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(54) Title: ORGANIC WASTE WATER TREATMENT METHOD AND APPARATUS FOR REDUCING AMOUNT OF GENERATED EXCESS SLUDGE

(57) Abstract: The present invention provides a technique which enables a reduction in the amount of discharged excess sludge in a method and apparatus for biologically treating organic waste water. An aspect of the present invention provides a method for treating organic waste water in a biological treatment system such that excess sludge is generated, which comprises treating the organic waste water by the biological treatment system, solubilizing obtained sludge and then returning the solubilized sludge to the biological treatment system, wherein sludge drawn from the biological treatment system is introduced into an acid fermentation tank, and the sludge in the acid fermentation tank is introduced into an ultrasonic treatment apparatus by means of a pump and pulverized by the ultrasonic treatment apparatus and then circulated to the acid fermentation tank.

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DESCRIPTION

ORGANIC WASTE WATER TREATMENT METHOD AND APPARATUS FOR REDUCING
AMOUNT OF GENERATED EXCESS SLUDGE

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TECHNICAL FIELD

The present invention relates to a technique enabling a reduction in the amount of excess sludge generated during the biological treatment of organic waste water such as sewerage and organic industrial waste water, and more particularly to an organic waste water treatment method and apparatus which enable a reduction in the energy consumption required to liquefy sludge.

15

BACKGROUND ART

Sewerage and organic industrial waste water are treated by a biological treatment method which uses activated sludge. The biological treatment of organic waste water is an excellent treatment method, but a large amount of excess sludge is generated by the process, and in the whole of Japan, this amount reaches or exceeds ten million tons per year. The excess sludge is usually dewatered and then buried or incinerated, but the processing costs required for these operations increase by the year, causing an increase in the overall waste water treatment costs. Hence, in recent years, techniques for suppressing the amount of generated excess sludge have been gaining attention. For example, in an "Excess Sludge Treatment Method" disclosed in Japanese Examined Patent Application Publication JP-B-S57-19719, excess sludge is reduced by irradiating sludge with ultrasonic waves, thereby breaking the cell membranes of the microorganisms in the sludge so that the content of the sludge is transformed into liquefied organic matter, and then

mineralizing this liquefied organic matter through biological treatment. In addition to ultrasonic treatment, a method of pulverizing (micronizing) the activated sludge physically, and a method of liquefying the sludge through the addition of an alkali or acid, for example, have also been proposed. Various other methods of liquefying sludge have been proposed, such as a technique of solubilizing (liquefying) sludge using thermophilic bacteria while maintaining the sludge in a heated state (Japanese Unexamined Patent Application Publication JP-A-H11-90493), and a technique of solubilizing sludge using ozone (Japanese Unexamined Patent Application Publication JP-A-H6-206088). The sludge that is liquefied by these various methods is returned to a biological treatment tank and mineralized by the microorganisms in the biological treatment tank, and thus the amount of generated excess sludge is reduced.

However, it has been learned that a great deal of energy is required to reduce sludge by means of ultrasonic treatment or the like, and simply returning the ultrasonic-treated sludge to an aerobic biological treatment tank leads to a deterioration in the quality of the treated water and discharge of the activated sludge.

DISCLOSURE OF THE INVENTION

It is therefore an object of the present invention to provide an organic waste water treatment method and apparatus for reducing excess sludge without causing a deterioration in the quality of treated water. Another object of the present invention is to provide an organic waste water treatment method and apparatus enabling a reduction in the amount of energy required to liquefy the sludge.

The present invention achieves the objects described above by the following means.

1. A method for treating organic waste water in a biological treatment system such that excess sludge is generated, which comprises treating the organic waste water by the biological treatment system, solubilizing obtained sludge and
5 then returning the solubilized sludge to the biological treatment system, wherein sludge drawn from the biological treatment system is introduced into an acid fermentation tank, and the sludge in the acid fermentation tank is introduced into an ultrasonic treatment apparatus by means of a pump and pulverized by the
10 ultrasonic treatment apparatus and then circulated to the acid fermentation tank.

2. A method for treating organic waste water in a biological treatment system such that excess sludge is generated, which comprises treating the organic waste water by the
15 biological treatment system, solubilizing obtained sludge and then returning the solubilized sludge to the biological treatment system, wherein sludge drawn from the biological treatment system is introduced into an acid fermentation tank, and the sludge in the acid fermentation tank is introduced into a flow-type
20 ultrasonic treatment apparatus by means of a pump and pulverized by the ultrasonic treatment apparatus and then circulated to the acid fermentation tank.

3. A method for treating organic waste water in a biological treatment system such that excess sludge is generated,
25 which comprises treating the organic waste water by the biological treatment system, solubilizing obtained sludge and then returning the solubilized sludge to the biological treatment system, wherein sludge to be introduced into an acid fermentation tank and sludge discharged from the acid fermentation tank are
30 introduced into a heat exchanger.

The present invention also provides the following means.

B-1. A method for treating organic waste water in a

biological treatment system such that excess sludge is generated, which comprises treating the organic waste water in a biological treatment tank, introducing sludge drawn from the biological treatment tank into an acid fermentation tank, introducing sludge
5 in the acid fermentation tank into an ultrasonic treatment apparatus by means of a pump, pulverizing the sludge by the ultrasonic treatment apparatus and then circulating the pulverized sludge to the acid fermentation tank, while returning sludge stored in the acid fermentation tank to the biological
10 treatment tank.

B-2. A method for treating organic waste water in a biological treatment system such that excess sludge is generated, which comprises treating the organic waste water in a biological treatment tank, introducing sludge drawn from the biological
15 treatment tank into an acid fermentation tank, introducing sludge in the acid fermentation tank into a flow-type ultrasonic treatment apparatus by means of a pump, pulverizing the sludge by the ultrasonic treatment apparatus and then circulating the pulverized sludge to the acid fermentation tank, while returning
20 sludge stored in the acid fermentation tank to the biological treatment tank.

B-3. A method for treating organic waste water in a biological treatment system such that excess sludge is generated, which comprises treating the organic waste water in a biological
25 treatment tank, introducing sludge drawn from the biological treatment tank to an acid fermentation tank and solubilizing it, returning sludge solubilized in the acid fermentation tank to the biological treatment tank, wherein sludge to be introduced into an acid fermentation tank and sludge discharged from the
30 acid fermentation tank are introduced into a heat exchanger.

Further, the present invention also provides the following means.

C-1. A method for treating organic waste water in a biological treatment system such that excess sludge is generated, which comprises treating the organic waste water by the biological treatment system, introducing all or a part of sludge
5 drawn from the biological treatment system into a sludge storage tank as is or following concentration thereof, introducing the sludge in the sludge storage tank into a sludge pulverizing apparatus and pulverizing it by the sludge pulverizing apparatus, and returning the pulverized sludge to the sludge storage tank
10 in circulatory fashion, and storing the sludge again in the sludge storage tank, whereupon the stored sludge is returned to the biological treatment system.

C-2. The organic waste water treatment method according to the above item C-1, wherein the sludge storage tank is heated
15 to a temperature between 30 to 70°C, and the storage time of the sludge in the sludge storage tank is set between 0.5 and 10 days.

C-3. An organic waste water treatment method, which comprises treating organic waste water in a biological treatment
20 tank using an aerobic biological treatment process, separating effluent from the biological treatment tank into treated water and separated sludge in a solid-liquid separation tank, introducing the separated sludge from the solid-liquid separation tank into and stored in a sludge storage tank,
25 introducing the sludge from the sludge storage tank into a sludge pulverizing apparatus and pulverizing the sludge and returning it to the sludge storage tank in circulatory fashion, and then returning the sludge in the sludge storage tank to the biological treatment tank, wherein the sludge storage tank is thermally
30 insulated to prevent heat diffusion, and/or the sludge flowing into the sludge storage tank and the sludge flowing out of the sludge storage tank are introduced into a heat exchanger, where

the sludge flowing into the sludge storage tank is heated by the heat of the sludge flowing out of the sludge storage tank, and/or the sludge flowing into the sludge storage tank and the sludge flowing out of the sludge pulverizing apparatus are
5 introduced into the heat exchanger, where the sludge flowing into the sludge storage tank is heated by the heat of the sludge flowing out of the sludge pulverizing apparatus.

C-4. The organic waste water treatment method according to any one of the above items C-1 through C-3, wherein the sludge
10 pulverizing apparatus employs at least one of an ultrasonic treatment apparatus, a homogenizer, a cutter mill, a ball mill, a stone crusher, and a blasting apparatus.

C-5. The organic waste water treatment method according to the above item C-4, wherein the sludge pulverizing apparatus
15 is an ultrasonic treatment apparatus, and the sludge in the sludge storage tank is introduced into a sludge crusher to pulverize coarse particles, and then introduced into the ultrasonic treatment apparatus.

C-6. An organic waste water treatment apparatus for
20 treating organic waste water in a biological treatment system comprising an aerobic biological treatment tank and a solid-liquid separation apparatus, which further comprises: a sludge storage tank in which sludge drawn from the solid-liquid separation apparatus is introduced and stored; a sludge
25 pulverizing apparatus connected to the sludge storage tank by a circulation path; and a pipe for returning the sludge to the biological treatment tank from the sludge storage tank.

C-7. An organic waste water treatment apparatus which comprises: a biological treatment tank for treating organic waste
30 water using an aerobic biological treatment process; a solid-liquid separation tank for separating effluent from the biological treatment tank into treated water and separated sludge,

which further comprises: a sludge storage tank in which the sludge drawn from the solid-liquid separation tank is introduced and stored; a sludge pulverizing apparatus connected to the sludge storage tank by a circulation path; sludge storage tank thermal
5 insulation means for preventing heat diffusion from the sludge storage tank, and/or a heat exchanger into which the sludge flowing into the sludge storage tank and the sludge flowing out of the sludge storage tank are introduced, for heating the sludge flowing into the sludge storage tank using the heat of the sludge
10 flowing out of the sludge storage tank, and/or a heat exchanger into which the sludge flowing into the sludge storage tank and the sludge flowing out of the sludge pulverizing apparatus are introduced, for heating the sludge flowing into the sludge storage tank using the heat of the sludge flowing out of the
15 sludge pulverizing apparatus.

C-8. The apparatus according to the above item C-6 or the above item C-7, wherein the sludge pulverizing apparatus is an ultrasonic treatment apparatus, and a sludge crusher is disposed between the sludge storage tank and the sludge
20 pulverizing apparatus so that the sludge from the sludge storage tank is crushed by the sludge crusher, and then treated by the sludge pulverizing apparatus.

