Title: PROCESSING OF CONTAMINATED RIVER SEDIMENT IN A GLASS MELTING FURNACE

Abstract: A method and a reactor system for melting contaminated dredged sediment to eliminate hazardous organic substances and to convert the contaminated sediment into a low leaching glass product is disclosed. Contaminated river sediment and soils consisting primarily of inorganic material and very low amounts of combustible matter are directly melted by heating to a temperature above 2200 °F (1204 °C) in which the sediment material becomes a liquid or molten mass. The liquid or molten mass can be water quenched or further processed to make products having commercial applications, such as a glassy product. In another aspect of the invention, the contaminated river sediment is dried prior to being fed into the glass furnace in order to reduce the energy requirement and furnace size. In yet another aspect of the invention, the contaminated river sediment is tested and blended with other additives before being fed into the glass furnace. By testing the contaminated river sediment and blending the river sediment with additives, problems associated with excessive melting temperatures, increased gas use, and increased furnace refractory wear can be avoided.
PROCESSING OF CONTAMINATED RIVER SEDIMENT
IN A GLASS MELTING FURNACE

Cross-Reference to Related Application

This application claims priority from United States Provisional Patent Application No. 60/160,263 filed October 19, 1999.

Background of the Invention

1. Field of the Invention

The present invention generally relates to the treatment of contaminated sediment, and more particularly to a method and a reactor system for melting contaminated dredged sediment to eliminate hazardous organic substances and to convert the contaminated sediment into a low leaching glass product.

2. Description of the Related Art

Dredged river sediment contaminated with poly-chlorinated biphenyls (PCBs), dioxins, solvents, tars, fuels, and oils poses serious environmental problems, even at low levels of contamination. Currently, landfilling and incineration methods are typically selected for remediating the environmental threat of the contaminated river sediment. However, these methods do have disadvantages. For instance, one drawback of remediation methods employing landfilling is that toxic agents are never destroyed, only contained, and therefore, the toxic agents remain a possible threat for a long period of time due to potential leakage. Incineration methods also have disadvantages. For example, several types of incineration processes do not achieve an operating temperature sufficient to achieve the level of destruction needed to assure that toxic air emissions are eliminated. An additional concern with incineration processes is that the solid material generated from the incineration process may suffer from high degrees of variability which results in a material having no significant commercial market.

Without significant commercial markets available for the material, the material must ultimately be disposed of in a landfill.

Recently, other alternate methods for remediating the environmental threat of contaminated river sediment and soils have been proposed. For example, U.S.
Patent Nos. 5,803,894 and 5,855,666 disclose methods of thermochemically transforming contaminated sediment and soils into amorphous silicate materials that may be used in blended cements; and U.S. Patent No. 5,795,285 discloses a system for treating contaminated sediment wherein the sediment is melted in a plasma melter to form a glassy molten mass that is cooled to form a low-leachability product suitable for use as road fill or roofing granules. The remediation methods disclosed in these patents and other similar known methods do have disadvantages. For instance, these methods do not incorporate a drying step prior to melting the contaminated sediment. The lack of a drying step significantly impacts furnace efficiency and greatly increases the required furnace size to process a unit of material. These methods also do not account for the variability of the contaminated sediment in the area of mineral chemistry, or include a mixing step prior to melting. This limits the flexibility of the method in controlling the composition of the final product. The furnaces used in these methods may also operate under reducing conditions which can adversely affect the quality of the final product.

Thus, further advances are desired in methods for remediating the environmental threat of contaminated river sediment in order to overcome the foregoing and other deficiencies in prior remediation methods.

Summary of the Invention

It has been discovered that when contaminated river sediment and soils consist primarily of inorganic material and very low amounts of combustible matter, direct melting of the river sediments can be used in order to treat the contaminated material. This direct melting process can be distinguished from known incineration processes in that the direct melting process can be performed in the absence of, or in the presence of extremely low concentrations of, combustible material. The direct melting process or vitrification process of the present invention involves the heating of contaminated river sediment material to a temperature above 2200°F (1204°C) in which the sediment material becomes a liquid or molten mass. The liquid or molten mass can be water quenched or further processed to make products having commercial applications.
In one aspect of the invention, a glass furnace is used to melt contaminated river sediment into a molten mass which is cooled into a glassy product. Hazardous organic compounds contained in the contaminated river sediment are destroyed at the high temperatures attained in the glass furnace, and any trace metals in the contaminated river sediment are stabilized on the vitrified glass matrix, so that they cannot leach into the ground water.

