**Making MGP Wastes Beneficial**
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More than 11 billion gallons of coal tar were generated at MGP sites in the United States from 1816 to 1947. The types and quantities of waste discharged to surface waters from MGPs vary from site to site, and the disposition of several billion gallons is unknown and remains unaccounted for. Numerous locations in the United States have sediments and soils contaminated with wastes generated from former coal gasification operations.

MGP wastes include polyaromatic hydrocarbons (PAHs), which are found in coal tar, a by-product of gasification processes, and cyanide salts, which are found in iron oxide waste produced during purification of the manufactured gas. In addition to being a problematic soil and sediment contaminant, MGP solid waste frequently causes groundwater and surface water contamination with benzene, phenanthrene, anthracene, pyrene, and benzo(a)pyrene. These contaminants pose threats to human health to the extent that many MGP sites are listed on the Superfund National Priority List for cleanup and removal.

The USEPA references a number of technologies acceptable for disposing of or treating MGP residues. In general, MGP waste is 1) stored on-site until a more suitable, permanent treatment option is developed, 2) moved to a hazardous material landfill, or 3) incinerated in a hazardous waste incinerator. However, each of these disposal or treatment options has at least one of the following significant drawbacks: high costs, low destruction capabilities, high emissions, and/or a residual waste (long-term liability) with questionable leaching characteristics that require disposal.

In 2001, the Wisconsin Department of Natural Resources and the EPA's Great Lakes National Program Office sponsored Minergy Corp. in a successful Glass Furnace Technology (GFT) demonstration of the vitrification of PCB-contaminated river sediments. Vitrification, a mineral recovery technology using state-of-the-art oxygen and a natural gas (oxy-fuel) fired melter, converts high ash content waste into an inert beneficially reusable glass aggregate. Minergy, based in Neenah, Wis., has successfully commercialized several vitrification technologies for recycling of municipal biosolids and industrial sludges. The company's GFT was developed specifically to treat remediation wastes such contaminated sediment and soils.

Many MGP wastes share common characteristics with contaminated river sediment and municipal sludge. In March, 2003, based on the successful vitrification of river sediment and the similarities in the feedstocks, testing was conducted on MGP waste as part of a grant to Dr. Gregory Kleinheinz at the University of Wisconsin - Oshkosh.

The testing occurred in three phases, including a series of laboratory tests, a series of crucible melts, and a demonstration melt in a commercial-scale unit. The laboratory series was performed to determine the overall chemical and physical characteristics, and to predict melting temperatures. The crucible melts were performed to verify the viscosity of the waste when in a molten state. Finally, the commercial scale demonstration melt was performed to substantiate the behavior of the molten material in a large melter process, and to determine throughput predictions for full scale operation.

**Laboratory Tests**

A total of 4 samples were received for preliminary evaluation. A general description of the samples is shown in Table 1 below.

Table 1. Physical description of samples

| Sample ID | Location | Physical description |
|---|---|---|
| **ITR** | Canal bottom | High tar content |
| **TTP – 1** | Along shore 7 to 10 feet bgs | Clay with some tar |
| **TTP – 2** | Along shore 5 to 12.5 bgs | Viscous liquid with MGP odor |
| **TTP - 3** | Along shore 6 to 11.5 bgs | Clay with tar |

Note: Bgs. = below ground surface. The ITR sample was collected August 2002. All of the TTP samples were collected December 2002.

*Mineral Analysis*

To predict the melting properties of the material, all of the samples were prepared and analyzed for mineral composition. The samples were ground to 400 mesh and analyzed using X-ray fluorescence (XRF) methods. The XRF results are reported in the common oxide form and are summarized in Table 2.

