

Wastewater Sludge Processing System

GOVERNMENT INTEREST STATEMENT

[0001] None

BACKGROUND OF THE INVENTION

1. Field of Invention

[0002] The invention relates generally to a process for the treatment of wastewater sludge into desirable products with no undesirable waste left over. More specially the process relates to drying the sludge, and separating the sludge into oil, water, and cellulose/minerals by the use of chemical and physical reactions.

2. Description of the Background

[0003] Sewage is created by residences, institutions, hospitals and commercial and industrial establishments. Raw influent (sewage) includes household waste liquid from toilets, baths, showers, kitchens, sinks, and so forth that is disposed of via sewers. In many areas, sewage also includes liquid waste from industry and commerce. Municipal wastewater therefore includes residential, commercial, and industrial liquid waste discharges, and may include storm water runoff.

[0004] Conventional sewage treatment involves three stages, called primary, secondary and tertiary treatment. First, the solids are separated from the wastewater stream. Then dissolved biological matter is progressively converted into a solid mass by using indigenous, water-borne micro-organisms. Finally, the biological solids are neutralized then disposed of or re-used, and the treated water may be disinfected chemically or physically (for example by lagoons and microfiltration). The final effluent can be discharged into a stream, river, bay, lagoon or wetland, or it can be used for the irrigation of a golf course, green way or park. If it is sufficiently clean, it can also be used for groundwater recharge or agricultural purposes.

[0005] The sludges accumulated in a wastewater treatment process must be treated and disposed of in a safe and effective manner. The purpose of digestion is to reduce the amount of organic matter and the number of disease-causing

microorganisms present in the solids. The most common treatment options include anaerobic digestion, aerobic digestion, and composting.

[0006] Choice of a wastewater solid treatment method depends on the amount of solids generated and other site-specific conditions. However, in general, composting is most often applied to smaller-scale applications followed by aerobic digestion and then lastly anaerobic digestion for the larger-scale municipal applications.

[0007] SUMMARY OF THE INVENTION

[0008] It has now been found that wastewater sludge can be processed economically by virtue of using products of the treatment process as a fuel for one or more heating steps in the process. It has further been found that wastewater sludge can be processed such that at the end of the process of the present invention, all the useful materials—oil, cellulose and minerals—have been captured. Most important, it has still further been found that wastewater sludge can be processed such that there is nothing left to be incinerated, landfilled, or otherwise disposed of, making the system of the present invention a truly zero-waste process.

[0009] In accordance with an embodiment of the invention, a zero-waste method of processing wastewater sludge is provide such that at the end of the process of oil, cellulose, and minerals have been captured and there is substantially nothing left to be incinerated, landfilled, or otherwise disposed of.

[00010] In accordance with another embodiment of the invention, a process is provide which comprises the steps of;

- a- transferring solid wastewater sludge from a treatment plant to a wet sludge holding bin, said wastewater sludge containing from about 20 to 45% solids by weight,
- b- drying said wastewater sludge to about 90% solids,

grinding the dried wastewater sludge and transferring the dried ground sludge to a mixer reactor,

c- within the mixer reactor mixing the dried ground sludge with a solvent and heating to produce viscous suspension of hydrocarbons or cellulose and minerals in suspension,

d- separating liquids and solids,

e- heating the separated liquids to the boiling point of the solvent and the boiling point of the residual water prior and collecting evaporated solvent and residual water,

f- transferring solvent-free oil to a holding tank,

g- condensing evaporated solvent and residual water and separating water from solvent, and

h- transferring separated solvent and residual water to the mixer reactor of step (c).

[00011] In accordance with a further embodiment of the invention the step of separating liquids and solids is performed in a filter press, and further comprises the steps of;

i- collecting cellulose-mineral mixture from said filter press

j- drying said cellulose-mineral mixture and removing and collecting solvent

k- reusing collected solvent in the process at step (c), and

l- transferring dried cellulose/mineral mixture to a furnace and using the heat from the furnace in at least one of steps (b), (c) and (e).

[00012] In accordance with another embodiment of the invention the oil from step (f) is approximately 80% fatty acids, is approximately 65 weight % C16 and C18, and is substantially free of sulfur.