According to one embodiment of the present invention, the sludge that flows into the sludge storage tank and the sludge
25 that flows out of the sludge storage tank are introduced into a heat exchanger, where the sludge flowing into the sludge storage tank is heated by the heat of the sludge flowing out of the sludge storage tank, and/or the sludge that flows into the sludge storage tank and the sludge that flows out of the sludge pulverizing
30 apparatus are introduced into a heat exchanger, where the sludge flowing into the sludge storage tank is heated by the heat of the sludge flowing out of the sludge pulverizing apparatus. As

a result, the amount of generated excess sludge can be reduced, and the energy consumption required to liquefy the sludge can be reduced. Moreover, in terms of the treated water quality, a striking nitrogen removal effect can be obtained, enabling
5 the achievement of good water quality.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows the flow of a sludge liquefaction (solubilization) process of the present invention in which sludge
10 flowing into a sludge storage tank is heated by sludge flowing out of the sludge storage tank;

Fig. 2 shows the flow of a sludge liquefaction process of the present invention in which sludge flowing into the sludge storage tank is heated by sludge flowing out of a sludge
15 pulverizing apparatus;

Fig. 3 is a graph showing variation in a sludge liquefaction ratio and a storage time in example 1, in which the sludge is subjected to liquefaction using a combination of a sludge storage tank and ultrasonic treatment, and stored at a storage
20 temperature of 50°C;

Fig. 4 is a graph showing the relationship between the sludge liquefaction ratio and sludge concentration in example 1, in which the sludge is subjected to liquefaction using a combination of a sludge storage tank and ultrasonic treatment,
25 and stored at a storage temperature of 50°C;

Fig. 5 is a view showing the flow of organic waste water treatment in example 2;

Fig. 6 is a view showing the course of a cumulative generated sludge amount in example 2 and comparative examples 1 and 2, the abscissa illustrating a number of operating days (d), and the ordinate illustrating the cumulative generated sludge amount (kg);
30

Fig. 7 is a view showing an example of a control apparatus for controlling a sludge reduction amount, according to another aspect of the present invention;

Fig. 8 is a graph showing the relationship between a sludge
5 liquefaction amount and the sludge reduction amount;

Fig. 9 is a view showing the flow of an organic waste water treatment process, including a process for reducing the volume of the sludge;

Fig. 10 is a block diagram showing an example of a sludge
10 treatment apparatus according to another aspect of the present invention;

Fig. 11 is a partial block diagram showing another example of a heat exchange part of the sludge treatment apparatus shown in Fig. 10;

Fig. 12 is a partial block diagram showing another example
15 of a heat exchange part of the sludge treatment apparatus shown in Fig. 10;

Fig. 13 is a partial block diagram showing an example in which a coarse crusher is disposed in the upstream of a
20 solubilization apparatus in the sludge treatment apparatus shown in Fig. 10;

Fig. 14 is a partial block diagram showing an example in which a screen is disposed in a sludge supply pipe in the sludge treatment apparatus shown in Fig. 10;

Fig. 15 is a graph showing the relationship between an
25 ultrasonic wave emission amount and a COD liquefaction ratio;

Fig. 16 is a graph showing variation in the output of an ultrasonic wave oscillator depending on the presence or absence of an ultrasonic crusher;

Fig. 17 is a schematic diagram showing heat balance in
30 a sludge treatment apparatus of example 5;

Fig. 18 is a view showing an outline of ultrasonic wave

oscillator cleaning means;

Fig. 19 is a view showing the flow of an organic waste water treatment process used in example 4;

Fig. 20 is a graph showing variation over time in the
5 cumulative generated sludge amount in a system used in example 4; and

Fig. 21 is a view showing the flow of an example of a control method for controlling the sludge reduction amount.

The reference numerals in each of the drawings have the
10 following meanings.

- 1 raw water
- 2 treated water
- 3 activated sludge mixture
- 4 separated sludge
- 15 4a returned sludge
- 4b a part (or all) of the separated sludge
- 5 liquefied sludge
- 6 circulated liquid
- 7 denitrification tank (anaerobic portion)
- 20 8 nitrification tank (aerobic portion)
- 9 solid-liquid separation apparatus
- 10 sludge storage tank (acid fermentation tank)
- 11 ultrasonic treatment apparatus
- 12 heat exchanger
- 25 13 sludge
- 14 sludge pulverizing apparatus
- 15 pulverized sludge
- 20 liquefaction process
- 112 stored sludge
- 30 113 ammonia nitrogen concentration measuring apparatus
- 114 sludge pump
- 115 controller

- 116 stirring apparatus
117 heater
201 solubilization apparatus
202 reactor
5 203 circulation pump
204 stirrer
205 coarse crusher
206 screen
211 sludge supply pipe
10 212 circulating water pipe
213 sludge discharge pipe
214 concentrated separated liquid
221 heat exchange part
222 storage part
15 223 gravity settling part
224 partition wall
225 plate type heat exchanger
226 temperature sensor
227 corrugated tube
20 230 thickener
305 ultrasonic treated sludge
311 ultrasonic wave oscillator
316 washing water
317 centrifugal thickener supernatant liquid
25 318 centrifugal thickener
319 biological treatment tank
320 concentrated sludge
321 sludge crusher

30 DETAILED EXPLANATION OF THE INVENTION

An embodiment of the present invention will now be described in detail with reference to the drawings. Note that

in the following drawings, constitutional elements having identical functions will be described where appropriate using identical reference numerals.

Fig. 5 (a biological treatment apparatus used in example 5 2) is a schematic diagram showing a biological treatment apparatus and the flow of a sludge liquefaction process according to an embodiment of the present invention, comprising an organic waste water biological treatment tank (a denitrification tank 7 and a nitrification tank 8 in Fig. 5), a solid-liquid separation apparatus 9 for separating effluent ("activated sludge mixture") from the biological treatment tank into treated water 2 and separated sludge 4, a heat exchanger 12, a sludge storage tank 10, an ultrasonic treatment apparatus 11 (sludge pulverizing apparatus), and so on.

15 The organic waste water (raw water 1) is supplied to the biological treatment tank. In the biological treatment tank, the organic matter in the raw water 1 is mineralized by activated sludge. Any biological treatment tank having an aerobic portion such as a conventional activated sludge process, an
20 anaerobic-aerobic process, an anaerobic-anoxic-aerobic process, a nitrification-denitrification process, or a biofilm process may be applied as the biological treatment tank used here.

The activated sludge mixture 3 from the biological treatment tank is supplied to the solid-liquid separation
25 apparatus 9, and separated into the treated water 2 and separated sludge 4. A part or all 4b of the separated sludge 4 is supplied to the heat exchanger 12. The part or all 4b of the separated sludge that is heated by the heat exchanger 12 is then transmitted to the sludge storage tank 10, pulverized/liquefied by the
30 ultrasonic treatment apparatus 11, and then returned to the sludge storage tank 10. Liquefied sludge 5 that is treated in the sludge storage tank 10 passes through the heat exchanger

12, heats the separated sludge 4b, and is then returned to the biological treatment tank. When only a part 4b of the separated sludge 4 is transmitted to the heat exchanger 12, the remainder 4a of the separated sludge 4 is returned directly to the biological treatment tank.

Next, the features of an organic waste water biological treatment method according to the present invention will be described using Fig. 1.

All or a part of sludge 13 drawn from a biological treatment system is stored in the sludge treatment tank 10, which comprises a circulation path including a sludge pulverizing apparatus 14, either as is or following concentration. A part or all of the stored sludge inside the sludge storage tank 10 is pulverized by the sludge pulverizing apparatus 14, and then returned to the sludge storage tank 10 as pulverized sludge 15. The stored sludge inside the sludge storage tank 10 is then returned to the biological treatment system as the liquefied sludge 5.

By means of this constitution, the sludge 13 drawn from the biological treatment system is stored temporarily in the sludge storage tank 10. In the sludge storage tank (acid fermentation tank) 10, organic acid production through acid fermentation or the like and protein breakdown occur as a result of the action of the microorganisms contained in the stored sludge, and hence the sludge is converted into easily decomposable organic matter. Hereafter, this change will occasionally be referred to as "liquefaction (solubilization)". Further, a part of the sludge decomposes to carbon dioxide and is mineralized (digested). As a result, the sludge decreases in volume. The liquefied sludge 5 liquefied in the sludge storage tank 10 is returned to the biological treatment system, and the easily decomposable organic matter is mineralized in the biological treatment tank together with the organic matter contained in

the organic waste water.

When the sludge 13 from the conventional activated sludge process is supplied to the sludge storage tank 10, the concentration thereof is in many cases no more than 2%, and although liquefaction of the sludge progresses even at this concentration, the liquefaction amount can be increased by storing the sludge 13 following concentration thereof. Furthermore, in so doing the size of the sludge storage tank 10 can be reduced, enabling a reduction in the overall size of the sludge treatment facility.

A part or all of the stored sludge in the sludge storage tank is pulverized/liqefied by the sludge pulverizing apparatus 14. Here, an apparatus which pulverizes/liquefies sludge physically, such as an ultrasonic treatment apparatus or a ball mill, may be applied as the sludge pulverizing apparatus 14. In the sludge pulverizing apparatus 14, floc and contaminants contained in the sludge are pulverized, and in certain cases liquefied. In the sludge pulverizing apparatus 14, the sludge is pulverized, and since this is a physical action, the energy applied to the sludge is eventually converted to heat. Hence, the sludge treated in the sludge pulverizing apparatus 14 is heated, and by returning the heated pulverized sludge 15 to the sludge storage tank 10, the sludge in the sludge storage tank 10 is also heated. Since the sludge in the sludge storage tank 10 is heated, the sludge is not simply stored, but solubilization of the sludge is greatly accelerated.

The viscosity of the heated sludge in the sludge storage tank 10 decreases, and therefore the energy consumption of the pump required to pump the sludge to the sludge pulverizing apparatus (ultrasonic treatment apparatus) 14 can be reduced. Moreover, since the viscosity of the sludge decreases, pressure loss occurring as the sludge passes through the sludge

pulverizing apparatus 14 decreases, enabling a reduction in the energy consumption of the pump and stabilization of the operation.

