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Treatment of Asbestos Wastes Using the GeoMelt® Vitrification Process

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ABSTRACT

The disposal of waste asbestos from decommissioning activities is becoming problematic in countries which have limited disposal space. A particular challenge is the disposal of asbestos wastes from the decommissioning of nuclear sites because some of it is radioactively contaminated or activated and disposal space for such wastes is limited. GeoMelt® vitrification is being developed as a treatment method for volume and toxicity minimization and radionuclide immobilization for UK radioactive asbestos mixed waste. The common practice to date for asbestos wastes is disposal in licensed landfills. In some cases, compaction techniques are used to minimize the disposal space requirements. However, such practices are becoming less practical. Social pressures have resulted in changes to disposal regulations which, in turn, have resulted in the closure of some landfills and increased disposal costs.

In the UK, tens of thousands of tonnes of asbestos waste will result from the decommissioning of nuclear sites over the next 20 years. In Japan, it is estimated that over 40 million tonnes of asbestos materials used in construction will require disposal. Methods for the safe and cost effective volume reduction of asbestos wastes are being evaluated for many sites.

The GeoMelt® vitrification process is being demonstrated at full-scale in Japan for the Japan Ministry of Environment and plans are being developed for the GeoMelt treatment of UK nuclear site decommissioning-related asbestos wastes. The full-scale treatment operations in Japan have also included contaminated soils and debris. The GeoMelt® vitrification process result in the maximum possible volume reduction, destroys the asbestos fibers, treats problematic debris associated with asbestos wastes, and immobilizes radiological contaminants within the resulting glass matrix. Results from recent full-scale treatment operations in Japan are discussed and plans for GeoMelt treatment of UK nuclear site decommissioning-related asbestos wastes are outlined.

INTRODUCTION

Asbestos is a naturally occurring fibrous, magnesium silicate material that occurs in six different varieties. Chrysotile or white asbestos accounts for about 95% of the world's production of asbestos [1]. Asbestos is an excellent thermal insulation material and some forms are highly resistant to chemical corrosion. Because of these properties, asbestos has been widely used for fire protection and insulation on structures and systems such as ovens, boilers and steam pipes and in thousands of manufactured products such as general building materials and break linings [1].

There are ample instances of adverse health effects caused by exposure to microscopic asbestos fibers that range from lung tissue scaring to lung cancer and mesothelioma. According to the International Labor Office, asbestos kills 100,000 workers a year worldwide [2].

In the UK, asbestos exposure has been the main cause of occupational health problems from about 1950 onwards and is the greatest single work-related cause of death with approximately 4,000 related deaths per year [3].

Significant progress has been achieved in banning or limiting the use of asbestos in many industrialized countries. However, asbestos continues to be a substantial threat because it's historical pervasive use. World-wide production of asbestos peaked in the 1970s and early 1980s at nearly five million tonnes per year and is now around two million tonnes per year. In terms of consumption, the United Kingdom imported approximately six million tonnes of all types of asbestos since the turn of the century with peak annual consumption in 1973 at over 195,000 tonnes [4]. Japan was the most consistent large user of asbestos in Asia from 1920 to 1970. Its import peaked at nearly 350,000 tonnes in 1974 but its import and use has since been banned as of 2002 in all but a handful of products [5].

The massive volumes used, the hazards from exposure and the impact on landfill space all represent significant challenges for the collection and safe disposal of asbestos wastes.

Asbestos clean-up work in most industrialized countries is required to be performed under strict work controls by licensed contractors. The collected waste is usually double bagged and sent to landfills for disposal. Co-disposal in municipal waste landfills was an accepted practice in the United Kingdom until July 2004 when the European Union Landfill Directive banned co-disposal. According to a study by Wilson and Smith, prior to the ban on co-disposal, there were over 200 landfill sites in England and Wales that accepted hazardous wastes including 36 in-house landfills. In the year following, only 11 commercial hazardous waste landfills remained plus a further eight in-house landfills. In addition, 13 non-hazardous waste landfills have been issued permits to receive stable non-reactive hazardous waste in separate cells (the wastes include double bagged asbestos and stabilized/solidified hazardous wastes that meet the new waste acceptance criteria) [6].

