9.0 HEALTH AND SAFETY PLAN

9.1 KEY PERSONNEL AND RESPONSIBILITIES

- Dr. Jeffrey L. Means, Project Manager, is responsible for the overall performance and compliance with the work plan. In the event the Project Manager becomes aware of a deficiency in implementation of the Health and Safety Plan, recommends changes to the plan, or recommends changes in the interpretation of the plan, he shall take appropriate action and inform the appropriate people. Dr. Means has served as Chairperson of the Battelle Environmental Sciences Safety Committee and is currently Chairperson of the Battelle Radiological Safety Committee.
- Mr. Gregory L. Headington, Senior Research Technician, is responsible for sampling and coordinating field activities. Mr. Headington is experienced in field sampling including involvement in numerous field sampling programs and satisfactory completion of the 40-hour Hazardous Waste Training Course plus annual 8-hour refresher courses.
- Mr. Jerry Hansen, Owner and Operations Manager, will be responsible for overseeing all operations conducted at the ARA processing plant.
- Mr. Jeffery C. Heath, the NCEL Project Officer, is responsible for the overall coordination between HPA, the contractors, the Navy, and regulatory agencies.

9.2 JOB HAZARD ANALYSIS

The job hazard analysis is provided to ensure all possible risks are understood before any work is conducted.

9.2.1 Primary Health Hazards

The sandblasting grit contains a variety of metals in low concentrations, most importantly the following:

- Zinc up to 2,500 ppm
- Copper up to 2,500 ppm
- Barium up to 340 ppm
- Lead up to 330 ppm
- Nickel up to 270 ppm
- Total chromium up to 180 ppm
- Hexavalent chromium up to 14 ppm.

The most significant of these in terms of possible health effects are hexavalent chromium and lead. Also, the treated grit pile has alkaline pH, up to 12-12½, due to the stabilization chemicals that were added and contains reactive sulfide in low ppm concentrations, which could be converted to H₂S if exposed to a strong acid.

The primary potential health hazards associated with exposure to the chemical substances identified in detectable concentrations are provided in Table 9-1. Applicable employee 8-hour permissible exposure limits (PEL) and TLVs are also indicated in Table 9-2 where available. The applicable PELs are defined by the United States Department of Labor, Occupational Safety and Health Administration (OSHA), in the volume identified in the Code of Federal Regulations (CFR), Title 29, Labor, Section 1910.1000, or other appropriate sections.

The TLVs listed are recommended by the American Conference of Governmental Industrial Hygienists. TLVs refer to airborne concentrations of substances and represent conditions during which it is believed that nearly all workers may be repeatedly exposed, 8 hours per day, day after day, for a 40-year working lifetime, without adverse effect. Because of a wide variation in individual susceptibility, however, a small percentage of workers may experience discomfort to chemical substances at concentrations equal to or below the TLV. A still smaller percentage of persons may be affected more seriously from exposures at or below the TLV due to aggravation of a pre-existing condition or development of an occupation illness. TLVs are based on the best available information from industrial experience, from human and animal studies, and when possible from a combination of the three sources.

TABLE 9-1. PRIMARY HEALTH HAZARDS AND EXPOSURE LIMITS OF
CHEMICAL SUBSTANCES DETECTED ON SUBJECT SITE

Compound	Federal OSHA Exposure Limit (gm/m ³)	ACGIH TLV (mg/m ³)	Primary Health Hazard
Barium	0.5	0.002	Dermal and nasal irritant Lung disease, suspected carcinogen
Beryllium	0.002 0.005C	0.002	Respiratory irritant, systemic toxin
Cadmium	0.2	0.05	Skin and respiratory irritant
Chromium (III)	0.5	0.5	Skin, eye, respiratory irritant; rhinitis; lung carcinogen
Chromium (VI)	0.5	0.5	Skin and eye irritant
Copper	1.0	1.0	Skin, eye, respiratory irritant; systemic toxin
Fluoride	2.5	2.5	Systemic and reproductive toxin
Lead	0.05	0.15	Mucous membrane irritant, low toxicity
Molybdenum (soluble)	5.0	5.0	Mucous membrane irritant, low toxicity
(insoluble)	15.0	10.0	
Nickel	1.0	0.1	Dermatitis, sinus and lung cancer
Vanadium	0.5	0.05	Eye and bronchial irritant, lung disease
Zinc	5.0	5.0	Irritant, low toxicity