The sludge is supplied to the sludge pulverizing apparatus 14 from the sludge storage tank 10 in a constant flow volume by means of a pump and then returned to the sludge storage tank 10, and therefore the flow velocity of the sludge in the sludge pulverizing apparatus 14 can be controlled regardless of the sludge treatment amount. It is preferred to provide the pump supplying sludge to the sludge pulverizing apparatus 14 with an inverter and the like whereby pumping rate may be regulated. This may enable control of treatment condition in the sludge pulverizing apparatus 14 depending on the change in concentration or properties of the sludge due to season variation or change in settling property of the sludge. Further, by increasing the flow velocity in the sludge pulverizing apparatus 14, adhesion of the sludge to the sludge pulverizing apparatus 14 can be suppressed, and as a result, the frequency of maintenance operations such as cleaning can be reduced.

Note that when an ultrasonic treatment apparatus is used as the sludge pulverizing apparatus 14, a separate sludge crusher such as a cutter mill may be provided in the upstream of the ultrasonic treatment apparatus. An ultrasonic treatment apparatus is capable of pulverizing comparatively small particles, but cannot easily pulverize coarse particles such as hair and toilet paper. Moreover, when these coarse particles are supplied to the ultrasonic treatment apparatus, the coarse particles adhere to the ultrasonic wave oscillator, causing a deterioration in the treatment performance. By crushing coarse particles in advance, adhesion of the sludge to the ultrasonic wave oscillator can be suppressed, enabling a stable operation.

When employing a flow in which nitrogen removal, such as

a nitrification-denitrification process, is performed as the organic waste water biological treatment method, by supplying the liquefied sludge 5 to a tank or part for performing denitrification, the easily decomposable organic matter contained in the liquefied sludge 5 may be used as the hydrogen donor in the denitrification reaction, enabling effects such as acceleration and stabilization of the denitrification reaction, a reduction in the organic matter load in the aerobic portion, and so on.

The operation conditions of the sludge storage tank 10 in the present invention are set such that the sludge storage tank 10 is heated to a temperature between 30 and 70°C, and more preferably between 40 and 50°C, and such that the sludge storage time is preferably within a range of 0.5 to 10 days.

When the temperature of the sludge storage tank 10 is below 30°C, liquefaction by the microorganisms slows, and when the temperature is above 70°C, acid fermentation slows and the ammonia that is generated during the liquefaction process disperses as a gas and must be treated. Therefore, the temperature of the sludge storage tank 10 is preferably held within a range of 30 to 70°C. The sludge storage time in the sludge storage tank 10 depends on the temperature, but is preferably between 0.5 and 10 days. If the temperature of the sludge storage tank 10 is low, the storage time can be lengthened, and if the temperature is high, the storage time can be shortened. Note that the reaction time may be set by determining the degree of sludge liquefaction through measurement of the concentration of the soluble organic matter, for example. In an experiment conducted by the inventor, the preferred temperature range was 40 to 60°C, and the storage time was within a range of 0.5 to 3 days.

Note that when the sludge is heated, less energy is required

as the sludge volume decreases, and therefore concentrating the excess sludge 13 is also effective in terms of heating.

Next, the liquefaction process applied to the sludge 13 according to the organic waste water treatment method and apparatus of the present invention will be described in further detail.

The organic waste water treatment apparatus according to the present invention comprises the sludge storage tank 10 and the sludge pulverizing apparatus 14, and preferably further comprises thermal insulation means for preventing diffusion of the heat in the path connecting the sludge storage tank 10 and sludge pulverizing apparatus 14 and the heat in the sludge storage tank 10, and means for heating the sludge storage tank 10 using the heat that is generated by the sludge pulverizing apparatus 14.

More specifically, as shown in Fig. 1, the sludge 13 that flows into the sludge storage tank 10 and the liquefied sludge 5 that flows out of the sludge storage tank 10 are introduced into the heat exchanger 12, and thus the sludge 13 flowing into the sludge storage tank 10 can be heated by the heat of the liquefied sludge 5 flowing out of the sludge storage tank 10. Alternatively, as shown in Fig. 2, the sludge 13 that flows into the sludge storage tank 10 and the pulverized sludge 15 that flows out of the sludge pulverizing apparatus 14 are introduced into the heat exchanger 12, and thus the sludge 13 flowing into the sludge storage tank 10 can be heated by the heat of the pulverized sludge 15 flowing out of the sludge pulverizing apparatus 14.

In the organic waste water treatment apparatus according to the present invention, heating the sludge storage tank 10 is effective in accelerating liquefaction, as described above. However, in order to save the energy required for the heating,

thermal insulation is preferably implemented. Moreover, to suppress heat diffusion from the sludge storage tank 10, the sludge that flows into the sludge storage tank is preferably heated by the sludge that flows out of the sludge storage tank 10. Further, in the treatment performed by the sludge pulverizing apparatus 14, the treated sludge contains heat, and if this heat is prevented from escaping and used to heat the sludge storage tank 10, energy usage can be suppressed effectively. Note that in cases where waste heat can be used in a factory or the like, this heat may be used to heat the sludge storage tank 10, enabling a reduction in the amount of energy required to heat the sludge storage tank 10.

In the organic waste water biological treatment method of the present invention, the sludge pulverizing process using the sludge pulverizing apparatus 14 may employ at least one device from an ultrasonic treatment apparatus, a homogenizer, a cutter mill, a ball mill, a stone crusher, a blasting apparatus, and so on, but an ultrasonic treatment apparatus comprising an ultrasonic wave oscillator is preferably employed.

An ultrasonic wave oscillator has a simply structure and is compact, enabling easy incorporation to an apparatus. Moreover, in the processing performed by an ultrasonic wave oscillator, when the input energy amount is constant and the sludge concentration is within a range of no more than 5%, the sludge liquefaction ratio is constant regardless of the sludge concentration, and therefore, when concentrated sludge is subjected to ultrasonic treatment, the sludge liquefaction amount can be increased with the same energy. The optimum input energy when using an ultrasonic wave oscillator is between 25 and 200kJ/liter in relation to the volume of the sludge 13 supplied to the sludge storage tank 10, and the energy consumption per ultrasonic horn cross section is preferably no less than 30W/cm².

Note that sludge volume reduction is not directly related, but since ultrasonic treatment is capable of inactivating the filamentous bacteria that cause bulking, an effect of suppressing bulking which causes great problems during the activated sludge treatment operation, can also be expected.

When an ultrasonic treatment apparatus comprising an ultrasonic wave oscillator is used to pulverize the sludge, the oscillator of the ultrasonic wave oscillator becomes dirty during sludge treatment, causing a reduction in output. Moreover, when the oscillator becomes dirty, the sludge flows less smoothly, causing an increase in the sludge pump pressure and making a stable operation difficult. Moreover, when the sludge pump pressure rises, the output of the ultrasonic wave oscillator also rises, causing an increased load which may lead to breakage of the oscillator. To prevent these problems, the ultrasonic wave oscillator is preferably cleaned periodically. An example of a specific method is shown in Fig. 18. Upstream side and downstream side motor-operated valves are attached to an ultrasonic wave oscillator 311 in advance. A pressure gauge is attached to the ultrasonic wave oscillator 311 to monitor pressure. When the pressure increases beyond a predetermined value, the ultrasonic wave oscillator 311 is stopped and an upstream side valve a and a downstream side valve b are closed. Note that the pressure at which the ultrasonic wave oscillator 311 is stopped may be determined in accordance with the pressure resistance capability of the ultrasonic wave oscillator and sludge pump. As an alternative to a method of determining the pressure, it is also possible to provide the ultrasonic wave oscillator 311 with a power meter measuring output thereof to measure the power consumption of the ultrasonic wave oscillator 311, and to stop the ultrasonic wave oscillator 311 when the power consumption is higher than a predetermined value. Next,

a valve c and a valve f are opened, and cleaning water 316 is supplied. After the cleaning water has been supplied for a fixed time period, the valves c and f are closed. Next, valves d and e are opened, and the cleaning water is supplied for a fixed
5 time period in a reverse direction to the normal flow of sludge. The valves d and e are then closed, the valves a and b are opened, whereupon sludge treatment is resumed to obtain ultrasonic treated sludge 305. Note that if the ultrasonic wave oscillator is operated as the cleaning water is supplied, the sludge adhered
10 to the oscillator becomes easier to remove, and hence the ultrasonic wave oscillator is preferably operated.

Hence, another aspect of the present invention is as follows.

4. A method of pulverizing sludge using a flow-type
15 ultrasonic treatment apparatus having an ultrasonic wave oscillator, which comprises detecting the output of said ultrasonic wave oscillator, stopping said ultrasonic wave oscillator when said detected output is lower than a predetermined output and cleaning the interior of said ultrasonic
20 wave oscillator by flowing cleaning water through the ultrasonic wave oscillator.

5. A method of pulverizing sludge using a flow-type ultrasonic treatment apparatus having an ultrasonic wave oscillator, which comprises detecting the pressure in said
25 ultrasonic wave oscillator, stopping said ultrasonic wave oscillator when said detected pressure is higher than a predetermined pressure and cleaning the interior of said ultrasonic wave oscillator by flowing cleaning water through the ultrasonic wave oscillator.

30 The present invention also provides the following means.

C-9. A method of pulverizing sludge by treating the sludge using an ultrasonic treatment apparatus having an ultrasonic

wave oscillator, which comprises: detecting the output of the ultrasonic wave oscillator; stopping the ultrasonic wave oscillator when the detected output is lower than a predetermined output; and cleaning the interior of the ultrasonic wave oscillator by supplying water in both a sludge flow direction and an opposite direction thereto.

C-10. An ultrasonic treatment apparatus for pulverizing sludge using ultrasonic waves, having a sludge supply port and a treated sludge discharge port and having an ultrasonic wave oscillator, which also comprises: a detector for detecting the output of the ultrasonic wave oscillator; a controller having a function for stopping the ultrasonic wave oscillator when the output thereof is detected to be lower than a predetermined output; and a structure which is capable of introducing cleaning water into each of the sludge supply port and the sludge discharge port of the ultrasonic treatment apparatus.

The method and apparatus described above may be employed as a sludge pulverizing method and apparatus in the organic waste water treatment method and apparatus according to the aforementioned embodiments of the present invention.

The present invention also relates to a method of determining a sludge liquefaction amount during a sludge liquefaction process, a method of controlling a sludge reduction amount, and a control apparatus that can be used therein. More specifically, the present invention provides a method of measuring, as an index of molecular weight reduction in the sludge, a generated ammonia nitrogen amount within a sludge mixture produced in a liquefaction process, or more particularly a filtrate obtained by filtering the sludge mixture produced in the liquefaction process, and determining a sludge liquefaction amount on the basis of the measured value.