In another aspect of the invention, the contaminated river sediment is dried prior to being fed into the glass furnace in order to reduce the energy requirement and furnace size. The reduced furnace size reduces the initial capital costs of the system. The river sediment drying can be performed using an indirect type of dryer to minimize the amount of energy needed and to minimize the resulting effluent from the dryer off gas.

In another aspect of the invention, the contaminated river sediment is blended with other additives before being fed into the glass furnace. Typically, river sediment inorganic mineral chemistry is highly variable. Variable factors include local geology, sediment particle size characteristics, river speed, and other factors. Sand, clays, limestone, shale, and other materials are the primary constituents of the river sediment. In many cases, the contaminant of environmental concern is of such a small concentration, it has little or no influence whatsoever on the process of drying and/or vitrification. Since the ratio of sand, clay, and limestone can vary from river to river, in river depth, and along river width, the present invention includes a system that allows for testing and batching to provide for a consistent finished product that considers final markets, glass furnace life, and fuel usage. By testing the contaminated river sediment and blending the river sediment with additives in a batch operation, problems associated with excessive melting temperatures, increased gas use, and increased furnace refractory wear can be avoided.

It is therefore an advantage of the present invention to provide a process that destroys hazardous organic compounds in contaminated river sediment and soils.

It is another advantage of the present invention to provide a process that
destroys hazardous organic compounds in contaminated river sediment and soils that contain large amounts of water.

It is still another advantage of the present invention to provide a process that destroys hazardous organic compounds in contaminated river sediment and soils and that allows for the production of a commercially marketable glass product having a predetermined target chemistry.

It is yet another advantage of the present invention to provide a glass furnace based reactor system that destroys hazardous organic compounds in contaminated river sediment and soils.

It is a further advantage of the present invention to provide a glass furnace based reactor system that destroys hazardous organic compounds in contaminated river sediment and soils and that allows for the production of a commercially marketable glass product having a predetermined target chemistry.

Brief Description of the Drawings

These and other features, aspects, objects, and advantages of the present invention will become better understood upon consideration of the following detailed description, appended claims and accompanying drawings where:

Figure 1A is a schematic flow diagram showing a process in accordance with a first embodiment of the invention;

Figure 1B is a schematic flow diagram showing a process in accordance with a second embodiment of the invention; and

Figure 2 is a schematic drawing showing various components of a reactor system in accordance with the present invention.

It should be understood that the drawings are not necessarily to scale and that the embodiments are sometimes illustrated by graphic symbols, phantom lines, diagrammatic representations and fragmentary views. In certain instances, details which are not necessary for an understanding of the present invention or which render other details difficult to perceive may have been omitted. It should be understood, of course, that the invention is not necessarily limited to the particular embodiments illustrated herein.

Like reference numerals will be used to refer to like or similar parts from
Detailed Description of the Invention

Referring first to Figure 1A, there is shown a schematic flow diagram of a process in accordance with the invention. Incoming contaminated sediment and/or soil, such as sediment dredged from a river, is mechanically dewatered by a centrifuge, filter or the like. The dewatered river sediment is then dried in a suitable dryer system to substantially reduce the moisture content of the contaminated sediment. The dried sediment is then tumbled or mixed in order to obtain a homogeneous batch of dried sediment. A suitable mixing system is a rotary batch mixer. After mixing, samples are obtained from the batch of homogeneous dried sediment and the samples are subjected to physical and chemical analyses to determine the mineral proportions and the total organic compound content of the samples to enable selection of the type and quantities of additives needed for both final product requirements and good furnace operation.

Additives, such as silica sand, limestone, dolomite, soda ash, cullet, ammonium nitrate, sodium nitrate, mixtures thereof, and other materials, are then added to the batch of homogeneous dried river sediment in order to meet the target chemistry determined in the preceding physical and chemical analyses. The batch of homogeneous dried sediment and any additives are then mixed into a homogeneous feed material. The feed material is then fed into a furnace where the material is heated at a temperature in the range of 2200°F (1204°C) to 2700°F (1482°C) to transform the material into a molten mass. Any organic compounds contained in the feed material are destroyed in the heating process.