[00013] In accordance with still another embodiment of the invention the process extracts about 18% oil by weight from undigested sludge and 11% oil by weight from digested sludge.

[00014] In accordance with another embodiment of the invention the step of separating liquids and solids produces a filtrate comprising extracted oil, residual solvent, and traces of water.

[00015] BRIEF DESCRIPTION OF THE DRAWINGS

[00016] FIG. 1 is part 1 of the process flow diagram.

[00017] FIG. 2 is part 2 of the process flow diagram.

[00018] FIG. 3 is part 3 of the process flow diagram.

DETAILED DESCRIPTION

[00019] It is advantageous to define certain terms before describing the invention. It should be appreciated that the following definitions are used throughout this application.

Definitions

[00020] The term "wastewater sludge" and "sludge" means sludge accumulated in a wastewater treatment process.

[00021] The term "solvent" means a substance capable of dissolving another substance.

[00022] The term "filtrate" means a liquid or gas that has been filtered.

[00023] The term "screw feeder" means a screw feeder such as a volumetric screw feeder or gravimetric screw feeder, capable of metering material in a production process.

[00024] The term "filter press" means a machine using filtering cloths and plates to separate solids and liquids.

[00025] The term "biodiesel feedstock" means organic material used in the production of biofuels.

[00026] The terms "about" and "approximately" means a deviation of no greater than 15% from an absolute value.

[00027] The term "substantially" means plus or minus 10%.

[00028] The term "holding tank" means any piece of equipment that is used to store product.

[00029] The term "%", unless otherwise specified, refers to percent by weight.

[00030] The Wastewater sludge processing system takes sludge directly from the municipal waste water treatment plant, transforms it into useful products, and leaves no waste behind. It is a low-temperature, low pressure process.

[00031] The municipal solid waste (101) is transferred from a treatment plant to a wet sludge holding bin (103). In the holding bin (103) the waste is 20-45% solids by weight. The sludge is transferred by first screw feeder (105) to a dryer (107) where it is dried to 90% solids. During the drying, liquid is removed as steam (109). The dried sludge is then ground in a grinder (111). The dried ground sludge is transferred to a dried feed holding bin (203). The dried ground sludge is transferred by a screw feeder (205) along the path (1001A) to the path (1001B) to the mixer reactor (113).

[00032] Solvent is added to the sludge in the mixer reactor (113) via pump a first pump (115). Within the mixer reactor (113) the mixture is mixed and heated. The resulting material is viscous hydrocarbon and/or cellulose and minerals in suspension. The resulting solution is pumped by pump (215) into a filter press (117) where the filtrate and solids are separated. The filtrate which includes extracted oil, residual solvent, and traces of water, is sent to a holding tank (119). The filtrate is pumped via a second pump (215) along the path (2005A) to the path (2005B) to the heat exchanger (121). The filtrate is heated to the boiling point of the solvent and the boiling point of the residual water prior to entering the flash drum (123). In the flash drum (123), the solvent and residual water are evaporated and removed via the vacuum pump (125). The solvent-free oil is collected from the bottom of the flash drum (123) and moved by third pump (315) to a holding tank (127) ready for shipping as biodiesel feedstock.

[00033] The solvent and residual water vapor from the vacuum pump (125) discharge and the vent lines from the upstream process along the path (2003A)

to the path (2003B) are collected and are routed to the solvent recovery system indicated generally as (129). In the second heat exchanger (221) vapors are condensed back to a liquid state. The liquid then travels along the path (2001A) to the path (2001B) to the condenser/separator (131) which removes the water from the solvent. The water and the solvent are both returned to be reused in the process.

[00034] The cellulose and minerals are moved from the condenser/separator (131) by a fourth pump (415) into the make-up solvent tank (133). The vented vapor from the condenser/separator (131) goes to an activated carbon canister (135) and then into the make-up solvent tank (133). Fresh solvent is also added to the make-up solvent tank (133). Hot water (139) is also removed from the condenser/separator (131) for reuse.