It has been proposed (Ebara Engineering Review No. 192

(2001-7), "Study on Sludge Reduction and Other Factors by Use of an Ozonation Process in Activated Sludge Treatment", Kiyomi ARAKAWA et al.) that in a method of reducing the volume of sludge by subjecting the sludge to pulverizing processing

5 (liquefaction) as described above, the amount of generated Kjeldahl nitrogen (Kj-N) and COD_{Cr} within a filtrate obtained by filtering sludge mixture produced in a liquefaction process be measured and used as a liquefaction index.

However, during sludge liquefaction, there is not always
10 a correlation between the sludge liquefaction amount and the actual sludge reduction amount as described above, and hence it is difficult to estimate the sludge reduction amount from the sludge liquefaction amount. It is particularly difficult to estimate the sludge reduction amount from the sludge
15 liquefaction amount in a sludge liquefaction process where a nitrification reaction such as heating processing may occur.

Furthermore, when an attempt is made to control the sludge reduction amount in a sludge volume reduction process, the measurement of Kj-N and COD_{Cr} relies on manual analysis, and
20 since dangerous reagents and the like are used, this can hardly be described as a simple method. Hence, a better method of determining the sludge liquefaction amount is required.

The present invention has been designed in consideration of the technical requirements and related background art
25 described above, and it is an object thereof to establish a method of determining a sludge liquefaction amount having a greater degree of precision in a sludge liquefaction method, and to provide a method and apparatus with which a sludge reduction amount can be predicted simply from the determined sludge
30 liquefaction amount, as well as a method of controlling the sludge reduction amount and a control apparatus that can be used therein.

The present inventors have focussed on ammonia nitrogen

contained in a filtrate obtained by filtering a sludge liquid produced by sludge liquefaction in a sludge liquefaction process. The present inventors discovered that by measuring the $\text{NH}_4\text{-N}$ concentration of the filtrate (sludge filtrate) obtained by filtering the sludge liquid produced by sludge liquefaction, the sludge liquefaction amount can be determined efficiently. The present inventors also discovered that the sludge liquefaction amount can be determined efficiently by measuring the $\text{NH}_4\text{-N}$ concentration of not only the filtrate obtained by filtering the sludge liquid produced by sludge liquefaction, but also the sludge liquid produced by sludge liquefaction.

In other words, another aspect of the present invention is as follows.

6. A method for treating organic waste water in a biological treatment system such that excess sludge is generated, which comprises treating the organic waste water by the biological treatment system, solubilizing obtained sludge and then returning the solubilized sludge to the biological treatment system, further comprising predicting a sludge reduction amount by determining a sludge liquefaction amount, determining an amount of sludge to be sent to a liquefaction process on the basis of said predicted sludge reduction amount.

The present invention also provides the following means.

B-6. A method for treating organic waste water in a biological treatment system such that excess sludge is generated, which comprises treating the organic waste water in a biological treatment tank, solubilizing sludge drawn from the biological treatment tank, and then returning the solubilized sludge to the biological treatment tank, which further comprises predicting a sludge reduction amount by determining a sludge liquefaction amount in the solubilizing treatment, determining an amount of sludge to be sent to a solubilizing treatment process

on the basis of said predicted sludge reduction amount.

Further, the present invention also provides the following means.

C-11. A method for liquefying a sludge, wherein a sludge
5 liquefaction amount is determined using a generated amount of ammonia nitrogen as an index.

C-12. The method according to the above item C-11, wherein the generated amount of ammonia nitrogen in a filtrate obtained by filtering liquefied sludge is measured.

10 C-13. The method according to the above item C-12, wherein a sludge liquefaction process comprises the step of heating the sludge.

C-14. A method for liquefying a sludge, wherein a sludge reduction amount is predicted by determining a sludge
15 liquefaction amount; and the sludge reduction amount is controlled by determining an amount of sludge to send to a liquefaction process on the basis of the predicted sludge reduction amount.

C-15. The sludge reduction amount control method
20 according to the above item C-14, wherein the sludge liquefaction process comprises the step of heating the sludge or the step of pulverizing the sludge.

C-16. A sludge treatment apparatus comprising: a heating tank for storing sludge in a heated state; an ammonia nitrogen
25 concentration measuring apparatus for measuring the ammonia nitrogen concentration of a sludge liquid in the heating tank; a sludge pump for pumping sludge to the heating tank; and a controller for predicting a sludge reduction amount from the measured ammonia nitrogen concentration, and issuing an
30 instruction to the sludge pump to pump sludge to the heating tank.

C-17. An organic waste water treatment apparatus

comprising the sludge treatment apparatus according to the above item C-16.

To describe this in further detail, the $\text{NH}_4\text{-N}$ concentration of the sludge filtrate prior to liquefaction is extremely low, and hence may be ignored without trouble, whereas by measuring the $\text{NH}_4\text{-N}$ concentration of the sludge filtrate following liquefaction, the sludge liquefaction amount can be determined. A sludge liquefaction amount $\Delta\text{LNH}_4\text{-N}$ (g/d) using the ammonia nitrogen concentration as an index has a relationship of approximately $\Delta X/\Delta L=1$ with a sludge reduction amount ΔX , and since $\Delta\text{LNH}_4\text{-N}$ and ΔX have a proportional relationship (see Fig. 8), the sludge liquefaction amount can be determined on the basis of the $\text{NH}_4\text{-N}$ concentration of the sludge filtrate. In other words, the ammonia nitrogen concentration (i.e. the generated ammonia nitrogen amount) of the sludge liquid is extremely useful as a determining factor of the sludge liquefaction amount and as a factor for predicting the sludge reduction amount.

By measuring the $\text{NH}_4\text{-N}$ concentration of the liquefied sludge liquid, and more preferably by measuring the ammonia nitrogen concentration of the filtrate obtained by filtering the liquefied sludge liquid, the sludge liquefaction amount can be determined efficiently. Moreover, the sludge reduction amount can be predicted from the sludge liquefaction amount determined in this manner, and the sludge reduction amount can be controlled with good efficiency. When measuring the $\text{NH}_4\text{-N}$ concentration of the liquid, a more precise measurement value can be obtained with less effect on the measuring instrument by measuring the filtrate obtained by filtering the liquefied sludge liquid rather than directly measuring the liquefied sludge liquid.

Next, the embodiment described above will be described in further detail with reference to the drawings.

Fig. 8 shows the relationship between the sludge liquefaction amount and the sludge reduction amount. The sludge liquefaction amount using ammonia nitrogen as an index (to be referred to hereafter as "the ammonia nitrogen-based sludge liquefaction amount"; $\Delta\text{LNH}_4\text{-N}$) has a relationship of approximately $\Delta X/\Delta L=1$ with the sludge reduction amount ΔX , and $\Delta\text{LNH}_4\text{-N}$ and ΔX have a proportional relationship. On the other hand, with a sludge liquefaction amount using Kjeldahl nitrogen as an index (to be referred to hereafter as "the Kjeldahl nitrogen-based sludge liquefaction amount"; $\Delta\text{LKj-N}$), the sludge reduction amount ΔX substantially stops increasing at a sludge liquefaction amount of 400g/d or more, and hence it is difficult to estimate the sludge reduction amount from the sludge liquefaction amount. In actuality, the $\text{NH}_4\text{-N}$ concentration of the sludge filtrate prior to liquefaction is extremely small, and hence the sludge reduction amount can be controlled by measuring the $\text{NH}_4\text{-N}$ concentration of the sludge filtrate following liquefaction. It is particularly advantageous to use the ammonia nitrogen-based sludge liquefaction amount as an index during processing in which ammonia elution is great, such as heating processing.

As shown in the flow in Fig. 9, with a sludge liquefaction amount using CODCr as an index (to be referred to hereafter as "the CODCr-based sludge liquefaction amount"; ΔLCODCr), nitrification occurs in the sludge storage tank, causing a decrease in organic matter, and hence the numerical values become lower than those of the ammonia nitrogen-based sludge liquefaction amount and the Kjeldahl nitrogen-based sludge liquefaction amount. Accordingly, use of the CODCr-based sludge liquefaction amount as an index is not preferable.

A method of calculating the ammonia nitrogen-based sludge

liquefaction amount is illustrated below. As a reference, conventional methods of calculating the Kjeldahl nitrogen-based sludge liquefaction amount and the CODCr-based sludge liquefaction amount are also illustrated. The sludge filtrate
 5 was created using filter paper with an average pore size of 1.0 μm , but the present invention is not limited thereto.

$$\Delta\text{LNH}_4\text{-N} = \text{sludge amount} \times [(\text{NH}_4\text{-N concentration of sludge filtrate following liquefaction}) - (\text{NH}_4\text{-N concentration of sludge filtrate prior to liquefaction})] / [(\text{overall NH}_4\text{-N concentration of sludge prior to liquefaction}) - (\text{NH}_4\text{-N concentration of sludge filtrate prior to liquefaction})]$$
 10

$$\Delta\text{LKj-N} = \text{sludge amount} \times [(\text{Kj-N concentration of sludge filtrate following liquefaction}) - (\text{Kj-N concentration of sludge filtrate prior to liquefaction})] / [(\text{overall Kj-N concentration of sludge prior to liquefaction}) - (\text{Kj-N concentration of sludge filtrate prior to liquefaction})]$$
 15

$$\Delta\text{LCODCr} = \text{sludge amount} \times [(\text{CODCr concentration of sludge filtrate following liquefaction}) - (\text{CODCr concentration of sludge filtrate prior to liquefaction})] / [(\text{overall CODCr concentration of sludge prior to liquefaction}) - (\text{CODCr concentration of sludge filtrate prior to liquefaction})]$$
 20

Fig. 9 shows the flow of an organic waste water biological treatment process, including a sludge volume reduction process. The raw water 1 is introduced into the denitrification tank 7,
 25 and then subjected to aerobic treatment in the nitrification tank 8. The activated sludge mixture 3 is separated into a solid and a liquid in the solid-liquid separation apparatus 9, whereupon a part of the concentrated sludge 4 is returned to the denitrification tank 7 as returned sludge 4a. Further, a
 30 part of the separated sludge 4 is introduced into the sludge storage tank 10 as liquefaction process inflow sludge 4b and subjected to heating processing. The temperature of the sludge

storage tank 10 is preferably within a range of 30 to 70°C. When the temperature of the sludge storage tank 10 is below 30°C, liquefaction by the microorganisms slows, and when the temperature is above 70°C, acid fermentation slows. The sludge storage time in the sludge storage tank 10 depends on the temperature, but is preferably between 0.5 and 10 days. In an experiment conducted by the inventors, the preferred temperature range was 40 to 60°C, and the storage time was within a range of 0.5 to 3 days. The sludge that is heated in the sludge storage tank 10 is introduced into the ultrasonic treatment apparatus 11 and subjected to ultrasonic treatment. Following ultrasonic treatment, the sludge is returned in a circulatory fashion to the sludge storage tank 10. The liquefied sludge 5 obtained in this liquefaction process is then returned to the denitrification tank 7.