Table 2. XRF mineral analysis results for MGP samples

| **Mineral** | **% by weight** | **% by weight** | **% by weight** | **% by weight** |
|---|---|---|---|---|
| **Sample ID** | **ITR** | **TTP – 1** | **TTP – 2** | **TTP - 3** |
| $SiO_2$ | 61.6 | 53.3 | 53.3 | 60.7 |
| $P_2O_5$ | 0.15 | 0.24 | 0.24 | 0.24 |
| $FeO_3$ | 6.74 | 4.81 | 4.81 | 5.27 |
| CaO | 11.8 | 15.4 | 15.4 | 9.4 |
| MgO | 6.0 | 10.5 | 10.5 | 7.86 |
| $Al_2O_3$ | 10.7 | 11.6 | 11.6 | 12.5 |
| $TiO_2$ | 0.58 | 0.62 | 0.62 | 0.62 |
| $Na_2O$ | 0.57 | 0.57 | 0.64 | 0.71 |
| $K_2O$ | 1.83 | 3.55 | 3.55 | 3.52 |

**Crucible Melts**

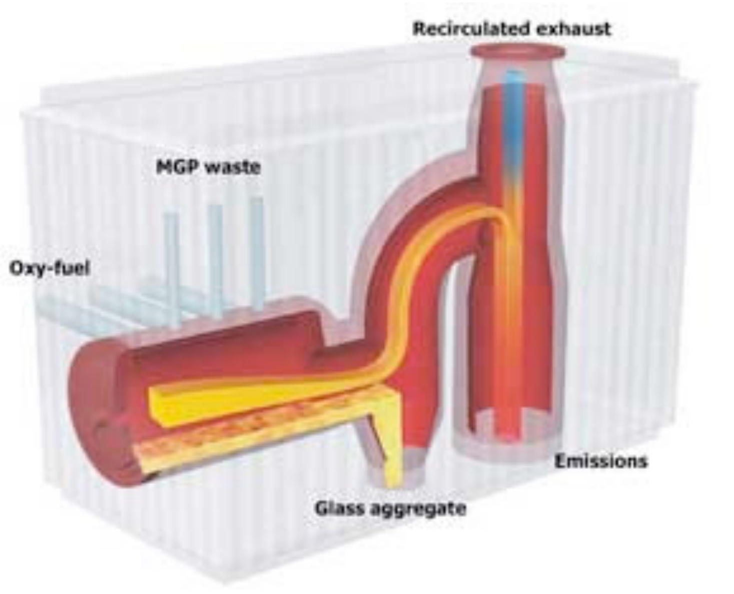
A total of five crucible melts were performed in an oxy-fuel fired furnace with 8 cubic feet of internal volume and a heat input rating of 165,000 Btu/hr of maximum heat input. The furnace has a maximum operating temperature of approximately 2800 F. Melts were performed in a 2000cc fused silica crucibles capable of withstanding temperatures of 2800 F.

*Test Procedures*

The MGP waste was added to the crucible and loaded into an idle (< 1800 F) furnace. After the crucible temperature stabilized, the furnace temperature was raised. The crucible melts demonstrated that all MGP waste successfully melted into glass and also confirmed acceptable viscosity at typical melter operating temperatures. The molten glass from each crucible was poured off into a water bath to form an aggregate product.

**Commercial Demonstration Melt**

The third phase of this study processed a batch of MGP waste material in Minergy's GFT melter. The melter's normal rating is 3 glass tons per day. The melter can accept up to 9 mmBtu/Hr of heat input, and is intended to operate at a temperature of 2500 F to 2800 F. The melter has 10 $ft^2$ of melting area, and is fired with a combination of natural gas and pure oxygen (oxy-fuel combustion). The system consists of a melter, aggregate quench tank, aggregate recovery screw, an oxygen and natural gas supply and control system, an exhaust fan, a water cooled packed tower, and instrumentation necessary to collect all process critical data.



The oxy-fueled GFT melter proved capable of processing MGP waste with high destruction efficiencies, low operating costs, low emissions, and creation of highly inert glass aggregate.

**Glass Aggregate Qualities**

The melter yielded glass aggregate product within 30 minutes of initiating testing. Qualitative analysis by Minergy indicated that the glass was of the same gradation and hardness as glass aggregates produced by its other vitrification processes.