The molten mass may then be processed in a variety of alternative steps. In the embodiment of the invention shown in Figure 1A, the molten mass is drained from the furnace into a water bath to quench the molten material and thereby form a glass frit. The glass frit is then recovered from the water bath. The glass frit recovered from the process can be used for various applications including but not limited to construction fill sand, air-blast abrasives, additives to roofing materials, and the like. In the embodiment of the invention shown in Figure 1B, the molten mass is drawn to form glass fibers, mineral wool, or other
useful articles or materials.

Referring now to Figure 2, there is shown a schematic drawing depicting various components of a reactor system 30 in accordance with the present invention. Mechanically dewatered river sediments containing contaminants, such as PCBs or dioxins, are loaded into a dryer 3. The dryer 3 reduces the moisture content of the river sediments to form a dried material having less than 10% moisture on a weight basis. Optionally, waste heat from the furnace (described below) may be used in the dryer 3. The dried material then exits the dryer 3 and is transported into a batch silo 4 for temporary storage. The dried material may be transported from the dryer 3 to the batch silo 4 by way of a conduit or may manually transferred to the batch silo 4. The dried material is then fed out of the batch silo 4 (manually or by way of automated material handling equipment) into a weighing device 4A to measure the weight of the portion of dried material to be processed further in the reactor system. The weighed portion of dried material is then transferred (manually or by way of automated material handling equipment) into a batch mixer 8. After the dried material transfer is complete, the dried material is tumbled in the batch mixer 8 until a homogeneous mixture is obtained. Preferably, the batch mixer 8 is either a rotary drum type or a pan type mixer.

A representative sample of the tumbled dried material is obtained (manually or by way of automated material handling equipment) from the batch mixer 8 at a sampling station 9 and is chemically analyzed in analytical equipment 10. The results of the chemical analysis are used for manual and/or automatic computation (e.g., computer) of the various additives and their quantities needed to be added to the tumbled dried material in order to achieve a predetermined composition for a final product. Additive silos, indicated at 5, 6, and 7, are provided for storage and delivery of various additives to the tumbled dried material contained in the batch mixer 8. For instance, the additive silos 5, 6, 7 may contain materials such as silica sand, soda ash, dolomite, limestone, or other raw materials necessary to achieve the correct mineral chemistry. In addition, one of the additive silos preferably contains an oxidizing agent, such as ammonium...
nitrate or sodium nitrate, that serves to counter the effects of organic materials and prevent the melting furnace (described below) from operating in a reducing atmosphere. Automated measurement and feeding equipment, indicated at 5A, 6A and 7A, is associated with each additive silo 5,6,7 and is used to measure the prescribed amount of each additive and feed the weighed additive into the batch mixer 8. Preferably, the batch mixer 8 is mounted on a conveying apparatus that serves to move the batch mixer 8 under the automated measurement and feeding equipment, 5A,6A,7A, associated with each additive silo 5,6,7 so that each additive may be charged into the batch mixer 8. The dried material and all additives are then tumbled in batch mixer 8 until a homogeneous mixture is formed.

The mixed batch of dried material and additives in the batch mixer 8 is then introduced (manually or by way of automated material handling equipment) into a feed hopper 11. The feed hopper 11 continuously or intermittently feeds the mixed dried material and additives into a glass furnace 12 where the dried material and additives are heated to temperatures sufficient to transform the dried material and additives in a molten mass. One type of glass furnace 12 suitable for use in the reactor system 30 is a glass furnace that is used for the production of soda lime glass and is typically used for melting container and window glass.

The glass furnace 12 can be provided with a number of measures to improve fuel efficiency. Three preferred forms of the furnace are the recuperative, regenerative, and oxygen fired furnace. The recuperative furnace uses a heat exchanger to continuously exchange heat from the hot exhaust gas of the furnace to the cool combustion supply air for the furnace. The recovered heat reduces the amount of fuel needed to transform the dried materials and additive to a molten mass. The regenerative type furnace consists of two chambers constructed from refractory brick. The brick is stacked in such a way to allow air or gas to pass through the brick. The combustion air and hot exhaust gas flows are reversed periodically to allow cold combustion air to pass alternately through each chamber. This also reduces the amount of fuel needed to transform the dried materials and additive to a molten mass. The oxygen fired furnace uses enriched
oxygen rather than air as the source of oxygen for combustion of the fuel. This results in a reduced amount of exhaust gas flow and reduced amount of exhaust heat losses from the furnace. Oxides of nitrogen in the exhaust gas are also significantly reduced by oxygen/fuel firing and heat transfer to the molten mass of dried materials and additives is significantly increased.