TABLE 9-2. EXPOSURE TO CONTAMINANTS WITH 5 MG/M³ TOTAL EXPOSURE

	Conc. (mg/kg)	PEL/TLV (mg/m ³)	Exposure (mg/m ³) @ 5 mg/m ³ total dust
Aluminum	3000	10	0.015
Barium	100	0.002	0.0005
Beryllium	0.04	0.002	0.0000002
Cobalt	5	0.05	0.000025
Chromium	40	0.5	0.0002
Copper	2000	1	0.01
Iron	100000	1	0.05
Potassium	200	NE*	0.001
Magnesium	5000	10	0.025
Manganese	200	5	0.001
Molybdenum	10	5	0.00005
Nickel	70	0.1	0.00035
Lead	200	0.05	0.001
Antimony	10	0.5	0.00005
Strontium	20	NE*	0.0001
Titanium	100	NE*	0.0005
Vanadium	10	0.05	0.00005
Zinc	900	5	0.00045

* NE - None established

The time-weighted average TLV, or TLV-TWA, represents a time-weighted average exposure for an 8-hour work day, 40-hour work week. The majority of TLVs are expressed as TLV-TWAs. Certain substances have a "skin" notation following the TLV which implies that the overall exposure to a substance is enhanced by skin, mucous membrane, and/or eye contact exposure. Some substances have a ceiling value designated by the letter "C". Ceiling values should not be exceeded at any time during the work day.

9.2.2 Potential Safety Hazards at Site

Potential Safety Hazard	HPA, ARA, or Both	Required Control Measure(s)
Low clearance; objects dropped from above	ARA	Hard hats will be worn
Flying particulate	Both	Goggles and/or safety glasses shall be worn
Objects striking foot	Both	Boots shall have steel-reinforced toes
Slips, trips, falls	Both	Attempts shall be made to minimize slips, trips, and falls by providing clear footing
Formation of hydrogen sulfide gas from treated grit pile	Both	An action level of 5 ppm will be set. A hydrogen-sulfide monitoring device will be available at all times. No work will be initiated if levels are greater than 5 ppm. If hydrogen sulfide exceeds 5 ppm while working, workers will leave the area at once.

9.3 ANTICIPATED WEATHER CONDITIONS

The anticipated weather conditions at HPA and ARA during the proposed work time schedule is expected to include temperatures ranging from approximately mid 60°F to mid 80°F, with a possibility of light wind and rain.

9.4 RISK ASSESSMENT SUMMARY

The total dust exposure as a result of any project activities is not expected to approach a concentration of 5 mg/m³ as an 8-hour, time-weighted average. Even if this exposure level were reached, the exposure to the contaminants would be orders of magnitude below the TLV or PEL (whichever is lower) for the contaminant as presented in Table 9-2. See Chapter 11 for a summary of a risk screening analysis pertaining to the screening of grit and the loading of trucks with grit at the HPA.

9.5 PERSONAL PROTECTIVE EQUIPMENT

Based upon the risk assessment that exposure to airborne concentrations of metals and their salts during the collection of the samples will be orders of magnitude below the applicable TLVs, Level D personal protective equipment shall be worn by all persons entering the work site. The Level D equipment includes the following:

- Coveralls or similar protective clothing
- Steel-toed boots
- Gloves
- Safety glasses
- Hard hats when there is low clearance.

In addition, Level C equipment shall be available in the event that upgrading of the protection level is required. This equipment will include outer disposable coveralls; chemical protective gloves and boots; and negative pressure NIOSH approved, HEPA-filtered respirators in addition to Level D equipment. Level C personal protective equipment will be donned if any of the following conditions occur:

- Unusual odors are detected
- Any irritation of the eyes, nose, or throat is detected
- Significant dust is encountered.

