FLOWABLE SLURRY : PART 1

By

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FLOWABLE SLURRY: PART 1

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EXECUTIVE SUMMARY

This research project is the result of funding made available by the UWS Solid Waste Research Council (Ms. Eileen Norby, Solid Waste Management and Research Program Coordinator, Madison, WI); and other industrial co-sponsors. This report contains information collected and analyzed on flowable slurry, its constituent materials and uses, foundry by-products, and leachate characteristics of fly ash and foundry sand slurry.

This report includes Phase I of the project - Literature search and information gathering. It is divided into four main parts. The first part deal with introduction, foundry processes, materials, and waste generated. The second part is a review of flowable slurry, constituent materials, tests, and uses. The third part includes a review of methods of leaching, and works performed on leachate testing of foundry sand and fly ash. The final part consists of a list of references relevant to this project.
The authors would like to express sincere thanks to UWS Solid Waste Research Council for providing financial support for this study. Special appreciation is expressed to Ms. Eileen Norby for her interest in this project.

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CHAPTER 1
INTRODUCTION

1.1 GENERAL

This report gives an overview of the materials used for the flowable slurry, and the work done at the Center for By-Products Utilization (CBU). The development of a new construction material called flowable slurry (a.k.a. Manufactured Dirt) has been under development at CBU since 1989 [1]. Manufactured Dirt, primarily containing fly ash, based upon the initial project [1] has been approved by the WI-DNR for construction projects; and, it is being used in Wisconsin. At this stage, the main emphasis is to study the leaching characteristics of this product.

An extensive literature review was carried out to study what has been reported in this area. The availability of industrial by-products materials such as fly ash and foundry sand, which can be economically utilized in preparing flowable slurry mixes, are discussed. Also information on the characteristics of foundry sand and fly ash that make them a suitable raw material for flowable slurry are discussed. The development of this product will help in utilizing a major portion of the 700,000 tons/year of used foundry sand and additional about 500,000 tons of fly ash and bottom ash that is dumped in Wisconsin landfills.
Flowable slurry is used as a backfill material for utility trenches containing ducts and/or pipes, around manholes, excavations on streets, foundation backfill for buildings, abandoned sewers, water tanks, and other underground facilities. This material is engineered so that it is easy to excavate, at a later age, if required. Therefore, the design compressive strength is maintained at 50 to 100 psi at the age of 28 days.

However, if this material is used as planned, then it has to be established that it is not hazardous and does not contaminate the ground water. State and federal government agencies have maximum limits on various chemical elements that may leach from this product. TCLP is the accepted method to analyze the leachates.

The laboratory work consists of designing and preparing various mixes of flowable slurry that would be suitable for filling underground facilities. The strength, setting and hardening, plastic shrinkage and drying shrinkage properties, and permeability were studied to evaluate the performance of this material. Also the TCLP test was conducted on over a dozen of selected samples.

1.2 OBJECTIVE AND SCOPE
The objective of this project was to study the leaching characteristics of flowable slurry containing used foundry sand with or without fly ash.

The scope of this research project was divided into three phases: Phase I: Published Literature Review; Phase II: Laboratory Investigations; and, Phase III: Market Analysis.

Phase I: Literature search was undertaken to collect the information about leachate testing methods, their acceptance by professionals (researchers, government agencies, etc.) in terms of reliability, reproducibility, practicality, etc., and construction projects using flowable slurry.

Phase II: This laboratory investigation phase included preparation of the flowable slurry in the laboratory, physical and mechanical properties testing, and leachate testing.

More than two dozen different flowable slurry mixes were made in the CBU laboratory at UW-Milwaukee. The mix which was taken as control had 100% Class F fly ash and no foundry sand in it. The other mixes were prepared by replacing varying amounts of fly ash with foundry sands from two different sources. Leachate analysis was conducted for the basic "dry" materials as well as the slurry "cake" itself.
2.1 INTRODUCTION

During the last two decades federal and state agencies have paid increasingly greater attention to industrial safety, pollution, and waste management. The Federal Resource Recovery and Conservation Act passed in 1976 regulating waste disposal. It made things more difficult for industrial waste disposal. Foundry industry, along with other industries, therefore, had to reevaluate their standard practice of waste disposal. These industries had to find alternative uses for their waste material [2]. Foundry sand was given a "Special Waste" status due to its bulk volume. Landfill space is becoming scarce throughout the United States. Also the tipping fee has been rising at a high rate. Though many possible uses for foundry sand were attempted, their use as a construction material was found promising. However, only limited work has been done in this area [2].