The reactor system 30 shown in Figure 2 uses an oxygen fired furnace. Gaseous fuel is introduced through conduit 17 to an oxy-fuel burner 19. Oxygen provided through conduit 18 combines in oxy-fuel burner 19 with the fuel gas. The design of the oxy-fuel burner 19 (or multiple burners if desired) is configured to provide the correct heating profile and operating temperatures. Exhaust gases are vented out of the furnace 12 through exhaust stack 20.

The molten mass created from the dried materials and additives flows from one end of the glass furnace 12 to the other end. The molten mass may then be processed in a variety of glass forming equipment. In the reactor system 30 shown in Figure 2, the molten mass is drained from the furnace 12 through holes 13 into a water tank 15 and is quenched in a water bath 14. The molten material fractures into a granular frit glass, which is removed from the quench tank through an outlet port 16 in the water tank 15. In an alternate embodiment of the invention, the water tank 15 is replaced by equipment capable of forming insulating fibers or other useful glass articles. The apparatus and process of manufacturing such fibers or articles is an established art.

Therefore, it can be seen that the present invention provides a method and a reactor system that destroy hazardous organic compounds in contaminated river sediment and soils and that allow for the production of a commercially marketable glass product having a predetermined target chemistry.

Although the present invention has been described with reference to certain embodiments, one skilled in the art will appreciate that the present invention can be practiced by other than the described embodiments, which have been presented for purposes of illustration and not of limitation. Therefore, the scope of the appended claims should not be limited to the description of the embodiments contained herein.
CLAIMS

What is claimed is:

1. A method for treating contaminated sediment, the method comprising:
   providing a source of contaminated sediment;
   drying the contaminated sediment to form dried contaminated sediment;
   heating the dried contaminated sediment to form a molten mass; and
   cooling the molten mass to form a vitrified product.

2. The method of claim 1 further comprising:
   tumbling the dried contaminated sediment after drying and prior to heating
   in order to make the dried contaminated sediment homogeneous.

3. The method of claim 2 further comprising:
   obtaining a sample of the homogeneous dried contaminated sediment after
   tumbling and prior to heating;
   performing at least one analysis on the sample, the analysis selected from
   the group consisting of chemical analyses and physical analyses; and
   adding at least one additive to the homogeneous dried contaminated
   sediment after tumbling and prior to heating in order to control the chemistry of
   the vitrified product.

4. The method of claim 3 wherein the additive is selected from the
   group consisting of sand, limestone, dolomite, soda ash, cullet, ammonium
   nitrate, sodium nitrate, and mixtures thereof.

5. The method of claims 3 or 4 wherein the analysis determines
   mineral proportions and total organic content in the sample.
6. The method of any of the preceding claims wherein the step of cooling the molten mass to form a vitrified product comprises:
   quenching the molten mass in water to form glass frit.

7. The method of any of the preceding claims wherein the step of cooling the molten mass to form a vitrified product comprises:
   drawing the molten mass to form a glass fiber.

8. The method of any of the preceding claims further comprising:
   dewatering the contaminated sediment prior to drying the contaminated sediment.

9. The method of any of the preceding claims wherein the step of drying the contaminated sediment to form dried contaminated sediment comprises:
   drying the contaminated sediment to form dried contaminated sediment having a moisture content of less than 10% on a weight basis.

10. The method of any of the preceding claims wherein the step of heating the dried contaminated sediment to form a molten mass comprises:
    heating the dried contaminated sediment to a temperature between 2200°F (1204°C) to 2700°F (1482°C).

11. The method of any of the preceding claims wherein:
    the dried contaminated sediment is heated in an oxidizing atmosphere.

12. The method of any of the preceding claims wherein the step of heating the dried contaminated sediment to form a molten mass comprises:
    heating the dried contaminated sediment in an oxygen fired glass furnace.
13. The method of any of claims 1 to 11 wherein the step of heating the dried contaminated sediment to form a molten mass comprises:
   heating the dried contaminated sediment in a furnace that produces heat by combusting fuel gas and combustion air, the combustion air being preheated by a regenerative air heater.

14. The method of any of claims 1 to 11 wherein the step of heating the dried contaminated sediment to form a molten mass comprises:
   heating the dried contaminated sediment in a furnace that produces heat by combusting fuel gas and combustion air, the combustion air being preheated by a recuperative air heater.