With the ban on co-disposal and the limitation on disposal sites in the United Kingdom, and similar social and regulatory pressures in Japan, there has been an increasing interest within the industry to find innovative solutions that decrease the volume and toxicity of the asbestos wastes requiring disposal. As a result of this interest, GeoMelt® is being demonstrated in Japan for the treatment of asbestos wastes and similar plans for treatment are being developed for the United Kingdom.

GEOMELT® PROCESS DESCRIPTION

The GeoMelt®[1] vitrification process is an electric melting process used to treat hazardous and radioactive wastes through Joule heating. The treatment results in the destruction, removal or permanent immobilization of contaminants. This process has been used successfully to treat a wide range of hazardous and radioactive wastes. The melt temperature typically ranges from 1300-2000 ºC depending on the materials being treated and the process configuration being used. Silica (SiO_2) or alumina (Al_2O_3) may be added to the waste in order to increase the melt to the desired temperature. Primary attributes for the process in its various configurations include the following:

- Soil provides the source of glass formers for the processing media (molten soil) and to form the resulting glass product.
- The process can treat contaminated soils or non-soil wastes can be added to soil for treatment.
- Treatment rates of up to 100 tonnes per day.
- The process has been demonstrated on a commercial basis to be effective for the treatment of chlorinated organic wastes including dioxins, pesticides and polychlorinated biphenyls (PCBs) [7].
- No organic contaminants remain in the glass product due to the inability of organics to exist in the melt at such high temperatures.
- The destruction and removal efficiency (DRE) for organic contaminants achieved during commercial operations is greater than 99.9999%. This DRE includes the percentage destroyed by the melt (typically 90 to 99.9%) and the percentage destroyed and/or removed from the off-gas stream by the off-gas treatment equipment [7, 8].
- The process can accommodate relatively high concentrations of heavy metals and radionuclides resulting in permanent immobilization within the vitrified product.
- Most metals and radionuclides are retained in the melt, with typical melt retention efficiencies (REs) of 99.99% or better for the non-volatile species.
- The degree of retention in the melt of semi-volatile heavy metals such as lead, cadmium and arsenic is quite high and generally around 80 to 90%. In some GeoMelt® treatment configurations, cesium has been processed with resulting in REs of 99.9% or more [9].
- GeoMelt® can accommodate complex mixtures of contaminant types as well as debris such as concrete, bitumen, bricks, steel, wood, plastic and automobile tires.
- Off-gases that evolve from the melt are collected in a steel containment hood and directed to an off-gas treatment system.
- The off-gas treatment steps vary depending on project requirements but generally consist of particulate filtration, quenching, wet scrubbing, a second stage of particulate filtration, and carbon adsorption and/or thermal oxidation. Additional treatment steps can be added to meet project-specific requirements.

[1] GeoMelt is a registered trademark of Geosafe Corporation

- The vitrified product normally consists of a mixture of glass and crystalline materials and often has an appearance similar to volcanic obsidian.
- The product is typically ten times stronger than concrete and is extremely leach resistant. The vitrified product readily satisfies the requirements of the US Environmental Protection Agency's (EPA) Toxicity Characteristic Leaching Procedure (TCLP) [10].
- The product resulting from most applications normally is 10 to 100 times more durable and leach resistant than typical borosilicate glasses used to immobilize high-level nuclear waste. The durability and leach resistance of the glass is due to a high concentration (60 to 90 wt%) of glass formers (SiO_2 and Al_2O_3) and the ability to treat most soils and wastes without temperature-lowering additives such as sodium.

The primary benefits for the treatment of asbestos wastes by GeoMelt® include:

- The asbestos is dissolved in the melt and the fibers are destroyed rendering the resulting glass product non-hazardous and non-toxic.
- The volume is significantly reduced. Up to 80% volume reduction has been demonstrated for asbestos wastes.
- The process is robust and can accommodate a wide range of debris. Bags of asbestos waste can be treated directly by the process without the need for sorting or pre-treatment which minimizes the potential for worker exposures.
- The inert glass product can be recycled for other uses such as aggregate for construction or tiles.