[00035] Back at the filter press (117), the cellulose/mineral mixture is collected and sent to a dryer (141) where the solvent is removed and recovered. The cellulose/mineral mixture proceeds to a holding tank (303). The third screw feeder (305) takes the cellulose/mineral mixture along the path (2007A) to the path (2007B) to a furnace (143) that provides heat for the process. Optionally, the ash that remains can be processed for further byproduct recovery (145) or alternatively, it is used as a byproduct without further processing.

[00036] A nitrogen tank (147) uses the fifth pump (515) to move the nitrogen along the path (1001A) to the path (1001B) to the mixer reactor (113), the filtrate tank (119), the dryer (141) and the dried cellulose bin (303).

[00037] Preferably, the system does not employ further separation, but rather, the cellulose/mineral mixture is used as fuel in an alternative fuel furnace to dry the incoming sludge. The oil has a 19,000 Btu/pound energy value and the cellulose/mineral mixture has a 7000 Btu/pound energy value.

[00038] The oil is considered to be a perfect feedstock for biodiesel. It is 80% fatty acids (65% C16 and C18), and has almost no sulfur. It also can be used as fuel oil without further processing.

[00039] The process extracts 18% oil by weight from undigested sludge and 11% oil by weight from digested sludge. A bone dry pound of sludge yields 11-18% oil,

50-60% cellulose and 30% minerals (though the process need not separate the cellulose and minerals).

[00040] The drying step of the process takes about 45% of the energy cost of the process. It should be noted that because the process does not employ a washing step, drying costs are minimized.

[00041] At the end of the process of the present invention, all the useful materials—oil, cellulose and minerals—have been captured. Most important, there is nothing left to be incinerated, landfilled, or otherwise disposed of, making the system of the present invention a truly zero-waste process.

[00042] The following examples are for illustrative purposes and are not indicative of the limits of the present invention.

EXAMPLE

[00043] Process design Criteria and Assumptions

<u>Item</u>	<u>Units</u>	<u>Design</u>
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[00044] Municipal Solid Waste (MSW)

MSW Filter cake as feed to dryer	lb/hr	40
Moisture content	%	75
Solids content	%	25
Bulk density of MSW cake	lb/ft ³	65
Temperature (avg.) of MSW cake	-F	65

[00045] Average Composition of Reactor Feed Solids

Dried MSW as feed to reactor	lb/hr	10
Solids content	%	90
Moisture content	%	10
Oil (dry solids basis)	%	10
Cellulose (dry solids)	%	50-60

Bulk density of cellulose	lb/ft ³	11
Specific heat capacity	Btu/lb--F	7850
Metal oxides (MO), dry solids	%	25-35 NT
Bulk density of MO	lb/ft ³	156
Sp. Gr. (average) of MO	-	2.5
Specific heat capacity of MO	Btu/lb--F	0.23

[00046] Average Composition of Metal Oxides

Iron oxide	%	10.0
Calcium oxide	%	6.25
Phosphorus oxide	%	4.5
Aluminum oxide	%	2.25
Other oxides	%	2.0

[00047] Solvent Characteristics

Heptane (C ₇ H ₁₆)		
Specific gravity	-	0.684
Bulk density of C ₇ H ₁₆	lb/ft ³	42.64
Boiling point of C ₇ H ₁₆	-F	209.1
Specific heat capacity of C ₇ H ₁₆	Btu/lb--F	0.5
Latent heat of vaporization	Btu/lb	76.45

<u>Item</u>	<u>Units</u>	<u>Design</u>
Nitrogen Gas		
Specific heat capacity of nitrogen	Btu/lb--F	0.25
Density of nitrogen	lb/ft ³	0.073

[00048] Product Fuel Oil

Specific gravity of oil	-	0.9
Bulk density of oil	lb/ft ³	56
Specific heat capacity of oil	Btu/lb--F	18,000

[00049] Plant Operation

Length of shift	hr/d	10
Operating hours per shift	hr/shift	8
Dried MSW feed processed	lb/hr	10
Solvent addition		
Pounds per pound of dry solids	lb/lb	4:1
Solvent loss/lb of product oil	%	1.0

[00050] MSW Feed to Dryer

Raw MSW filter cake	lb/hr	40
Solids content	%	25
Moisture content	%	75
Bulk density of dried MSW cake	lb/ft ³	21-31

Pilot Plant Operation Parameters

[00051] The Mixer/Reactor was sized** to process 20 lb of solids on a dry basis (22.2 lb of dried MSW containing 90% solids) per batch of 3 hours duration. Forty (40) pounds of dry solids processed during a shift contain an estimated 37.5% or 15 pounds of oil. Approximately two (2) gallons of oil at 95% recovery are to be produced during the 8 hours of operation each day.