2.2 FOUNDRY PROCESS AND BY-PRODUCT MATERIALS

In a foundry, the main process is melting metal or alloys and pouring this it in molds to get the desired product. The process and product
may vary based on the source of the material and the final product.

The basic processing steps in production of metal castings are core making, molding, melting, cleaning, and inspecting. Figure 2.1 shows an iron and steel foundry process flow and emission sources [3]. The estimated pounds of foundry waste per ton of metal casting is shown in Table 2.1.

Table 2.1

Estimated Pounds of Foundry Waste Per Ton of Metal Castings Produced [2]

<table>
<thead>
<tr>
<th>Waste Type</th>
<th>Malleable</th>
<th>Ductile Iron</th>
<th>Gray Iron</th>
<th>Steel</th>
<th>Aluminum</th>
<th>Brass and Bronze</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refractories</td>
<td>40</td>
<td>50</td>
<td>80</td>
<td>140</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>System Sand</td>
<td>1,250</td>
<td>2,190</td>
<td>670</td>
<td>2,790</td>
<td>280</td>
<td>100</td>
</tr>
<tr>
<td>Core Sand</td>
<td>310</td>
<td>100</td>
<td>30</td>
<td>550</td>
<td>1,370</td>
<td>140</td>
</tr>
<tr>
<td>Cleaning Room Waste</td>
<td>60</td>
<td>90</td>
<td>80</td>
<td>270</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Slag</td>
<td>100</td>
<td>400</td>
<td>220</td>
<td>350</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Coke Ash</td>
<td>--</td>
<td>60</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Dust Collector Discharge</td>
<td>20</td>
<td>--</td>
<td>190</td>
<td>30</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>5</td>
<td>--</td>
<td>110</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>TOTALS</td>
<td>1,785</td>
<td>2,890</td>
<td>1,380</td>
<td>4,135</td>
<td>1,695</td>
<td>315</td>
</tr>
</tbody>
</table>
After a number of repeated use the characteristics of the sand used for molds change and are hence thrown out. The following are the main types of foundry waste sands.

**Molding Sand (a.k.a. Green Sand):**

Molding sand is compacted around a pattern similar to the casting to be made. The pattern is removed and molten metal is poured in its place. The most commonly used molding sand is the green sand. Inert silica is the main constituent of the green sand. 4-10 percent of western or southern Bentonite clay is often used as a binder in the green sand. It provides strength and plasticity. Carbonaceous materials are also added sometimes to improve certain properties such as surface finish, easier cleaning, etc.

After a number of uses the molding sand is thrown out as a waste. It generally contains discarded metal fibers.
**Core Sand:**

Core sands are used to produce cavities in the finished product. This is not possible by the normal molding operation. Similar to the molding sand it is also essentially silica with certain binders. The core sand should have sufficient strength and has to be easily collapsible. The binder used could be organic or inorganic. Organic binders could be oil, synthetic, cereal protein, pitch, or wood flour. Oil binders are widely used in the US foundries.

The core sands are exposed to very high temperatures when the metal is poured. They may partially or fully degrade. When its binder is fully degraded, they may not be reused. They are called core butts, or hardened core sands. These may have to be broken down to be reused; or may be directly thrown away in a landfill. Molding sand and core sand contribute the major portion of the waste sand produced in the foundry [5].

**Cleaning Room Sand:**

After the castings are removed from molds they are shaken and cleaned. Cleaning room material includes sand, grinding material, steel shots, etc. Steel shots are small steel
pellets that are "shot" on to the casting to remove excess sand and to obtain the desired surface finish.