Fig. 7 shows an example of a sludge reduction amount control apparatus. Fig. 21 shows a specific example of the flow of a sludge reduction amount control method. First, a target sludge reduction amount is set. The sludge is heated in the sludge storage tank 10 while being stirred with a stirring apparatus 116. Heating is performed by a heater 117. An ammonia nitrogen concentration measuring apparatus 113 is submerged in the heated stored sludge 112 to measure the ammonia nitrogen concentration of the sludge liquid. A controller 115 calculates the ammonia nitrogen-based sludge liquefaction amount on the basis of the measured ammonia nitrogen concentration, and then predicts the sludge reduction amount from the relationship between the sludge liquefaction amount and sludge reduction amount shown in Fig. 8 above. When the predicted sludge reduction amount is smaller than the set sludge reduction amount, the controller 115 issues an instruction to the sludge pump 114 to pump sludge to the sludge storage tank 10. If, on the other hand, the predicted sludge

reduction amount is greater than the set sludge reduction amount, the controller 115 issues an instruction to continue the operation as is. Note that in an experiment conducted by the inventors, it was learned that the sludge liquefaction amount
5 increases as the sludge concentration rises. The ammonia nitrogen concentration measuring apparatus 113 achieves a higher degree of prediction precision when submerged in a filtrate obtained by filtering the liquefied sludge mixture.

According to the aspect described above, by measuring the
10 ammonia nitrogen concentration of the liquefied sludge liquid or a filtrate (sludge filtrate) obtained by filtering the liquefied sludge liquid, the sludge reduction amount can be controlled efficiently, which is useful in the treatment of waste water that generates a large amount of excess sludge, in
15 particular sewerage and organic industrial waste water.

The method and apparatus of the aspect described above maybe employed as sludge liquefaction means, and means and an apparatus for controlling the sludge reduction amount, in the organic waste water treatment method and apparatus according
20 to foregoing embodiments of the present invention.

A further aspect of the present invention provides a waste product treatment apparatus for solubilizing organic waste slurry such as sludge obtained during the aerobic biological treatment of organic waste water.

25 According to this aspect, an organic waste slurry treatment apparatus for solubilizing organic waste slurry, which comprises a reactor for storing slurry to be treated, a solubilization apparatus comprising an ultrasonic treatment apparatus, and a circulation line enabling the slurry to be treated to circulate
30 between the reactor and solubilization apparatus. The reactor comprises a storage part for keeping surplus heat applied to the slurry to be treated in the solubilization apparatus inside

the reactor, and a heat exchange part for heating the slurry to be treated that is supplied to the reactor with heat possessed by treated slurry that is discharged from the reactor.

In the apparatus described above, the ultrasonic treatment
5 apparatus is preferably a flow-type apparatus. Further, the apparatus may further comprise a line for supplying the slurry to be treated to the reactor, and a thickener for concentrating the solid content of the slurry to be treated that is supplied to the line. The apparatus may further comprise a temperature
10 sensor disposed inside the reactor for detecting the internal temperature of the reactor, and means for performing operation, stoppage, or output control of the solubilization apparatus in accordance with the measured internal temperature of the reactor.

By means of this constitution, the amount of generated
15 excess sludge can be reduced effectively using a small amount of power.

According to this aspect, sludge generated from an aerobic biological treatment facility is stored temporarily in the reactor, whereupon the sludge stored in the reactor is supplied
20 to the solubilization apparatus, which employs ultrasonic waves, to be solubilized. The obtained treated liquid is returned to the reactor, and the heat that is discharged by the ultrasonic treatment is used effectively to accelerate solubilization of the sludge. The organic waste slurry to which this aspect of
25 the present invention may be applied is not limited to sludge generated from an aerobic biological treatment facility, and includes all types of slurry-form waste products containing organic matter, such as sludge generated from an anaerobic treatment facility, food residue, and livestock excreta.

30 This aspect will now be described in detail using the drawings.

Fig. 10 is a block diagram showing an example of an

embodiment of an organic waste slurry treatment apparatus according to an aspect of the present invention. In Fig. 10, excess sludge supplied from an aerobic biological treatment process for treating organic waste water is supplied to a reactor 202 through a sludge supply pipe 211. The solubilization effect of ultrasonic treatment is dependent on the volume of the slurry to be treated rather than the solid matter concentration, and therefore the excess sludge is preferably concentrated by a thickener 230 employing a method such as gravity concentration, centrifugal concentration, pressurized flotation, normal pressure flotation, coagulation and settlement, or membrane concentration before being supplied to the reactor 202. The excess sludge stored in the reactor 202 is supplied to the solubilization apparatus 201 by a circulation pump 203 and solubilized, whereupon the excess sludge is returned to the reactor 202 through a circulating water pipe 212. The solubilization apparatus 201 must be constituted to prevent the circulating sludge from short-circuiting so that all of the circulating sludge can be irradiated reliably with ultrasonic waves, and therefore a flow-type ultrasonic treatment apparatus is more suitable for use as the solubilization apparatus 201 than a water tank disposed type.

Here, the term "flow-type ultrasonic apparatus" indicates an ultrasonic treatment apparatus in which an ultrasonic wave oscillator is disposed in the interior of the solubilization apparatus 201, through which the treatment subject flows in a fixed direction, so that the area of influence of the cavitation generated by the ultrasonic waves extends over the entire cross section of the flow passage.

A storage part 222 of the reactor 202 is insulated by a thermal insulation material covering the outside thereof, and hence the heat of the solubilized sludge, which is heated by

the heat discharged in the solubilization apparatus 201, is held within the storage part 222. Further, the reactor 202 has a structure enabling heat exchange by having the sludge that is to be discharged through a sludge exhaust pipe 213 and the sludge that is supplied through the sludge supply pipe 211 face each other at a heat exchange part 221 partitioned by a partition wall 224 that is made of a thermal insulation material. Accordingly, even when the ultrasonic wave output of the solubilization apparatus 201 is low, the sludge storage part 222 can be kept at a high temperature. In the heat exchange part 221, a method of submerging a corrugated tube or plate type heat exchanger in the sludge is also effective. When the temperature of the storage part 222 is excessively high, protein contained in the sludge coagulates, causing a deterioration in biodegradability, and hence the temperature of the storage part 222 is preferably held between 40 and 60°C, and more preferably between 50 and 55°C. When the temperature of the storage part rises excessively, a temperature sensor 226 detects the temperature of the storage part 222, and when the solubilization apparatus 201, circulation pump 203, and crusher are provided, the crusher is halted automatically in accordance with the measured temperature, or the output of the solubilization apparatus 201 is automatically suppressed. Thus the internal temperature of the storage part 222 of the reactor 202 can be controlled.

When the properties of the sludge supplied to the solubilization apparatus 201 change, this affects the solubilization performance of the solubilization apparatus 201, and hence it is preferable to store the sludge in the storage part 222 for a long time period. However, if the sludge storage time is excessively long, fermentation in the reactor 202 advances, possibly leading to the generation of combustible gases

such as methane. Hence, the sludge storage time in the storage part 222 is preferably set between approximately one and four days, and more preferably approximately two days. Further, by providing a part 223 which is capable of subjecting the sludge to gravitational sedimentation in the part from which the sludge flows out from the storage part 222, short-circuit flow can be avoided, large sludge particles can be kept within the storage part 222 and broken down reliably by the solubilization apparatus 201, and the solubilized small sludge particles can be discharged to the exterior.

By means of the constitution described above, sludge is solubilized directly by ultrasonic waves, and in addition, excess sludge can be solubilized efficiently and with a small amount of power by means of a composite effect comprising an autolysis effect produced by storing the sludge and an autolysis acceleration effect produced by keeping the sludge in a heated state.

Fig. 11 is a partial block diagram showing an example in which a plate type heat exchanger 225 is used in the heat exchange part 221 of the apparatus shown in Fig. 10. Fig. 12 is a partial block diagram showing an example in which a corrugated tube 227 is used.

In cases such as when sediment, fibrous matter, and other contaminants are contained in the excess sludge, the solubilization apparatus may become blocked. In this case, as shown in Fig. 13, the contaminants may be coarsely crushed to approximately 10mm in advance by disposing a coarse crusher 205 in the upstream of the solubilization apparatus 201.

Similarly, as shown in Fig. 14, when sediment, fibrous matter, and other contaminants are contained in the excess sludge, the excess sludge supplied by the sludge supply pipe 211 may be subjected in advance to contaminant removal processing by

a screen 206, thereby preventing blockages of the solubilization apparatus 201.

The embodiment as explained above are as follows.

C-18. An organic waste slurry treatment apparatus for
5 solubilizing organic waste slurry, which comprises: a reactor
for storing slurry to be treated; a solubilization apparatus
comprising an ultrasonic treatment apparatus; and a circulation
line for circulating said slurry to be treated between said
reactor and said solubilization apparatus, said reactor
10 comprising: a storage part for keeping inside said reactor
surplus heat that is applied to said slurry to be treated in
said solubilization apparatus; and a heat exchange part for
heating said slurry to be treated that is supplied to said reactor
with heat possessed by treated slurry that is discharged from
15 said reactor.

C-19. The apparatus according to the above item C-18,
wherein said ultrasonic treatment apparatus is a flow-type
apparatus.

C-20. The apparatus according to the above item C-18 or
20 C-19, which further comprises: a line for supplying said slurry
to be treated to said reactor; and a thickener for concentrating
solid matter contained in said slurry to be treated that is
supplied to said line.

C-21. The apparatus according to the above-item C-18, C-19,
25 or C-20, which further comprises: a temperature sensor disposed
inside said reactor for detecting the internal temperature of
said reactor; and means for performing operation, stoppage, or
output control of said solubilization apparatus in accordance
with said measured internal temperature of said reactor.

30 In the present invention, an appropriate organic waste
water treatment system or sludge treatment system may be
constructed by appropriately combining the various embodiments

described above.

In the following, the embodiments of the present invention will be described in further detail using examples. However, the scope of the present invention is not limited by these examples.