APPROACH

The treatment of asbestos wastes with the GeoMelt® process was previously investigated in Japan through a series of one tonne sized batch melts in 1997. This preliminary work established that the GeoMelt® process destroyed the asbestos fibers and reduced the waste volume by 80% while producing a vitreous product. Those results were used to help plan the current full-scale demonstrations.

In 2006, a series of full-scale demonstrations were conducted to assess the ability of the GeoMelt® process to treat asbestos wastes at a commercial scale. The work was carried out by AMEC's licencee, ISV Japan Ltd.(ISVJ) and its shareholders at a shareholder-owned waste treatment complex in the Mie Prefecture, Japan. The GeoMelt installation at this plant is depicted in Figure 1.

Fig. 1. Image of GeoMelt® treatment plant in Japan.

Three full-scale demonstrations were conducted each with a batch size of approximately 7.5 tonnes. The asbestos waste materials used for the demonstrations were roofing materials. The amount of asbestos waste material in each batch was progressively increased and clean soil was emplaced around and above the asbestos material in all cases. The covering layer of soil helps to insulate the melt increasing the efficiency of the process and also serves as filtering media to help minimize the emissions of particulate matter and asbestos fibers to the off-gas treatment system.

Each demonstration was operated on a batch basis in a re-usable, refractory-lined steel container. Figure 2 shows a worker in protective clothing standing on the asbestos waste material for the second demonstration after it has been loaded into the melt container before the containment hood and electrodes were installed. Figure 3 shows the rail-mounted melt container in position at the melt station during one of the demonstration melts.

Fig. 2. View of asbestos waste material loaded into the melt container.

Fig. 3. Rail-mounted melt container during asbestos melt operation.

Melt durations ranged from 36 to 58 hours. After each melt, the resulting glass was allowed to cool and solidify within the container. Following a period of cooling, the container was opened and the glass block removed for sampling and analysis. Figure 4 shows one of the glass blocks being carried by a forklift after its removal from the melt container and the interior of a glass block after it had been sampled. Table 1 summarizes process data for the 3 asbestos melts.

Fig. 4. Resulting glass block at left following removal from the melt container and interior of glass block at right showing convective flow patterns.

Table. I. GeoMelt Asbestos Treatment Process Data

	Melt 1	Melt 2	Melt 3
Start Date	20-Jun-06	24-Aug-06	21-Dec-06
Duration (hr)	36.33	58.83	44.16
Asbestos Mass (kg)	840	2,664	3,015
Clean Soil Mass (kg)	6,333	4,922	4,540
Treated Mass (kg)	7,173	7,586	7,555
Waste Loading (wt%)	12	35	40
Processing Rate (kg/hr)	197	129	171
Ramp Duration (h)	8	7	11.5
Target Power (kW)	370	175	200
Average Power (kW)	361	156	188
Energy (kWh)	10,790	7,357	6,870
Process Efficiency (kW/kg)	1.50	0.97	0.91
Max Melt Temperature (°C)	1,368	1,559	1,565

RESULTS

The three demonstrations provided the opportunity to optimize the configuration and operating parameters of the GeoMelt® asbestos treatment system. Each melt operation required approximately 48-50 h to process the asbestos waste material. Power consumption for each melt was typically 180-200 kW once full operating power was achieved resulting in melt temperatures over 1500 °C (for melts 2 and 3). Power delivered to the melt averaged approximately 1 kWh per kg of material melted which is quite efficient compared to other thermal hazardous waste treatment processes.

Various samples from the process and resulting product were collected and analyzed for the presence of asbestos fibers using polarized light microscopy (PLM) and transmission electron microscopy (TEM).

PLM is used to determine the presence or absence of asbestos in bulk materials by comparison to established mineralogical optical properties (refractive index, birefringence, etc.). This method is also used to classify specific asbestos varieties that may be present. TEM is a more sophisticated approach that allows determination of trace asbestos concentrations by phase identification by electron diffraction and elemental quantification by energy dispersive spectroscopy (EDS). Asbestos fibers were not detected in any of the samples. TEM analytical results are provided in Table II. An image from the TEM analysis is provided in Figure 5, which shows non-fibrous, non-asbestos dark glass shards, typical of pulverized GeoMelt vitrified product, on a transparent copper TEM grid.