Other foundry wastes include slag and refractories. Slag is a complex by-product material that results from melting a raw material and/or metal ores. Slags are usually removed with the use of fluxes or flocculents. Refractories are used to line furnaces and metal pouring laddles. It is capable of withstanding high temperatures. Different types of refractories are used in the industry. After several uses, they lose their properties and are discarded.
CHAPTER 3

FLOWABLE SLURRY

3.1 INTRODUCTION

Flowable slurry can be defined as cementitious material which is in a flowable state, easy to place, and has a specified compressive strength of 1200 psi or less at 28 days. It is used for low-strength, primarily non-structural, applications. In most cases its desired strength is similar to the surrounding soil [1]. The main uses of this material are to backfill trenches containing ducts, pipes, etc., and around manholes and similar excavations in streets or backfilling of foundation excavations. It can also be used to fill abandoned tunnels, sewers, or other underground facilities.

3.2 FLY ASH SLURRY

Naik et. al [1] has discussed tests performed on fly ash slurry at the Center for By-Products Utilization. A total of six mixes were prepared and tested. Typical mixture proportion and field test data are shown in Table 3.1. Fresh slurry was tested for flow, ambient air and slurry temperature, and density. From each mix, cylinders were prepared to measure compressive strength at different ages. The cylinder surfaces were inspected periodically for condition of
set, settlement, bleed water, and shrinkage cracks. Compressive strength test results are shown in Table 3.2. Based on these results it was concluded that a cement content of about 75 lb/yd$^3$ is necessary to produce compressive strength greater than 50 psi at 28 days. The flowability of slurry can be varied by slightly increasing the amount of water added.

Table 3.1
Mix Proportions and Field Test Data for Flowable Fly Ash Slurry [1]

<table>
<thead>
<tr>
<th>Mix Number</th>
<th>S-1</th>
<th>S-2</th>
<th>S-3</th>
<th>S-4</th>
<th>S-5</th>
<th>S-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specified design strength, at 28 days psi</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Cement, lb/yd$^3$</td>
<td>36</td>
<td>98</td>
<td>158</td>
<td>144</td>
<td>222</td>
<td>273</td>
</tr>
<tr>
<td>VPP fly ash, lb/yd$^3$</td>
<td>1425</td>
<td>1366</td>
<td>1262</td>
<td>1155</td>
<td>1496</td>
<td>1417</td>
</tr>
<tr>
<td>Water, lb/yd$^3$</td>
<td>1084</td>
<td>1068</td>
<td>1052</td>
<td>1146</td>
<td>970</td>
<td>963</td>
</tr>
<tr>
<td>Flow/spread, in. diameter</td>
<td>8¾</td>
<td>8¾</td>
<td>10½</td>
<td>16¾</td>
<td>5½</td>
<td>5½</td>
</tr>
<tr>
<td>Air content, percent</td>
<td>0.7</td>
<td>0.8</td>
<td>1.1</td>
<td>0.6</td>
<td>0.9</td>
<td>1.1</td>
</tr>
<tr>
<td>Air temperature, °F</td>
<td>49</td>
<td>55</td>
<td>49</td>
<td>49</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>Slurry temperature, °F</td>
<td>95</td>
<td>96</td>
<td>91</td>
<td>89</td>
<td>64</td>
<td>86</td>
</tr>
<tr>
<td>Slurry density, lb/ft$^3$</td>
<td>94.2</td>
<td>93.7</td>
<td>91.5</td>
<td>90.6</td>
<td>99.6</td>
<td>98.3</td>
</tr>
</tbody>
</table>
Krell [6] discussed using fly ash slurry as a backfill in flowing water; at a depth of about 20 feet. Class F fly ash slurry was placed at a relatively stiff consistency (slump of about 6 inches). The mix he used contained: 1800 lbs of dry fly ash (Class F); 90 lbs of portland cement; and, ±80 gal of water.

It was reported that this material was easily placed under water.
He has also observed that this material can support the weight of a loaded truck after 24 hours.