Chemical analysis of the initial MGP mixture and the final glass aggregate using gas chromatography, coupled with a mass selective detector (GC-MS), revealed that the process had successfully destroyed the PAHs present in the initial material. This group of compounds was chosen for analysis due to their prevalence in the starting material and their propensity to be carcinogenic, teratogenic, and/or mutagenic. They are among the most problematic and long-lived compounds in the starting MGP material. Analysis performed was EPA Method 8270C. All analysis was performed by an EPA certified laboratory.  A detailed list of analytes and concentrations are provided in Table 3. Additionally, there was no sign of secondary products requiring addition mitigation.

Table 3. Polyaromatic hydrocarbon (PAH) analysis of beginning MGP mixture and final glass aggregate product.

| Compound | Beginning MGP Mixture | Glass Product |
|---|---|---|
| | Concentration (µg/kg) | Concentration (µg/kg) |
| Acenaphthalene | 90,000 | <11[b] |
| Acenaphthylene | 65,500 | <19 |
| Anthracene | 130,000 | <11 |
| Benzo(s)anthracene | 88,000 | <6.2 |
| Benzo(b)fluoranthrene | 28,000 | <6.7 |
| Benzo(k)fluoranthrene | 31,000 | <9.3 |
| Benzo(g,h,i)perylene | 17,000 | <12 |
| Benzo(a)pyrene | 43,000 | <6.2 |
| Chrysene | 88,000 | <7.1 |
| Dibenzo(a,h)anthracene | 5,000 | <7.6 |
| Fluoranthrene | 140,000 | <8.2 |
| Fluorene | 110,000 | <6.2 |
| Indeno(1,2,3-cd)pyrene | 16,000 | <11 |
| 1-Methylnaphthalene | 120,000 | <7.2 |
| 2-Methylnaphthalene | 76,000 | <7.7 |
| Naphthalene | 77,000 | <7.7 |
| Phenanthrene | 380,000 | <6.2 |
| Pyrene | 160,000 | <13 |

[a]*Method was EPA SW846-8270C by GC-MS.*
[b]*"<" means less than the Level of Quantitation (LOQ) indicated.*

**Beneficial Reuse Opportunities**

Beneficial reuse is a general term that describes alternatives for managing waste material by focusing on its value as a mineral resource and not as a waste. In addition to manufacturing a marketable product in the form of glass aggregate, the GFT process provides a total solution to the disposal problem of MGP waste. Because the process incorporates very high operating temperatures with excellent fuel and oxygen mixing, high destruction efficiencies of organic compounds are achieved. Further trace heavy metals contained in the sediment are permanently sequestered in the glass aggregate matrix.

Minergy has successfully gained regulatory agency approval in Wisconsin, Michigan and Illinois for the beneficial reuse of glass aggregate produced from industrial sludges, municipal biosolids and remediation wastes. Glass aggregate produced through the vitrification of these materials demonstrate acceptable characteristics for use as a construction material, such as asphalt pavement and road bed construction. Minergy's glass aggregates have been incorporated into commercial asphalt mix designs that have been successfully used in Wisconsin Department of Transportation asphalt paving projects in addition to commercial asphalt mix designs. Minergy's glass aggregates have also been marketed and commercially accepted in the production of blended cements, pozzolan, structural construction fill, roofing shingle granules and blasting media.

**Cost**

Commercial-scale implementation of this technology will allow for the conversion of a large-quantity of highly hazardous solid waste into a usable product. This could potentially save hundreds of thousands of cubic yards of landfill space in addition to a significant savings in transportation and disposal costs.

Final unit cost will depend on the beneficial reuse of the material and the value in those markets. However, even with a nominal resale value of $2 per ton of glass, the unit cost for this technology is significantly less than other commercially available thermal treatment technologies. With landfilling near $40/ton, and the long-term environmental liability due to the threat of potential ground water and soil contamination, vitrification technology is a competitive, responsible and sustainable alternative.