Number of shifts per day	shifts/d	1
Duration of shift (total)	hr/shift	10

Number of batches per shift	batches/d	2
Reaction time per batch	hr/batch	3
Dried feed (90% solids) per batch	lb/batch	22.2
Dry solids content of Reactor feed	lb/batch	20
Solvent addition rate	lb/batch	40
Solvent added	lb/d	80

<u>Item</u>	<u>Units</u>	<u>Design</u>
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[00052] Product Oil

Oil in MSW feed solids	%	10
Oil content of MSW feed solids	lb/d	2
Estimated oil recovery	%	95
Estimated oil recovery	lb/d	14.25
Estimated oil recovery	gal/d	1.9

[00053] Mixer/Reactor

Solids processed on a dry basis = 10 lb/batch

Solvent (heptane) added per batch = 40 lb/batch

Mass of dried feed (90% solids) charged to Mixer/Reactor

$$= (10 \text{ lb/batch}) / (90\% \text{ solids})$$

$$= 11.1 \text{ lb/batch}$$

Volume of dried feed charged to Mixer/Reactor

$$= (11.1 \text{ lb/batch}) / (21.31 \text{ lb/ft}^3)$$

$$= 0.35\text{--}0.52 \text{ ft}^3/\text{batch}$$

Volume of solvent (heptane) added to Mixer/Reactor

$$= (40 \text{ lb/batch}) / (21.3 \text{ lb/ft}^3)$$

$$= .94 \text{ ft}^3/\text{batch}$$

Total volume of feed to Mixer/Reactor

$$= 0.35\text{-}.52 \text{ ft}^3 \text{ dried MSW filter cake} + 1.88 \text{ ft}^3 \text{ heptane}$$

$$= 1.29\text{-}1.46 \text{ ft}^3/\text{batch}$$

Size of Mixer/Reactor (D = diameter = height)

$$= \frac{(\pi) \times (D^2)}{4} \times (D) = 1.29\text{-}1.46 \text{ ft}^3$$

$$D = [(1.29\text{-}1.46) \times (4)/(\pi)]^{1/3} = 1.18\text{-}1.23 \text{ ft.}$$

The Mixer/Reactor is **1.5 ft. dia. x 2.5 ft. tall**, which includes a freeboard allowance of 1.0 ft. and equipped with 1.0 hp motor with variable frequency drive (VFD). [4.42 ft³]

[00054] Broad Scope of the Invention

[00055] Although the present invention has been fully described in conjunction with several embodiments thereof with reference to the accompanying drawings, it is to be understood that various changes and modifications may be apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims, unless they depart therefrom.

[00056] While illustrative embodiments of the invention have been described herein, the present invention is not limited to the various preferred embodiments described herein, but includes any and all embodiments having equivalent elements, modifications, omissions, combinations (e.g., of aspects across various embodiments), adaptations and/or alterations as would be appreciated by those in the art based on the present disclosure. The limitations in the claims are to be interpreted broadly based on the language employed in the claims and

not limited to examples described in the present specification or during the prosecution of the application, which examples are to be construed as non-exclusive. For example, in the present disclosure, the term "preferably" is non-exclusive and means "preferably, but not limited to." In this disclosure and during the prosecution of this application, means-plus-function or step plus-function limitations will only be employed where for a specific claim limitation all of the following conditions are present in that limitation: a) "means for" or "step for" is expressly recited; b) a corresponding function is expressly recited; and c) structure, material or acts that support that structure are not recited. In this disclosure and during the prosecution of this application, the terminology "present invention" or "invention" may be used as a reference to one or more aspect within the present disclosure. The language present invention or invention should not be improperly interpreted as an identification of criticality, should not be improperly interpreted as applying across all aspects or embodiments (i.e., it should be understood that the present invention has a number of aspects and embodiments) and should not be improperly interpreted as limiting the scope of the application or claims. In this disclosure and during the prosecution of this application, the terminology "embodiment" can be used to describe any aspect, feature, process or step, any combination thereof, and/or any portion thereof, etc. In some examples, various embodiments may include overlapping features. In this disclosure, the following abbreviated terminology may be employed: "e.g." which means "for example".