3.3 TESTS ON SLURRY

Krell [6] performed tests which are acceptable for actual field conditions. He performed the unconfirmed compressive strength of slurry containing cement, Class F fly ash, and water. He obtained a value of about 100 psi. This is better than any other conventional material for backfilling operations. The modulus of rupture for this material was found to be almost equal to its compressive strength.

The subgrade modulus of a typical material is usually taken as 50 times it unconfirmed compressive strength. The slurry material, therefore, has a subgrade modulus of 5000 lb/in\(^3\) whereas the subgrade modulus assumed for a typical conventional material is only 500 lb/in\(^3\).

The slurry material was also tested for erosion. At present there is no standard test method for erosion. Therefore, the material was placed in a tank in which water was continuously poured over it. The aim was to study how much material would be eroded and how it will affect the water quality. It showed that slurry performed better than any other conventional material. Only clean rock fill would be able to replace the slurry in this respect. The results are given in Table 3.3.
Table 3.3

Erosion Test Results [6]

<table>
<thead>
<tr>
<th>Material sample</th>
<th>Sample size</th>
<th>Total amount of sample in suspension (percent)</th>
<th>Total amount of sample loss (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White silica sand</td>
<td>10-in. Diam. x 4-in. High</td>
<td>1.6</td>
<td>10.0</td>
</tr>
<tr>
<td>Coarse brown sand and gravel</td>
<td>10-in. Diam. x 4-in. High</td>
<td>2.7</td>
<td>11.4</td>
</tr>
<tr>
<td>Yellow fill sand</td>
<td>10-in. Diam. x 4-in. High</td>
<td>8.3</td>
<td>44.9</td>
</tr>
<tr>
<td>Clay</td>
<td>12-in. Diam. x 4-in. High</td>
<td>8.9</td>
<td>22.6</td>
</tr>
<tr>
<td>Stabilized fly ash</td>
<td>12-in. Diam. x 4-in. High</td>
<td>0.7</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Compaction tests were also conducted on slurry containing about 5 percent cement. It was observed that the stiff fly ash slurry obtained a relative density of 85% per ASTM D1557 modified proctor test.

3.4 USES FOR SLURRY

Larsen [7] discusses various instances where this material was successfully used. Iowa-DOT filled two-200 gal. and one-1000 gal. abandoned fuel tanks with flowable fly ash slurry. This project was completed for $1,140, while removing the tanks was estimated
to cost $8,000. In accordance with Federal and State rules, filling in-place tanks with inert solid material is an alternative to tank removal.

Several counties in Iowa placed culverts on fly ash slurry bedding. This would prevent water from getting to the bottom of the culvert pipe and/or the bedding and eroding the pipe support. Excavations for pipe lines can be made smaller when flowable fly ash slurry is used as a backfill. This is because it is self compacting.

Slurry was also used for erosion prevention. A V-shaped drainage ditch for a parking lot in Iowa was lined with rip rap and loose rock. But due to high volume of storm water run off, the material in the rip rap was washed away. When this was rebuilt, the ditch was relined with rip rap. The top of the ditch was offset by 2 to 3 ft. parallel to the parking area. Fly ash slurry was placed through the rip rap and in the offset area to a depth of 4 inches. Also the slurry was placed over the rip rap as a capping material. Slurry was also used as an erosion control material on a river bank.

Voids were created under a bridge pier in St. Paul, Minnesota. Erosion was caused by wash outs. Therefore, the material to be selected should be able to withstand these forces. A 4 in. pipe was positioned down each pier to the bottom of the void under the footing. Rip rap was placed into the void around the pipe. Flowable fly ash slurry was pumped into the void and through the rip rap until
it came out into the current. Subsequent sounding test showed that the support for these footings remained very solid.