15. A method for treating contaminated sediment, the method comprising the steps of:
   providing a source of contaminated sediment;
   drying a first portion of the contaminated sediment to form a first portion of dried contaminated sediment;
   heating the first portion of dried contaminated sediment in a furnace to form a first portion of molten mass;
   recovering waste heat from the furnace;
   drying a second portion of the contaminated sediment with the recovered waste heat to form a second portion of dried contaminated sediment;
   cooling the first portion of molten mass to form a vitrified product;
   heating the second portion of dried contaminated sediment in the furnace to form a second portion of molten mass; and
   cooling the second portion of molten mass to form a vitrified product.
16. A method for treating contaminated sediment, the method comprising the steps of:

- providing a source of contaminated sediment;
- drying a first portion of a continuous stream of the contaminated sediment to form a first portion of dried contaminated sediment;
- heating the first portion of dried contaminated sediment in a furnace to form a first portion of molten mass;
- recovering waste heat from the furnace;
- drying a second portion of the continuous stream of the contaminated sediment with the recovered waste heat to form a second portion of dried contaminated sediment;
- cooling the first portion of molten mass to form a vitrified product;
- heating the second portion of dried contaminated sediment in the furnace to form a second portion of molten mass; and
- cooling the second portion of molten mass to form a vitrified product.

17. A product produced by the method of any of claims 1 to 16.

18. An apparatus for treating contaminated sediment comprising:

- a dryer (3) for drying the contaminated sediment to form dried contaminated sediment;
- a mixer (8) in communication with the dryer, the mixer receiving the dried contaminated sediment from the dryer and mixing the dried contaminated sediment to form a homogeneous dried contaminated sediment;
- a furnace (12) for receiving the homogeneous dried contaminated sediment from the mixer and for heating the dried contaminated sediment to form a molten mass; and
- a cooling apparatus for receiving the molten mass from the furnace and for cooling the molten mass to form a vitrified product.
19. The apparatus of claim 18 wherein:
the dryer receives recovered waste heat from the furnace.

20. The apparatus of any of claims 18 to 19 further comprising:
at least one additive storage vessel (5,6,7), each additive storage vessel
providing an additive to the mixer prior to heating in the furnace.

21. The apparatus of any of claims 18 to 20 wherein:
the furnace is operated with an oxidizing atmosphere.

22. The apparatus of any of claims 18 to 21 wherein:
the furnace is a glass furnace that produces heat by combusting fuel gas
and enriched oxygen.

23. The apparatus of any of claims 18 to 21 wherein:
the furnace produces heat by combusting fuel gas and combustion air, the
combustion air being preheated by a regenerative air heater.

24. The apparatus of any of claims 18 to 21 wherein:
the furnace produces heat by combusting fuel gas and combustion air, the
combustion air being preheated by a recuperative air heater.

25. The apparatus of any of claims 18 to 24 wherein:
the cooling apparatus comprises a quench tank (15) containing a quench
fluid (14).

26. The apparatus of any of claims 18 to 24 wherein:
the cooling apparatus comprises a fiber drawing apparatus for drawing the
molten mass to form a glass fiber.
27. The apparatus of any of claims 18 to 26 further comprising:
an analyzer (10) for performing at least one analysis on a sample of the
homogeneous dried contaminated sediment prior to heating in the furnace.

28. The apparatus of claim 27 wherein:
the analyzer determines mineral proportions and total organic content in
the sample.
FIG. 1B

(A) CONTAMINATED SEDIMENT
  ➔ DEWATER
  ➔ B DEWATERED SEDIMENT
  ➔ D DRIED SEDIMENT
  ➔ C DRIED SEDIMENT
  ➔ TUMBLE / MIX
  ➔ D HOMOGENEOUS DRIED SEDIMENT
  ➔ E ADDITIVES ➔ MIX
  ➔ F HOMOGENEOUS FEED MATERIAL ➔ HEAT
  ➔ G MOLTEN MASS ➔ DRAW
  ➔ H GLASS FIBER

SUBSTITUTE SHEET (RULE 26)
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B09C1/06 B09B3/00 C03B5/00

According to International Patent Classification (IPC) or to both national classification and IPC.

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B09C B09B C03B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched.

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
WPI Data, EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Patent family members are listed in annex.

* Special categories of cited documents:
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  * P document published prior to the international filing date but later than the priority date claimed

Date of the actual completion of the international search: 29 January 2001
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Name and mailing address of the ISA
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-3040, Tx. 31 651 epo nl, Fac. (+31-70) 340-3016

Authorized officer: Laval, J
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