What is claimed is:

Claim 1 A zero-waste method of processing wastewater sludge such that at the end of the process, oil, cellulose, and minerals have been captured and there is substantially nothing left to be incinerated, landfilled, or otherwise disposed of, comprising the steps of;

- a- transferring solid wastewater sludge from a treatment plant to a wet sludge holding bin, said wastewater sludge containing from about 20 to 45% solids by weight,
- b- drying said wastewater sludge to about 90% solids,
grinding the dried wastewater sludge and transferring the dried ground sludge to a mixer reactor,
- c- within the mixer reactor mixing the dried ground sludge with a solvent and heating to produce viscous suspension of hydrocarbons or cellulose and minerals in suspension,
- d- separating liquids and solids,
- e- heating the separated liquids to the boiling point of the solvent and the boiling point of the residual water prior and collecting evaporated solvent and residual water,
- f- transferring solvent-free oil to a holding tank,
- g- condensing evaporated solvent and residual water and separating water from solvent, and
- h- transferring separated solvent and residual water to the mixer reactor of step (c).

Claim 2 The method of claim 1, further comprising said step of separating liquids and solids is performed in a filter press,

- i- collecting cellulose-mineral mixture from said filter press
- j- drying said cellulose-mineral mixture and removing and collecting solvent
- k- reusing collected solvent in the process at step (c), and
- l- transferring dried cellulose/mineral mixture to a furnace and using the heat from the furnace in at least one of steps (b), (c) and (e).

Claim 3 The method of claim 2, wherein the oil from step (f) is approximately 80% fatty acids.

Claim 4 The method of claim 3, wherein the oil from step (f) is approximately 65 weight % C16 and C18.

Claim 5 The method of claim 3, wherein said oil is substantially free of sulfur.

Claim 6 The method of claim 1, wherein the process extracts about 18% oil by weight from undigested sludge and 11% oil by weight from digested sludge.

Claim 7 The method of claim 1, wherein said step of separating liquids and solids produces a filtrate comprising extracted oil, residual solvent, and traces of water.

Claim 8 Claim 1 A zero-waste method of processing wastewater sludge such that at the end of the process, oil, cellulose, and minerals have been captured and there is substantially nothing left to be incinerated, landfilled, or otherwise disposed of, comprising the steps of;

- a- transferring solid wastewater sludge from a treatment plant to a wet sludge holding bin, said wastewater sludge containing from about 20 to 45% solids by weight,
- b- drying said wastewater sludge to about 90% solids,

grinding the dried wastewater sludge and transferring the dried ground sludge to a mixer reactor,

- c- within the mixer reactor mixing the dried ground sludge with a solvent and heating to produce viscous suspension of hydrocarbons or cellulose and minerals in suspension,
- d- separating liquids and solids,
- e- heating the separated liquids to the boiling point of the solvent and the boiling point of the residual water prior and collecting evaporated solvent and residual water,
- f- transferring solvent-free oil to a holding tank,
- g- condensing evaporated solvent and residual water and separating water from solvent,
- h- transferring separated solvent and residual water to the mixer reactor of step (c),
- i- collecting cellulose-mineral mixture from step (d),
- j- drying said cellulose-mineral mixture and removing and collecting solvent
- k- reusing collected solvent in the process at step (c), and
- l- transferring dried cellulose/mineral mixture to a furnace and using the heat from the furnace in at least one of steps (b), (c) and (e),

wherein the oil from step (f) is approximately 80% fatty acids and 65 weight % C16 and C18, and

wherein said step of separating liquids and solids produces a filtrate comprising extracted oil, residual solvent, and traces of water.