CHAPTER 4

LEACHATE STUDIES

4.1 LEACHATES (METHODS OF TESTING AND LIMITATIONS)

Flowable slurry comprising of large volumes of fly ash and foundry sand developed at the Center for By-Products Utilization (CBU) [2] is used as a backfill material for utility trenches containing ducts and/or pipes, around manholes and other excavations in streets, around foundations, or as a fill for abandoned tunnels, sewers, storage tanks, and other underground facilities, etc. The action of rain, snow, and groundwater may permit water to move through this material and thereby leach water soluble constituents out from it. The leachate may join groundwater, creeks, or streams, and may possibly have polluting effect on them. This depends upon the constituents of the backfill slurry and their water soluble constituents.

There are four well known laboratory test procedures for determining the leaching characteristics of wastes or backfill materials. They are EP Toxicity Method, TCLP Method, AFS Method, and ASTM Method.
Table 4.1 gives a comparison of the steps and major differences in these four test procedures.

The Extraction Procedure (EP) Toxicity test, which specifies an
Table 4.1
Comparison of Laboratory Leaching Tests [5]

<table>
<thead>
<tr>
<th>Item</th>
<th>EP Toxicity</th>
<th>TCLP</th>
<th>AFS</th>
<th>ASTM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaching Medium</td>
<td>Deionized Water, 0.5 N Acetic Acid Added to adjust pH to 5.0 ± 0.2</td>
<td>pH 4.93 ± 0.05 Acetate Buffer</td>
<td>Deionized Water</td>
<td>Deionized Water</td>
</tr>
<tr>
<td>Liquid to Solid Ratio</td>
<td>20 to 1</td>
<td>20 to 1</td>
<td>5 to 1</td>
<td>4 to 1</td>
</tr>
<tr>
<td>Contact Time</td>
<td>24 hours</td>
<td>18 hours</td>
<td>24 hours 48 hours 72 hours</td>
<td>24 hours</td>
</tr>
<tr>
<td>Method of Mixing</td>
<td>Continuous Rotation at 30 RPM</td>
<td>Continuous Rotation at 30 RPM</td>
<td>Invert 15 times in 24 hours</td>
<td>Continuous Rotation at 30 RPM</td>
</tr>
<tr>
<td>Filtering</td>
<td>Once 0.45 micron</td>
<td>Once 0.7 micron glass</td>
<td>Once 0.45 micron</td>
<td>Once 0.45 micron</td>
</tr>
<tr>
<td>Number of Elutions</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

acidic (pH = 5 ± 0.2) leaching medium and a liquid to solid ratio of 20 : 1, is used to determine whether a solid waste leachate exhibits the characteristics of EP toxicity and would therefore be classified as a hazardous waste. If the filtrate from this test exceeds 100 times the primary drinking water standard for arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver, the leachate is classified as an EP Toxic hazardous waste. The extraction Procedure Flow Chart is shown in Figure 4.1 [5].
The Toxicity Characteristics Leaching test Procedure (TCLP) was developed to determine the mobility of both organic and inorganic contaminants in liquid, solid, and multiphase wastes.

The extraction fluid to be used is a function of the alkalinity of the solid phase of the waste. A subsample of the waste is extracted with the appropriate buffered acetic acid solution for 18 ± 2 hours.

The extract obtained from the TCLP (the "TCLP extract") is then analyzed to determine if any of the thresholds established by the Environmental Protection Agency have been exceeded.

The TCLP procedure consists of the following steps:

1. If the waste contains large lumps, break it down into pieces small enough to pass through 5/8 in. mesh screen.

2. Using a riffler, split the sample to be tested until a representative subsample of required size is obtained.

3. Reduce the particle size of a small part of this sample to 1 mm or less. Weigh out about 5 g. and use it to perform reagent determination test.
4. Mix necessary reagent, enough for samples to be leached plus one blank.

5. Weigh sample in container. Transfer sample in container into well rinsed 1 gallon contact jar. Re-weigh container and calculate net sample weight.

6. Measure out volume of reagents equal to 20 times the sample weight and slowly add to the contact jar.

7. Seal jar and rotate at 30 ± 2 rpm for 18 hours.

8. Prepare and label necessary leachate sample containers.

9. At appropriate time, stop extractor, remove sample and transfer to 250 ml plastic centrifuge bottles. Spin for 10 to 15 minutes at about 4500 rpm. Transfer sample to pressure chamber for filtering.

