Converting the dreaded PCBs into useful commodities

For decades polychlorinated biphenyls (PCBs) have been high on the list of toxins the public fears. A new vitrification technology is claimed to be able to completely destroy PCBs and other toxins in contaminated sediment by melting it into a glass aggregate product that can be used in the construction industry. This process, developed by Minergy Corp., costs about as much as landfilling, without the long-term environmental liabilities, and costs considerably less than other thermal treatment technologies.

The Great Lakes region of Canada and the United States was unfortunately the recipient of two decades' worth of PCB discharges. The Great Lakes Water Quality Agreement expressed the commitment of Canada and the United States to restore and maintain the chemical, physical and biological integrity of the Great Lakes Basin ecosystem. The U.S. and Canadian governments have identified 43 official "Areas of Concern": 26 in U.S. waters, 17 in Canadian waters (five are shared between United States and Canada on connecting river systems).

According to the U.S. Environmental Protection Agency (USEPA), contaminated sediment is a common problem throughout Areas of Concern within the Great Lakes Basin. Contaminated sediments significantly contribute to the impairment of nearly all identified beneficial land uses. Dredging of sediments is frequently done to improve environmental conditions where contaminated sediments pose unacceptable risk to human and ecological health.

The Great Lakes ecosystem health depends on, among other things, the elimination of persistent bioaccumulative contaminants. Removal of contaminated sediments from the ecosystem is often the preferred action because it permanently eliminates this exposure pathway to aquatic resources; however, few treatment technologies are effective at permanently detoxifying persistent bioaccumulative contaminants,

In 1999 the Wisconsin Department of Natural Resources (WDNR) contracted Minergy Corp. to complete a feasibility study on the effectiveness of vitrification to treat PCB-contaminated sediments removed from the Lower Fox River in Wisconsin.

Vitrification is a mineral recovery process that melts the mineral content of the sediment using a high-temperature furnace. The byproduct, glass aggregate, is used for sandblasting grit, roofing shingle granules and asphalt paving. More importantly, an ancillary benefit of the process' high temperature (> 2400 degrees Fahrenheit) and retention time is the thermal destruction of organic contaminants such as PCBs. Glass Furnace Technology (GFT) is one of several vitrification technologies that Minergy has developed and implemented to help the industry meet environmental goals and reduce costs through beneficial reuse of high-volume wastes.

Integrated environmental approach

Minergy approached the feasibility of this vitrification technology from the perspective of designing a system that would produce a high-quality, reusable glass aggregate product. It was recognized that the conditions necessary to produce this would also be ideal for destruction of organic contaminants, such as PCBs. Further, many trace metals found in sediment are permanently immobilized in the melting and quenching process, producing a final aggregate product that is very inert.

The first step of the feasibility study was to characterize the mineral composition of river sediments to estimate the glass quality, durability and melting points. Test results revealed that sediment characteristics are very consistent throughout the river and are very favorable for producing a quality glass product (Table 1). Further, the low Loss on Ignition (LOI) analyses confirmed that a vitrification technology is more appropriate for river sediments than the incineration technologies under consideration.

Chemical Analysis	Sediment Results Average (±SD) %
Na_2O	0.73 (0.12)
MgO	6.21 ()
Al_2O_3	11.34 (3.04)
SiO_2	63.73 (8.45)
P_2O_5	0.32 (0.16)
K_2O	3.05 (0.45)
CaO	8.36 (3.07)
TiO_2	0.6 (0.27)
Fe_2O_3	4.56 (1.46)
LOI @750°C (% dry basis)	8.59

Table 1. Mineral and LOI Analysis of River Sediment.

Glass aggregate product fresh from the quench tank.

Mineral components of the wastes do not have a definite melting point but rather exhibit a viscosity that is dependent on temperature. With promising results from the mineral characterization, crucible melts of Lower Fox River sediment were conducted to determine the actual melting conditions and glass characteristics/qualities of the sediment alone and when augmented with other materials (flux mixtures). Fluxes were added to the batch material to optimize the mineral composition, which in turn reduces the amount of energy necessary to melt the material.

Four different "recipes" were tested and all successfully melted the sediment into glass. The addition of a small amount of limestone as a fluxing agent provided the best glass characteristics at the lowest melting temperature. The final step in the feasibility study was to construct a pilot scale melter and process 14 dry tons of PCB-contaminated sediment removed from the Lower Fox River,

The glass furnace is simply a refractory-lined rectangular melter. The refractory is brick or concrete that has been specially treated to resist chemical and physical abrasion, has a high melting point and provides a high degree of

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insulating value to the process. The melter has a melting area of 10 square feet and was designed to produce 2 tons per day of glass aggregate.

Natural gas is fired in the furnace, raising the internal temperatures to between 2600 and 3000 degrees Fahrenheit. The melter has a maximum natural gas firing rate of 1.7 mmBtu/hour, and a maximum design oxygen consumption rate of 3500 SCFH (Standard Cubic Feet per Hour).

Exhaust treatment is simplified and energy efficiency improved by the melter's use of purified oxygen (oxy-fuel) rather than ambient air as the oxygen source. Due to low gas volumes produced by the oxy-fuel melter and the large volume of gas space above the molten line, gases remain resident in the melter for a significant period of time. At these temperatures, the sediment melts and flows out of the furnace as molten glass. Molten glass product was discharged into a 600-gallon water-filled quench tank.

A split stream of the 2800^{o} F exhaust gas from the melter was treated in a pilot-scale air quality control system. The apparatus consisted of a gas cooling section, wet scrubber and an activated carbon filter.