Example 1

Sludge was liquefied using a combination of the sludge storage tank 10 and an ultrasonic treatment apparatus serving as the sludge pulverizing apparatus 14 shown in Fig. 1. The results are shown in Figs. 3 and 4.

In this experiment, sludge having a sludge concentration of 3.7% was stored in the sludge storage tank 10, as shown in Fig. 1, and by supplying the sludge in the storage tank to the ultrasonic treatment apparatus 14 in a circulatory manner, the sludge was liquefied. Variation in the liquefaction ratio of the sludge over the storage time was investigated. Fig. 3 shows the course of the sludge liquefaction ratio (the proportion of untreated sludge that is liquefied) when the sludge was stored at a storage temperature of 50°C and subjected to an ultrasonic wave intensity of 100kJ/liter. It was found that the liquefaction ratio increased as the storage time lengthened, but exhibited substantially no increase within a range of two to three days, and hence it was learned that at a storage temperature of 50°C, a storage time of one to three days is sufficient.

Next, the sludge concentration was set at 0.7%, 2.0%, and 3.6%, and the relationship between the sludge concentration and the liquefaction ratio was investigated. The results of this experiment are shown in Fig. 4. When the sludge concentration was varied between 0.7%, 2.0%, and 3.6%, the liquefaction ratio remained at no less than 25%. It was also learned that the sludge liquefaction amount, which is determined by the liquefaction

ratio and the sludge treatment amount, increases as the sludge concentration increases.

Example 2

In this example, treatment was performed according to the processing flow shown in Fig. 5. In example 2, a circulation type nitrification-denitrification tank divided into the denitrification tank 7 and the nitrification tank 8 was provided as the biological treatment tank. The inflow amount of the raw water 1 (sewerage in this case) was set at $4\text{m}^3/\text{d}$, the volume of the denitrification tank (anaerobic tank) 7 was set at 1m^3 , and the volume of the aerobic tank 8 was set at 2m^3 . The sludge concentration of the biological treatment tank was set at 3000mg-SS/liter , and the sludge concentration of the returned sludge 4 was set at approximately $10,000\text{mg-SS/liter}$.

In the sludge liquefaction process, the sludge storage tank 10 and ultrasonic treatment apparatus 11 were provided. A part 4b of the separated sludge was supplied to the sludge storage tank 10. The sludge storage time in the sludge storage tank 10 was set at approximately two days, and the sludge in the sludge storage tank was heated to approximately 50°C by heat from a heater and the ultrasonic treatment apparatus 11. The sludge in the sludge storage tank 10 was supplied to the ultrasonic treatment apparatus 11 and subjected to ultrasonic treatment, and then returned to the sludge storage tank 10. The intensity of the ultrasonic waves used during the ultrasonic treatment was set at 70kJ/liter in relation to the liquefied sludge 5, but may be set within an approximate range of 50 to 200kJ/liter . The liquefied sludge 5 was returned to the denitrification tank 7. The results of the sludge treatment of example 2 are shown in Table 1 and Fig. 6 together with the results of processing performed in comparative examples 1 and 2.

Comparative Example 1

To compare the amount of generated sludge, an apparatus obtained by omitting the liquefaction process (the sludge storage tank 10 and ultrasonic treatment apparatus 11) from the biological treatment process shown in Fig. 5 was used and operated simultaneously under identical conditions to those of example 2. In other words, all of the separated sludge 4 was returned to the denitrification tank 7.

Comparative Example 2

To confirm the effects of the ultrasonic treatment, an apparatus obtained by omitting the ultrasonic treatment apparatus 11 from the liquefaction process of the biological treatment apparatus shown in Fig. 5 was used and operated under identical conditions to those of example 2, and the amount of generated sludge was compared with comparative example 1 (reference). The cumulative generated sludge amount (kg) is shown in Fig. 6.

Comparing the results of the sludge treatment in example 2 and comparative examples 1 and 2, as regards the cumulative generated sludge amount, it was possible to reduce the generated excess sludge amount by 60% or more in example 2 compared to comparative examples 1 and 2, as shown in Fig. 6. Furthermore, no differences could be seen between comparative example 2 and comparative example 1 in the generated excess sludge amount, and hence it was confirmed that in order to reduce the sludge volume, both ultrasonic waves and heating are required. It was learned from these results that the present invention is able to easily achieve the object of reducing the generated excess sludge amount.

As regards the water quality in the sludge treatment results of example 2 and comparative example 1, as shown in Table 1, the chemical oxygen demand, which is an index of organic matter, is 10.1mg/liter in example 2, which is slightly worse than the

8.8mg/liter in comparative example 1, but with respect to the biological oxygen demand, an equally favorable water quality was obtained. Moreover, the total nitrogen amount was 8.2mg/liter in example 2, and 11.9mg/liter in comparative example 1, and this indicates that nitrogen removal advanced further in example 2.

Table 1
Water quality of treated water
in example 2 and comparative example 1

Item	Raw water	Treated water	
		example 2	comparative example 1
Suspended matter	340	4	6
Chemical oxygen demand	100	10.1	8.8
Biological oxygen demand	253	<5	<5
Ammonia nitrogen	22.0	<0.1	<0.1
Nitrate nitrogen	<0.1	3.3	7.6
Total nitrogen	44.6	8.2	11.9

Unit: mg/l

Example 3

The ultrasonic wave oscillator 311 was cleaned using the apparatus shown in Fig. 18. Sludge having a sludge concentration of approximately 4.5% was supplied to the ultrasonic wave oscillator, having a maximum output of 4kW, and ultrasonic treatment was performed. Immediately after the sludge was supplied, the ultrasonic wave oscillator operated at an output of approximately 2kW, but after approximately two days, the output decreased to 1.5kW. Cleaning of the ultrasonic wave oscillator was implemented at the point where the output of the ultrasonic wave oscillator 311 fell to or below 1.5kW. The cleaning operation was performed as an automatic operation.

First, the ultrasonic wave oscillator 311 was stopped and the valves a and b were closed. Next, the valves c and f were opened, and cleaning water 16 was supplied for four minutes. The valves c and d were then closed. Next, the valves d and e were opened, and reverse cleaning was performed by allowing the cleaning water 16 to flow in the opposite direction to the flow of sludge during normal sludge treatment for four minutes. Once the cleaning operation was complete, the valves d and e were closed, the valves a and b were opened, and sludge supply and operation of the ultrasonic wave oscillator were resumed. It was confirmed that by means of this operation, it is possible to restore the output of the ultrasonic wave oscillator to 2kW or more, and to remove sludge adhered to the oscillator in the interior of the ultrasonic wave oscillator 311. By performing this cleaning operation, it was possible to operate the ultrasonic wave oscillator 311 with stability for approximately six months without the need to take the ultrasonic wave oscillator apart for maintenance.

Note that when cleaning is performed by supplying cleaning water 16 to the ultrasonic wave oscillator 311, adhered sludge can be removed more easily by operating the ultrasonic wave oscillator 311 as the cleaning water 16 is supplied so that the oscillator oscillates, and in so doing, the cleaning effect can be enhanced even further.

Example 4

Biological treatment of organic waste water was performed using the apparatus shown in Fig. 19. An oxidation ditch type biological treatment tank was provided as the biological treatment tank 319. The inflow amount of raw water 1 was set at $450\text{m}^3/\text{d}$, and the volume of the biological treatment tank 319 was set at 660m^3 . The sludge concentration in the biological treatment tank 319 was set at 3000mg/L , and the sludge concentration of the returned sludge 4 was set at approximately

6000mg/L.

The sludge storage tank 10, ultrasonic treatment apparatus 11, a centrifugal thickener 318, and a sludge crusher 321 were provided for the liquefaction process 20. A part 4b of the returned sludge was supplied to the centrifugal thickener 318, as a result of which concentrated sludge 320 having a sludge concentration of approximately 4.5% was obtained. The concentrated sludge 320 was passed through the heat exchanger 12 and supplied to the sludge storage tank 10. The sludge storage time in the sludge storage tank 10 was set at approximately 1.5 days. Although no heater or any other special device was provided in the sludge storage tank 10, the temperature of the sludge in the tank was raised to approximately 50°C by heat from the ultrasonic treatment apparatus 11 and sludge crusher 321. The sludge in the sludge storage tank 10 was supplied to the sludge crusher 321, where coarse particles in the sludge (hair, toilet paper, etc.) were crushed, and then the sludge was supplied to the ultrasonic treatment apparatus 11 to be subjected to ultrasonic treatment. Following the ultrasonic treatment, the sludge was returned to the sludge storage tank 10. The amount of the sludge supplied to the ultrasonic treatment apparatus 11 was regulated to 3.0-10.8-fold of the amount of the concentrated sludge 320 supplied to the sludge storage tank 10. The ultrasonic wave intensity during the ultrasonic treatment was set at 110kJ/L in relation to the sludge volume. The heat of the liquefied sludge 5 was collected in the heat exchanger 12, after which the liquefied sludge was returned to the biological treatment tank 319.

Note that a control experiment was conducted simultaneously, omitting the liquefaction process, in order to compare the amount of generated sludge with that of this example. In other words, in the control experiment, all of the separated

sludge 4 was returned to the biological treatment tank 319.

As a result of these operations, as shown in Table 2, it was possible to obtain a comparable water quality in the treated water of example 4 to that of the control experiment. Further, temporal variation in the cumulative sludge amount generated within the system is shown in Fig. 20. As can be seen in Fig. 20, it was possible to reduce the generated excess sludge amount in example 4 by approximately 40% in comparison with that of the control experiment.

Table 2

Results of example 4 (water quality)

	Raw water	Treated water of example 4	Treated water of control experiment
SS	173	5.2	2.4
BOD	131	6	3
S-BOD	17	2	2
T-N	33.0	3.5	3.6
T-P	4.4	2.2	2.9

Example 5

The sludge treatment apparatus shown in Fig. 10 was added to a domestic waste water treatment facility, and a waste water treatment experiment was performed. The results are shown in Table 3. In this example, a case in which the sludge treatment apparatus shown in Fig. 10, in which a flow-ultrasonic treatment apparatus 201 with a rated output of 1kW was incorporated into a domestic waste water treatment facility having a tank for treating domestic waste water with a volume of 3m³, was compared to a case in which no sludge treatment apparatus was provided. All of the treated liquid 213 of the sludge treatment apparatus was returned to the upstream side of the domestic waste water treatment facility. In the ultrasonic treatment apparatus 201,

the sludge was irradiated with ultrasonic waves at 44kW×s/L. By providing the sludge treatment apparatus shown in Fig. 10, it was possible to reduce the amount of generated excess sludge solid matter by 78%. As shown in Fig. 17, it was possible to

5 obtain a favorable effect with respect to the heat balance in the sludge treatment apparatus even when the ultrasonic wave emission output was suppressed to a low level by heat exchange.