10. Filter through rinsed 0.7 micron glass filters and collect in prepared sample containers.

11. Analyses to be completed immediately on leachates include:
Alkalinity, conductance, and pH.

Figures 4.2 and 4.3 shows the TCLP flow chart.

In comparison to leaching procedures with acidic leaching mediums, the American Society of Foundrymen's Test (AFS) uses deionized water and allow the material itself to determine the pH of the leaching medium.
FIGURE 4.2 : TOXICITY CHARACTERISTICS LEACHATE

PROCEDURE FLOW CHART [5]
The AFS leaching procedure is as follows:

1. Split and weigh required subsample similar to TCLP procedure.

2. Transfer the weighed sample to well rinsed contact jar, slowly add deionized water, an amount equal to 5 times the sample weight.

3. Seal the jar and invert it 15 times immediately and again at 12 ± 2 hours later.

4. Prepare and label necessary leachate sample containers.

5. After 24 hour contact time, open the sample jar and add one
more part of deionized water.

6. Transfer the sample to 250 ml centrifuge bottles, holding back 20 mls on which to measure the pH. Spin for 15 to 20 minutes at about 4500 rpm.

7. Gently pour sample into pressure chamber. Filter through well rinsed 0.7 micron glass filters and transfer into a container. Towards the end of this filtering step collect 50 to 100 mls into a beaker for alkalinity titration and another 250 to 500 mls for cyanide analysis.

8. Return sample to pressure chamber and refilter through well rinsed 0.45 micron membrane filter and collect in prepared sample containers.

9. Analysis to be completed on leachate samples immediately includes: Alkalinity, Conductance, and pH.

The AFS gives an indication of the release of certain chemical parameters over a period of time [5]. This allows for an assessment of whether or not release of a given constituent is limited by solubility.
Another water leaching test method was developed by the American Society for Testing Materials (ASTM). This method (D 3987) is called the ASTM Water Leach Test or the Shake Extraction of Solid Waste with Water. This method uses only one elution which is agitated for 48 hour period with a liquid to solid ratio of 4 : 1.

There are some limitations to laboratory leaching test methods, some of which are:

1. They do not simulate the actual field conditions. For example, stirring and shaking of the sample in the laboratory is more abrasive than actual field conditions.

2. The potential of long-term time rate of release of constituents into the leachates is not taken into consideration; i.e., they measure the amount of a constituent released by agitation of the sample in the leaching medium for a specified period of time.

3. They do not consider the natural flow between the material and their environment. For example, infiltration, adsorption, and ion exchange, which may reduce the amount and/or concentration of the constituents found.

4. They do not consider the dilution capacity of the ground water
which will further reduce the concentration of the pollutants released by the material.

4.2 LEACHATE TESTING ON FOUNDRY SAND

Environmental regulations and citizen concern for pollution, strong regulatory pressure to close existing landfills which were designed and constructed before today's stringent design standards, and refusal at many landfills to continue accepting industrial wastes such as used foundry sand and fly ash, has provided the impetus for foundry industries to consider alternative use for their wastes.

Many options are available for the constructive use of these wastes. However, before it can be used, a foundry must consider the physical and chemical properties of the waste and its effects on the environment. A series of experiments were conducted on the leachability of foundry waste materials by Ham, Boyle and Kunes [8].

While investigating the leachability of foundry solid wastes, they developed a procedure to maximize the leachability, or matter release, of foundry wastes. They concluded that:

1. Level of process temperature to which sand is subjected in the foundry has a major effect on the leaching potential. Sands not subjected to process temperatures generally showed the greatest matter release.
2. Different sands produce different release. This reflects differences in both quality and quantity of resins and binders present in the wastes.

3. The amount of molding sand containing clay and its distribution throughout a landfill is likely to have significant effect on fill permeability, leachate quality, and movement.

4. Based on results, which show differences in leaching among various sands, it follows that to evaluate leaching potential the following information must be obtained: (a) total amount and types of waste produced; (b) types and amount of resins and additives used; (c) process areas within the foundry producing waste, amounts produced from each, and process temperatures to which wastes have been subjected.