Initially the melter exhaust gas is cooled from 2800^{o} F to 400^{o} F. Initial gas cooling was accomplished by indirect cooling to simulate gas temperature/time profiles similar to incinerators with heat recovery. The wet scrubber consisted of a packed tower filled with stainless steel packing. Cooling water is used to reduce the exhaust gas temperatures to approximately 100^{o} F. Cooled exhaust gas was processed in a bed of activated carbon. The primary purpose of the activated carbon bed is to achieve mercury removal. A centrifugal blower and control valve direct proper air flow through the air quality control equipment. Sampling taps were installed after the gas cooling section and after the activated carbon filter.

Close-up of the glass aggregate product.

Process operations

The melter was operated on a continuous basis for one week to allow adequate time to collect all of the air samples required. The melter was fed at an average feed rate of 224 pounds per hour. The average rate of glass production was 1.7 tons per day. Melter operating temperatures ranged from 2750^{o} to 2930^{o} F. The average melter temperature during the testing was 2825^{o} F. Melter natural gas input rates averaged 748,000 Btu/hour on a higher heating value basis (HHV). Oxygen consumption averaged at 2098 SCFH.

All input and waste streams were sampled during the pilot program. Testing was performed for a wide range of chemicals, including 78 individual PCB congeners, dioxan/furans, semi-volatile organic compounds (SVOCs), volatile organic compounds (VOCs), and heavy metals. In addition, the glass aggregate was subjected to both ASTM water-leaching procedures and SPLP (Synthetic Precipitation Leaching Procedure) methods to determine beneficial reuse. More than 190 individual samples were collected from all possible waste streams.

The sediment charged into the melter during the pilot testing averaged 28 mg PCB/kg. Exhaust gas emissions were sampled on the pilot melter before and after the air quality control equipment. The average PCB concentration of the exhaust after the air quality control equipment was 35.1 ng/dry standard cubic meter (DSCM). Thus, on an hourly average post-air quality control stack basis, this equated to a PCB destruction efficiency of >99.9999 percent.

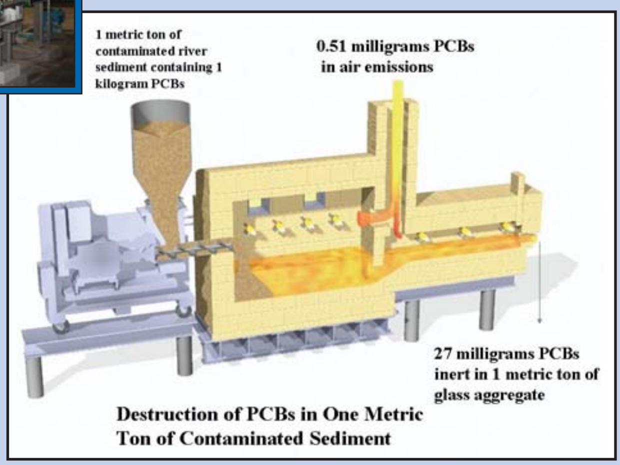

Illustration of the destructive efficiency, by vitrification, of one ton of PCB-contaminated sediment.

The formation of dioxins and furans, a concern identified by local environmentalists, was also sampled in all waste streams. On average the sediment contained 23.5 and 65.6 ng/kg 2,3,7,8 TCDD (dioxin) and 2,3,7,8 TCDF (furan), respectively. No 2,3,7,8 TCDD was detected in either the pre- or post-air quality control equipment or glass aggregate samples. 2,3,7,8 TCDF was detected only in the post-air quality control equipment at an average of 0.0018 ng/DSCM (Dry Standard Cubic Metre). On an hourly average basis during the pilot, 8815.5 ng of 2,3,7,8 TCDD and 2,3,7,8 TCDF were loaded into the melter, while less than 0.1 ng of only 2,3,7,8 TCDF was released in the exhaust. This not only represents a significant reduction in 2,3,7,8 TCDD/TCDF, but, more importantly, the data demonstrates that these compounds are not created to any significant extent in this process.

Mercury was another contaminant of significant concern. Mercury concentrations in the sediment averaged 0.7 mg/kg. All glass aggregate samples analyzed for mercury resulted in no detection, as did all the exhaust samples.

Beneficial reuse opportunities

Beneficial use is the general term that describes alternatives for managing dredge material by focusing on its value as a resource and not as a waste. In addition to manufacturing a marketable product, the Glass Furnace Technology process provides a complete solution to the disposal problem of contaminated sediments. Many other disposal technologies, including incineration, have significant quantities of ash or other waste that continue to pose disposal problems.

Because the process incorporates very high combustion temperatures with excellent fuel and air mixing, high destruction efficiencies of organic compounds are achieved, and trace metals contained in the sediment are permanently stabilized in the glass aggregate matrix.

The glass aggregate demonstrated acceptable characteristics for beneficial reuse. In fact, the ASTM water leach test and SPLP test did not detect any 2,3,7,8 TCDD or TCDF, not a single PCB congener, any SVOCs, nor any of the eight heavy metals. Upon reviewing these results, the WDNR has issued a Low Hazard Exemption to Minergy, approving glass aggregate produced from contaminated sediment for uses such as asphalt pavement, road bed construction, blended cements, structural construction fill and roofing shingles.

Cost

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 (US) $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, but also a potential long-term environmental liability due to the threat of potential ground water and soil contamination, vitrification technology is a competitive and reasonable alternative.

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