9.6 WORK PRACTICES

The workers will remain upwind of all activities that are expected to result in the potential release of airborne contaminants. This includes emptying of the sampling device, filling the sampling bottles, loading operations, unloading operations, and roadgrinding operations.

No eating, drinking, chewing of gum, or smoking will be permitted in the work area.

Any skin contact with the contaminated or potentially contaminated grit, samples, or equipment shall be avoided. The asphalt-treated grit has been analyzed and has passed all regulatory levels. Contact with asphalt-treated grit by personnel under normal conditions should not pose any unacceptable risk.

Removal of materials from protective clothing or equipment by blowing, shaking, or any other means that could disperse contaminated materials is prohibited.

9.7 DECONTAMINATION

Sampling equipment will be decontaminated with paper towels between samples and by three wipedowns with damp paper towels. All disposable materials, including disposable gloves, paper towels, etc., will be placed in appropriately marked containers (e.g., plastic bags) and disposed as either nonhazardous or hazardous waste, as appropriate. As discussed above, plastic liners, trucks, and other heavy equipment coming in contact with the grit will be washed with water and/or wet towels. The wash water will be analyzed and dispositioned as warranted.

9.8 EMERGENCY PLANS

The Point-of-Contact at the Hunters Point Naval Station in the event of emergency is as follows:

San Francisco General Hospital - (415) 821-8111/8200
St. Luke's Hospital - (415) 864-8600/6625
Mr. Westermeyer - Hunters Point Annex Contact - (415) 822-1243
Base Security - Hunters Point Annex - (415) 641-2535/6056
Fire Department - Hunters Point Annex - (415) 822-6635
Mr. Jim Sullivan - Hunters Point Annex - (415) 395-5454
National Response Center - (800) 924-8802
EPA - Emergency Response Section - (415) 974-7511
Chemtrec (24 hours) - (800) 424-9300
Department of Toxic Substances Control, Berkeley - (510) 540-2122
San Francisco Office of Emergency Services - (415) 441-6020

The emergency care medical facility nearest the subject site is San Francisco General Hospital located at 1001 Portrero Avenue, San Francisco, California, at Portrero and 23rd Street. A map to the nearest hospital is included in Figure 9-1. The police, fire department, paramedics, and ambulance may be reached via telephone by dialing 911.

These telephone numbers shall be posted at the worksite.



FIGURE 9-1. MAP TO HOSPITAL

APPENDIX F
Example QA/QC Plan

10.0 QA/QC PLAN

The following items are the essential elements of QA/QC for this program:

Project Coordination: The field demonstration study will be under the direction of Dr. Jeff Means of Battelle. Dr. Means will be responsible for daily activities and coordination with the subcontractors throughout the program. Dr. Means will also review all data and lab book entries. Dr. Means will also convey any problems directly to the client project engineer, Mr. Jeffery C. Heath of the Naval Civil Engineering Laboratory, for corrective action as required.

Sampling Procedures: These are discussed in Chapters 2 through 5. Any variations or exceptions will be documented in laboratory record books.

Sample Custody: All sample inventories will be entered on standard chain-of-custody forms. All sample bottles will be secured with chain-of-custody tape between collection time and receipt at laboratories. Laboratories will follow standard chain-of-custody control of samples.

Calibration: Laboratory calibration will be required according to each instrument standards procedure and will include linear dynamic range calibrations.

Analytical Procedures: Methods referenced for analysis will be used as specified. Any deviations or variations will be documented.

Data Reduction and Reporting: All analytical data will be reduced by the laboratory conducting the analysis and reported to the Project Manager, Dr. Jeff Means. Data should include the complete field sample number, any assigned laboratory numbers, any observations or problems, limits of detection for method of analysis, and concentration per mass of sample analyzed. Standard

data forms or permanent record copies will be maintained for analytical traceability. The results of any spikes and replicates will also be included.

Performance and System Audits. Audits are not anticipated for this program unless reported data are incomplete.