Ham, Boyle and Blaha [9] compared the leachate quality in foundry landfills to the quality of leachate obtained by laboratory testing. They sampled leachates above the zone of saturation in landfills and concluded that: (a) leachates from the unsaturated zone studied had relatively low concentration of contaminants with respect to the drinking water standards for all contaminants except iron, manganese, and fluoride; (b) the nonhomogeneous nature of foundry wastes and the corresponding landfills can significantly affect
leachate quality leading to highly variable water quality depending on the sampling point and time of sampling; and, (c) leach test run on auger samples of waste were more accurate in predicting field leachate composition than leach test run on raw composite wastes.

It was further concluded that to be able to assess the problem associated with leachate generation in foundry wastes, the following factors has to be known:

(a) quantity of leachate produced;

(b) the contaminants in the leachate;

(c) the concentration of the contaminants;

(d) the time distribution of the contaminants generated; and,

(e) the assimilative capacity of the underlying soil system for the contaminants.

4.3 LEACHATE TESTING ON FLY ASH

Fly ash is a by-product of burning of powdered coal at electric power plants. Some fly ashes exhibit more of pozzolanic properties than cementitious properties. These properties make fly ash useful as
a concrete additive, a subgrade stabilizer, a fill or embankment stabilizer, and as a soil amendment to promote plant growth. The leachate characteristics of fly ash to be used for flowable fill has to be investigated in accordance with the standard procedures.

Edil, Sandstorm, and Berthouex [10] studied the feasibility of using pozzolanic western coal fly ash, either by itself or mixed with sand, as a construction material for waste containment liners and impermeable covers. They noted that the liners can be constructed from pozzolanic fly ash or fly ash and sand mixtures to meet the usual requirement for the permeability of $10^{-7}$ cm/s, or less. They also investigated the effects of long-term permeation of inorganic leachates solutions on such liner materials. On comparison of leachate from specimens with two different permeabilities it shows that: Calcium and sulfur concentrations were lower when permeability is lower. Sodium, chloride, boron, cadmium, and pH data showed no significant changes and zinc concentrations were higher with lower permeabilities. It was, therefore, concluded that to have a low permeable fly ash liner material, with low level of leachates, major variables besides compaction effort and moisture content affecting the permeability of the fly ash liner material, is the type and percentage of fly ash used.

Triano and Frantz [11] studied the leachate characteristics of concrete containing municipal solid waste (MSW) fly ashes from both
refuse-derived fuel (RDF) and mass-burn plants using the EPTOX test method to determine the amounts of leachable heavy metals in the concrete. The results of their investigation are shown in Table 4.2. It shows that although municipal solid waste fly ashes had high levels of leachable heavy metals, very small amounts of heavy metal, well below toxicity limits, leached from the concrete.
<table>
<thead>
<tr>
<th>Leachate samples (1)</th>
<th>Metal Concentrations (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Silver (2)</td>
</tr>
<tr>
<td>Control</td>
<td>4</td>
</tr>
<tr>
<td>R7-7.5%</td>
<td>Below detection limit</td>
</tr>
<tr>
<td>R8-7.5%</td>
<td>Below detection limit</td>
</tr>
<tr>
<td>R9-7.5%</td>
<td>Below detection limit</td>
</tr>
<tr>
<td>R9-15%</td>
<td>Below detection limit</td>
</tr>
<tr>
<td>M-7.5%</td>
<td>4</td>
</tr>
<tr>
<td>M-15%</td>
<td>5</td>
</tr>
<tr>
<td>C-7.5%</td>
<td>Below detection limit</td>
</tr>
<tr>
<td>C-15%</td>
<td>Below detection limit</td>
</tr>
<tr>
<td>Detection limit</td>
<td>4</td>
</tr>
<tr>
<td>Toxicity limit</td>
<td>5,000</td>
</tr>
</tbody>
</table>

Note: Values for arsenic, mercury, and selenium are not shown because previous analyses showed negligible amounts of these metals.