Table 3

	No sludge treatment apparatus	With sludge treatment apparatus
Water inflow amount	4.1m ³ /day	
Inflowing water BOD	176 mg/L	
Inflowing water SS	98 mg/L	
Aeration tank volume	3.0 m ³	
MLSS in aeration tank	3200 mg/L	
BOD-SS load	0.08kg/kg×day	
Ultrasonic wave emission output	-	44 kW·s/L
Number of storage days in sludge tank	-	1.5 days
Sludge tank water temperature	-	50°C
Sludge solubilization ratio	-	23%
Generated sludge amount	0.393kg/day	0.086kg/day
Sludge reduction ratio	-	78%

10 Example 6

Fig. 15 shows the COD_{Cr} base solubilization ratio when the treated sludge of industrial waste water was concentrated in several stages until the solid matter concentration thereof reached a maximum of 4.1%, and then irradiated with ultrasonic

waves. It can be seen from Fig. 15 that the solubilization ratio of the sludge is dependent only on the ultrasonic wave output, and not the solid matter concentration of the sludge. Hence, it was learned that by concentrating the sludge prior to the
5 sludge solubilization process so that the liquid content of the sludge is reduced, the time required for the solubilization process can be reduced, and power can be saved.

When the sludge is treated with an ultrasonic wave emission output of 50kW×s/L, for example, the required power per 1m³ can
10 be reduced from 13.9kW×h to 3.5kW×h by concentrating sludge having a solid matter concentration of 1% to a solid matter concentration of 4% using a thickener.

Example 7

Fig. 16 shows the effects generated in a case in which
15 a cuttermill is disposed in the sludge treatment apparatus shown in Fig. 10 and operated as the coarse crusher 205 shown in Fig. 13. When the coarse crusher 205 was not used, fibrous contaminants became caught in the flow passage of the ultrasonic treatment apparatus, and as a result, the output of the ultrasonic
20 wave oscillator was unable to rise above approximately 1kW. Moreover, the value of the ultrasonic wave oscillator output was unstable. In contrast, when the coarse crusher 205 was used, an output of approximately 1.8kW was generated with stability. The particle size of the fibrous matter contained in the sludge
25 at the outlet of the coarse crusher 205 was no more than 10mm. The particle size distribution of the solid matter is shown in Table 4.

Table 4

Particle size (mm)	Solid matter amount. (weight ratio)
0.1 or less	94.4%
0.1-0.2	2.7%
0.2-0.5	1.9%
0.5-1	0.5%
1-2	0.3%
2-5	0.1%
5-10	0.1%
10 or more	0.0%

INDUSTRIAL APPLICABILITY

5 The present invention may be used to reduce the amount
of excess sludge generated during sewerage treatment in an
organic waste water treatment facility such as a sewerage
treatment plant or night soil treatment plant, for example, or
in the biological treatment of organic waste water discharged
10 from a waste water treatment process, such as waste water from
a food product factory or chemical factory.

Further, according to another aspect of the present
invention, by measuring the ammonia nitrogen concentration of
a liquefied sludge liquid or a filtrate ("sludge filtrate")
15 obtained by filtering the liquefied sludge liquid, the sludge
reduction amount can be controlled efficiently, which is useful
when treating waste water that generates a large amount of excess
sludge, in particular sewerage or organic industrial wastewater.

CLAIMS

1. A method of pulverizing sludge using a flow-type ultrasonic treatment apparatus having an ultrasonic wave oscillator, which comprises detecting the output of said ultrasonic wave oscillator, stopping said ultrasonic wave oscillator when said detected output is lower than a predetermined output and cleaning the interior of said ultrasonic wave oscillator by flowing cleaning water through the ultrasonic wave oscillator.

2. A method of pulverizing sludge using a flow-type ultrasonic treatment apparatus having an ultrasonic wave oscillator, which comprises detecting the pressure in said ultrasonic wave oscillator, stopping said ultrasonic wave oscillator when said detected pressure is higher than a predetermined pressure and cleaning the interior of said ultrasonic wave oscillator by flowing cleaning water through the ultrasonic wave oscillator.

3. A method for treating organic waste water in a biological treatment system such that excess sludge is generated, which comprises treating the organic waste water by the biological treatment system, solubilizing obtained sludge and then returning the solubilized sludge to the biological treatment system, further comprising predicting a sludge reduction amount by determining a sludge liquefaction amount, determining an amount of sludge to be sent to a liquefaction process on the basis of said predicted sludge reduction amount.

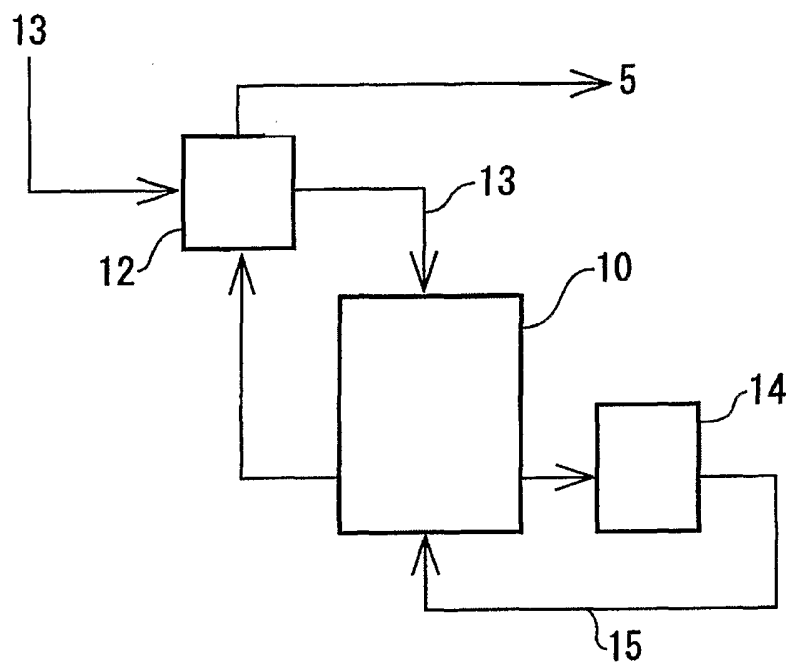
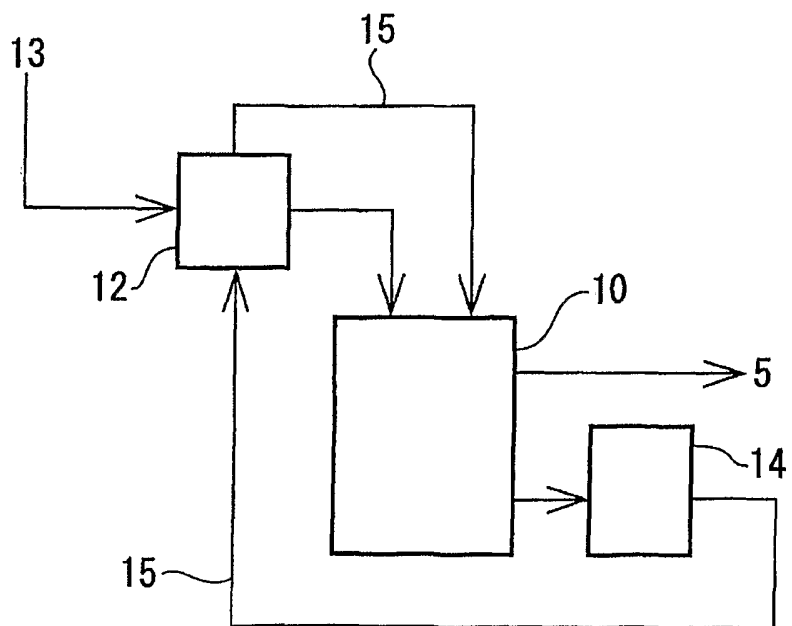
Fig. 1*Fig. 2*

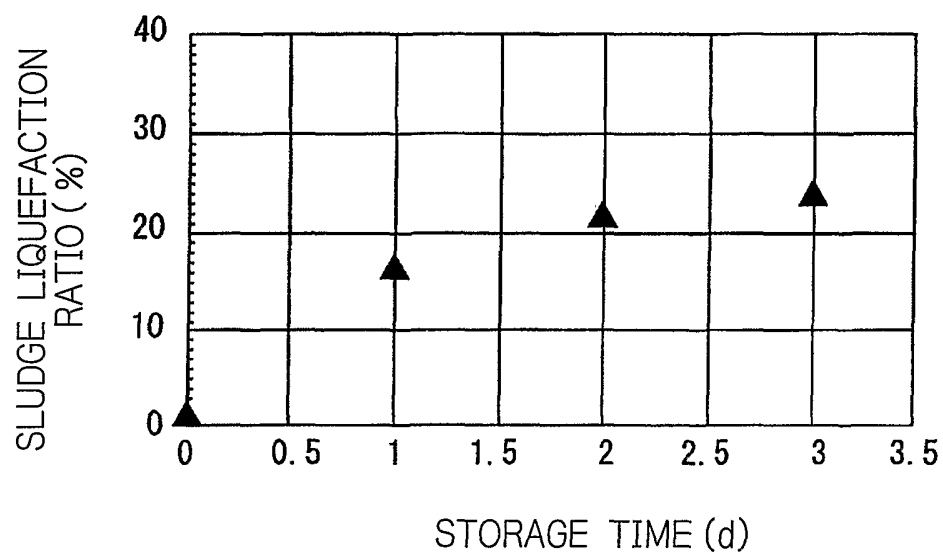
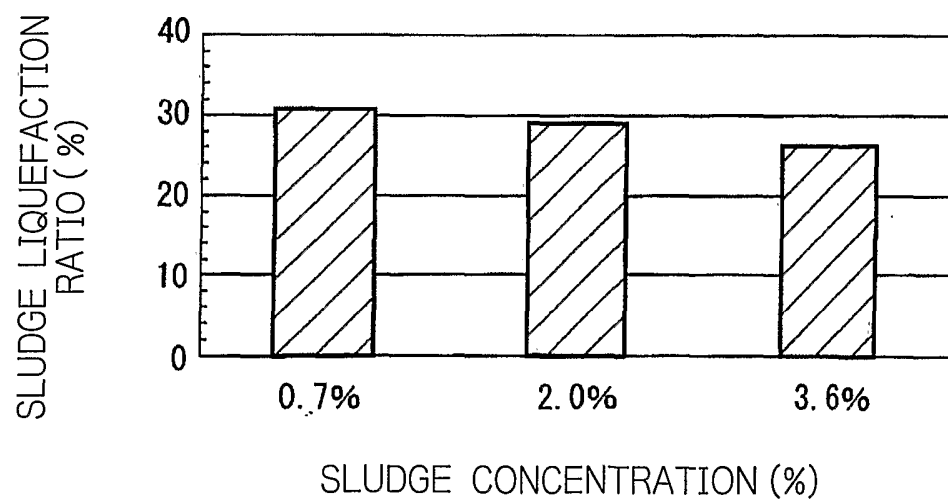
Fig. 3*Fig. 4*