Preventative Maintenance. Field and laboratory equipment will be maintained in a clean workable condition.

Procedures to Assess Data. All field records will be reviewed by the Project Manager or his designee. Sample inventories, chain-of-custody forms, and sample labels will be checked by a second person prior to shipment. Data will be reviewed for completeness by the Project Manager.

Corrective Action. Any inadequacies or errors will be noted and communicated to the responsible person (persons signing forms or records) for explanation as required. Any errors or corrections must be initialed and dated after a single line-through. No errors are to be corrected by tape erasing, white-out, or obliteration. All entries will be legible. Any corrections noted by the Project Manager will be made and then initialed and dated.

APPENDIX G

Example Statement of Work for Placing an ABM-to-Asphalt Recycling Contract

Statement of Work

ABM-TO-ASPHALT RECYCLING PROJECT AT HUNTERS POINT ANNEX, CALIFORNIA

1. **TITLE:** Full-scale demonstration of an asphalt solidification process.
2. **GENERAL:** The Naval Civil Engineering Laboratory (NCEL) has a requirement for a laboratory with experience in asphalt solidification of spent sandblasting grit and the cleanup of contaminated sites to characterize materials, analyze data, and evaluate processes. This work is important for evaluating the applicability of technologies for use at naval installations.

No Navy activity has the necessary in-house capability to perform the tasks specified in this work statement, and no other government laboratory or center has the capability to perform the requested work.

3. **OBJECTIVES:** The objectives of this task are to: (a) collect data on the physical and chemical characteristics of the asphalt test strips that were constructed at Hunters Point Annex (HPA); (b) conduct a roadgrinding operation on one set of these test strips to evaluate air emissions; and (c) develop a work plan for a full-scale demonstration project to evaluate the feasibility of recycling the entire 3,200 cubic yards of sandblasting grit, a hazardous waste, at HPA into asphalt concrete; (d) determine the effectiveness of sieving and milling technologies in removing debris and producing the desired particle size for recycling into asphalt concrete; (e) test and evaluate a full-scale asphalt solidification process; and (f) provide for the technology transfer of this technology for routine Navy use.
4. **SPECIFIC TASKS:** The contractor will conduct the following specific tasks:
 - a. Determine the long term effectiveness of the recycling of spent sandblasting grit into asphalt concrete during the pilot test conducted in November 1991. During the pilot test, test strips of asphalt concrete were made from grit in the covered piles at HPA. The contractor shall:
 - i. Collect approximately 9 asphalt samples, 3 each from the sulfide-treated grit, untreated grit, and control grit asphalt concrete strips, and analyze them for STLC and TTLC Cu and Pb. Physical properties such as cohesiometer and stabilometer values will be determined. Upon completion of sample collection, fog seal the permanent test strips and mark sample locations and test data on the strips.
 - ii. Install a traffic meter on the long-term test strips on Fisher Street and collect data on traffic flow.
 - iii. Develop a test plan for the roadgrinding operation to be conducted on the short-term test strips on Spear Street, including a description of roadgrinding procedures, air monitoring techniques, data evaluation, safety procedures, and schedule.