Table II. Summary Results of Asbestos Fiber TEM Analysis

Sample / Media	Result	TEM Detection Limit
Surface of Glass Block	No fibers detected	110 fibers / mg
Interior of Glass Block	No fibers detected	110 fibers / mg
Treated Off-Gas [(a)]	No fibers detected	3.3 fibers/L
Off-gas scrub solution	No fibers detected	2200 fibers / ml

(a) The primary off-gas treatment steps for this plant consisted of thermal oxidation, quenching, high efficiency wet scrubbing, HEPA filtration and finally granular activated carbon adsorption.

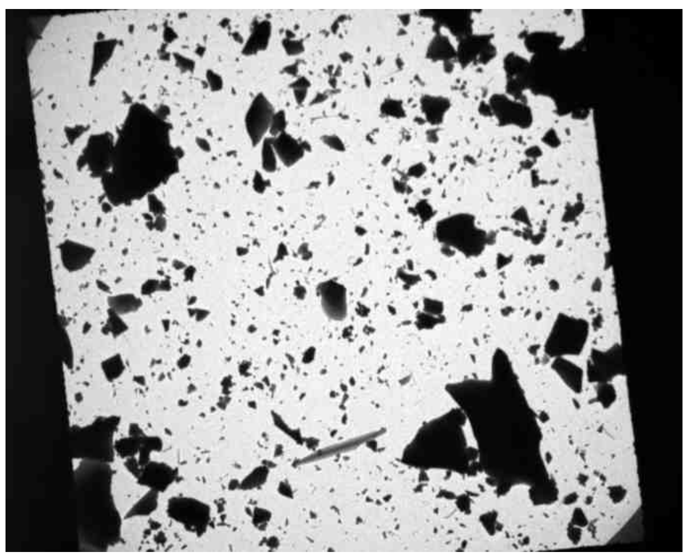

Fig. 5. Transmission Electron Microscope (TEM) image crushed pieces of glass product at 1200x magnification indicated no detectable asbestos fibers remained in the glass

CONCLUSIONS

The results from the three demonstrations established that the GeoMelt® process effectively destroyed the asbestos material and reduced the volume of the asbestos material by approximately 80%. No asbestos fibers were detected in the glass product, on the glass surfaces or in other process effluents.

The primary life cycle benefits resulting from the GeoMelt® treatment of asbestos waste include:

- The asbestos is dissolved in the melt and the fibers are destroyed rendering the resulting glass product non-hazardous and non-toxic. Consequently, the vitrified material may not have to be disposed in licensed landfills. For non-radioactive asbestos waste treated with GeoMelt®, recycling approaches such as crushing the vitrified product to produce construction aggregate could be used.

- Some asbestos waste associated with the decommissioning of nuclear facilities is radiologically contaminated with tritium. The GeoMelt® process would result in the removal of the tritium to result in a vitrified product that would satisfy radiological release criteria. Compared with conventional methods of managing tritiated asbestos waste (e.g., compaction and disposal) the GeoMelt® process can eliminate the need for its disposal in a licensed landfill because the tritium is removed during treatment.

- Because asbestos fibers are destroyed, the exposure risk to future generations is eliminated; this also eliminates the need for long-term institutional controls which present a long-term financial burden and liability to future generations for long-lived wastes such as untreated asbestos.

- The waste volume is significantly reduced. Up to 80% volume reduction has been demonstrated for asbestos wastes with the GeoMelt® process. Consequently, even if the vitrified material is disposed at regulated landfills, its volume is minimized which reduces the impact on landfill capacity which is limited in places such as Japan and the United Kingdom.

- The GeoMelt® process is robust and can accommodate a wide range of debris such as steel piping and cable. Bags of asbestos waste can be treated without the need for sorting or pre-treatment which minimizes the potential for worker exposure.

AMEC and ISVJ are currently using the results of the demonstrations to support design activities for larger capacity GeoMelt plants for the treatment of asbestos wastes in both Japan and the United Kingdom. AMEC is moving forward with plans to license the GeoMelt technology in the United Kingdom for the treatment of asbestos wastes.

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