- iv. Conduct the roadgrinding, test described in specific task a.iii. above and report on the results in terms of average and maximum expected exposures of occupational and public receptors to metal-laden dust.
- b. Collect data on the chemical characteristics of additional identified blasting grit and the debris in the sandblast piles. The contractor shall:
 - i. Collect 4 wood and 4 cloth samples from the untreated grit pile and analyze them for TCLP Pb.
 - ii. Collect 3 grit samples from the untreated grit pile and analyze them for asbestos.
 - iii. Collect 6 samples of grit from the building on HPA (PA44) where there is evidence of previous blasting operations and accumulation of approximately 100 tons of grit. Analyze these samples for TTLC (all 19 metals), STLC (those metals which could exceed STLC thresholds based on TTLC results) and TCLP (metals which could exceed the TCLP thresholds based on the STLC results).
 - iv. Upon completion of sampling activity, repair the broken seams in the liners on the untreated and treated grit piles.
- c. Develop a work plan for the full-scale demonstration of asphalt recycling technology on the 3,200 cubic yards of treated and untreated grit presently stored under the two liners at HPA. This work plan shall describe expected on-site activities, including the milling of the sulfide-treated grit, sieving of the untreated grit, debris disposal activities, air monitoring, hauling procedures, schedules, grit storage at the asphalt plant, the recipe for grit-containing asphalt, a safety plan, a sampling and analysis plan, a QA/QC plan, and a risk screening analysis to predict maximum possible dust emissions during the milling and screening operations.
- d. Test the effectiveness of milling technology to reduce the particle size of the sulfide-treated grit at HPA to $\leq \frac{1}{2}$ inch. The 800-cubic yard pile of sulfide-treated grit will be prepared for recycling into asphalt concrete. Data to be collected for the Field Demonstration Report (FDR) includes labor requirements, processing rate, product uniformity and size distribution, energy consumption, quantity of reject material produced, problems encountered, and work logs.
- e. Test the effectiveness of sieving and/or screening technology to remove debris from the untreated grit pile at HPA and prepare the approximately 2400-cubic yard untreated grit at HPA for recycling into asphalt concrete. Data to be collected for the FDR includes labor requirements, processing rate, product uniformity and size distribution, quantity of debris generated, problems encountered, and work logs.
- f. Dispose of nonhazardous and hazardous debris or reject from the operations in tasks (d) and (e) above in accordance with applicable state and federal regulations. For cost-estimating purposes, assume disposal of 300 tons of nonhazardous debris and 100 tons of hazardous debris. Actual quantity of debris and reject shall be included in the FDR, along with copies of all shipping manifests.
- g. Conduct on-site air monitoring during the milling and screening operations of a period of 3 days or until dust levels from 3 consecutive days of measurements are shown to be less than 5 mg/m^3 . The results of the air monitoring shall be included in the FDR.

- h. Evaluate the effectiveness of an asphalt solidification process during a full-scale demonstration. This task includes:
- i. Loading approximately 3,000 cubic yards of sulfide treated and untreated spent grit (after milling/sieving) at HPA into trucks and conducting on-site air monitoring during the loading operations at HPA for dust levels for a period of 3 days or until 3 consecutive days of measurement are shown to be less than 5 mg/m^3 . The contractor shall provide dust suppression for fugitive dust during loading. Results of the air monitoring shall be included in the FDR.
 - ii. Transport the grit to a Bay-area asphalt concrete manufacturer. Decontaminate the trucks at the conclusion of the project. Copies of the shipping manifests and weight tickets shall be included in the FDR.
 - iii. Hire a suitable Bay-area asphalt concrete manufacture to recycle the approximately 3,000 cubic yards of sandblasting grit into the production of asphalt concrete meeting Caltrans criteria. This effort will be conducted in compliance with applicable state, local, and federal regulations and a detailed workplan prepared under a separate effort. Strict adherence to the asphalt mix design determined during bench scale testing and pilot testing shall be maintained throughout the recycling project. Data to be collected includes processing rate, mix temperature, mix excursions, composition of additive aggregates and asphalt, actual processing time, labor requirements, problems encountered, and work logs.
 - iv. Conduct periodic chemical analyses to ensure that the asphalt concrete containing sandblasting grit conforms to STLC and TTLC criteria and Caltrans asphalt specifications. For costing purposes, assume 1 sample per every 2,500 tons of asphalt produced (approximately 18 samples over the entire project). Results of these analyses will be included in the FDR.
 - v. Upon completion of the full-scale demonstration, identify methods to decontaminate the liner as necessary for reuse at other sites and conduct the decontamination demonstration.
- i. Obtain any necessary Federal, State, and local permits for the performance of the tasks described in tasks 4a - 4h above.
- j. Prepare a Field Demonstration Report (FDR) summarizing the results of tasks 4a - 4i and make recommendations for the proper implementation of asphalt solidification technology for future Navy sandblasting grit recycling projects. The report should document all tasks and events that have occurred in the HPA asphalt demonstration and include all data in appendices or by reference to other published reports. The contractor shall evaluate the data to determine cost effectiveness of the process and environmental impacts of asphalt solidification of hazardous waste. Statistical analysis of the sampling data will be performed to determine actual solidification efficiencies, and summarized in easy to read charts, graphs, and tables where necessary.
- k. Prepare a 4-page asphalt solidification technology data sheet and a slide presentation discussing the project and its effectiveness.

5. REPORTING REQUIREMENTS: The contractor will provide the following:

- a. Oral reports as requested by the Point of Contact (POC) upon demand.
 - b. Monthly written summary of activities will be submitted to the POC. The monthly status report shall contain the schedule for the tasks outlined in section 4 above, actual status of each task, any changes to the schedule needed, progress made during the month, explanation of any delays, and expected progress for the next month. The report should contain a cost summary outlining the total budget estimated and actual expenses, cost for the previous month, total cost to date, current balance, and whether the project is within budget.
 - c. A draft test plan for the roadgrinding test containing the information described in section 4a, above. The draft test plan is due 60 days after contract award. Government comments will be returned 70 days after receipt of the draft. Final version of the document is due 15 days after receipt of final review comments from the Navy.
 - d. A draft work plan for the full-scale asphalt demonstration containing the information described in section 4c, above. The draft work plan is due 90 days after contract award. Government comments will be returned 70 days after receipt of the draft. Final version of this document is due 15 days after receipt of final review comments from the Navy.
 - e. A draft and final Field Demonstration Report (FDR) containing the information described in section 4j above. The draft report is due 9 months after contract award. Government comments will be returned 90 days after receipt of the draft. The final report is due 30 days after receipt of review comments.
 - f. A draft and final technology transfer sheet report and slide show containing the information described in section 4k above. The draft technology transfer sheet is due 10 months after contract award. Government comments are due 60 days after receipt of the draft. The final report and slide show is due 30 days after receipt of final review comments.
 - g. The contractor shall provide a 3½" or 5-¼" floppy disk containing each final report described in Section 5 in WordPerfect 5.1 or ASCII format to the POC within 30 days of completion of the services.
 - h. Four copies of each draft report and four copies of each final report shall be submitted to NCEL, Code L71. One copy of each final report shall be submitted to Battelle, RTP Office. One copy of the draft and final slide show shall be submitted to NCEL, Code L71.
6. QUALIFICATIONS REQUIREMENTS: The laboratory chosen for this work will have experience with grit solidification, geochemistry, and waste characterization, and have capabilities in analytical chemistry and engineering.
7. PLACE AND PERIOD OF PERFORMANCE
- a. This task will be completed within 14 months of contract initiation.
 - b. Approximately 80 working days for research scientist(s) or engineer(s) and 110 days of technician time are required for this study. Subcontractors will be needed for an analytical laboratory certified in the state of California, a firm to repair the liners, a milling firm, a mechanical screening firm, a trucking firm, a hazardous waste hauler, and a San Francisco Bay

asphalt contractor. It is expected that the contractor will need to rent the following equipment, not available for this project within the Navy:

- Roadgrinder Test Equipment -1 day
- Traffic Meter - 4 months
- Front End Loader(s) - 20 days
- End Dump Truck(s) - 120 days
- Water Truck - 3 days
- Vibrating Screen - 20 days
- Grinder/mill to reduce particle size of treated grit - 20 days

The Navy has explored other options and has found that rental of this equipment is the most cost efficient option for completing this task. The traffic meter described above may be purchased instead of rented if no rental is available or purchasing is more cost efficient. If the traffic meter is purchased, the traffic meter becomes the property of NCEL at the completion of the task.

- c. All work will be performed at the contractor's facilities with the exception of the work that is subcontracted as described in section 7b.
- d. Ten (10) round trips to San Francisco, California (and vicinity) are anticipated for this study.

8. RESTRICTIONS: There is no known conflict of interest associated with this task.

9. SECURITY CLEARANCE: No clearance required.

10. POINT OF CONTACT:

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