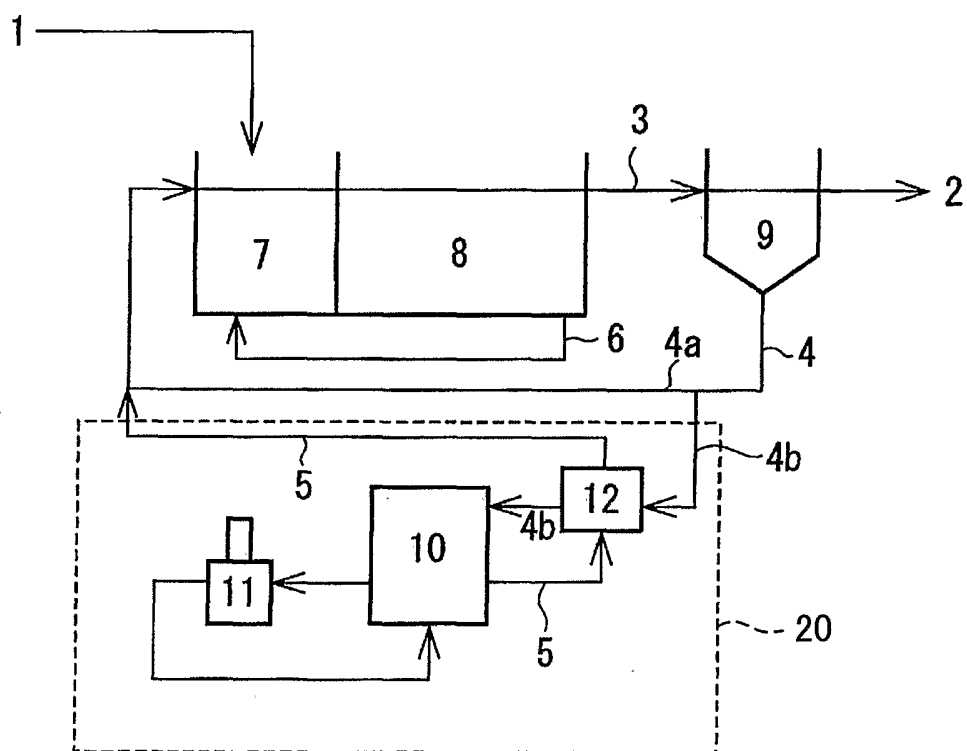
Fig. 5

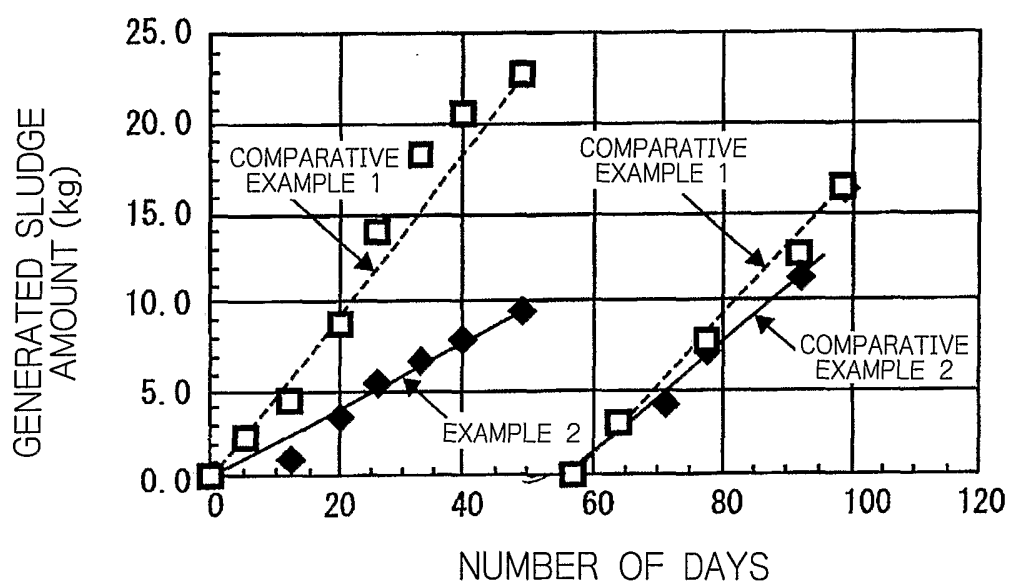
Fig. 6

Fig. 7

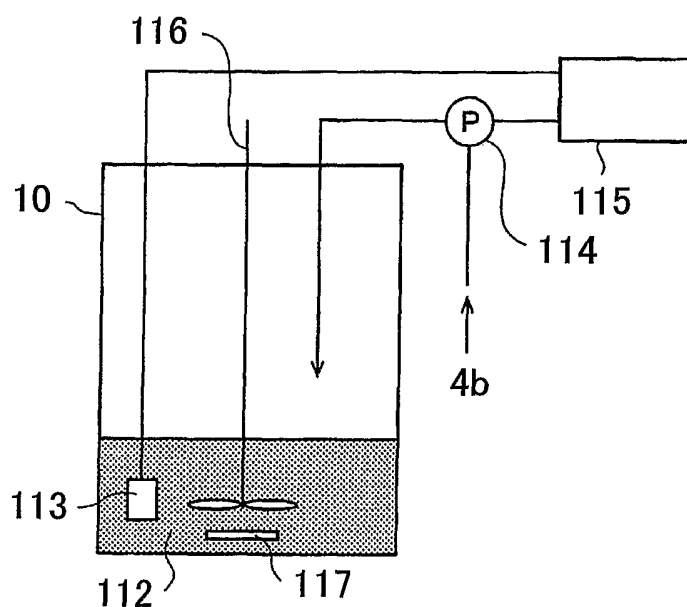


Fig. 8

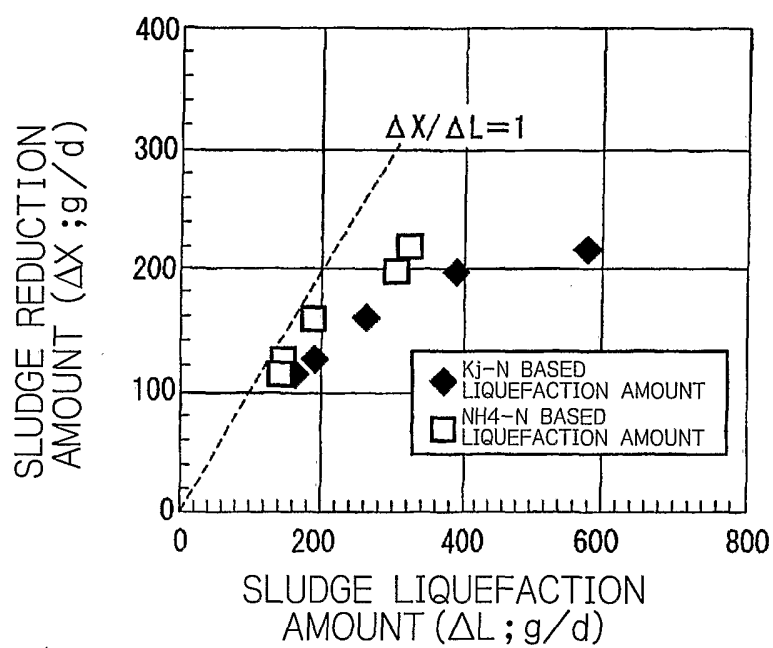


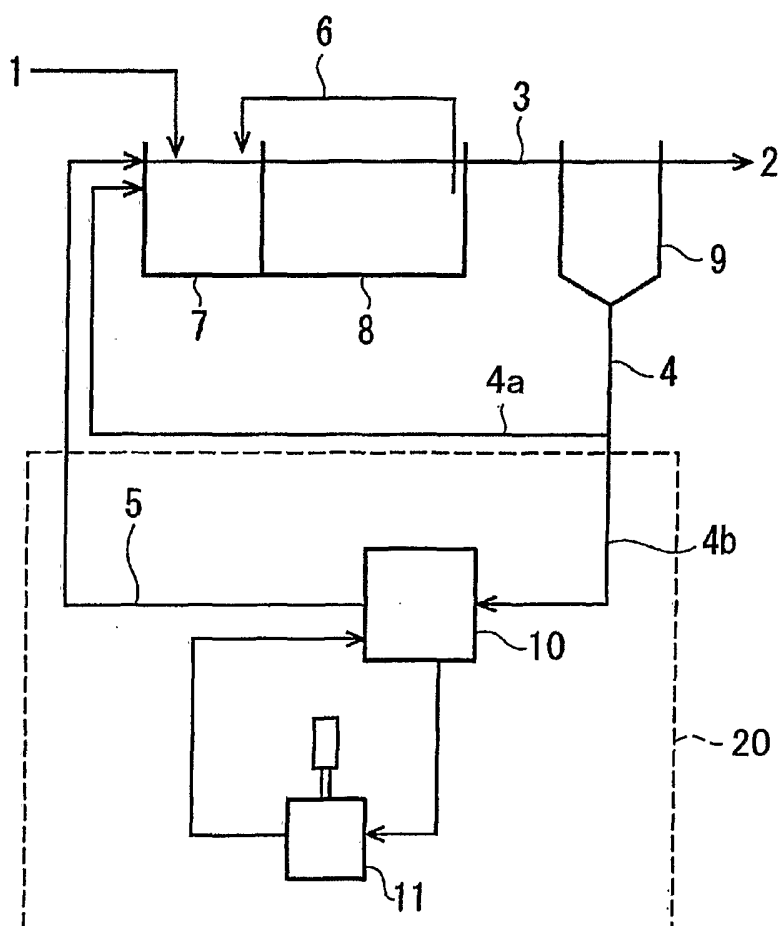
Fig. 9

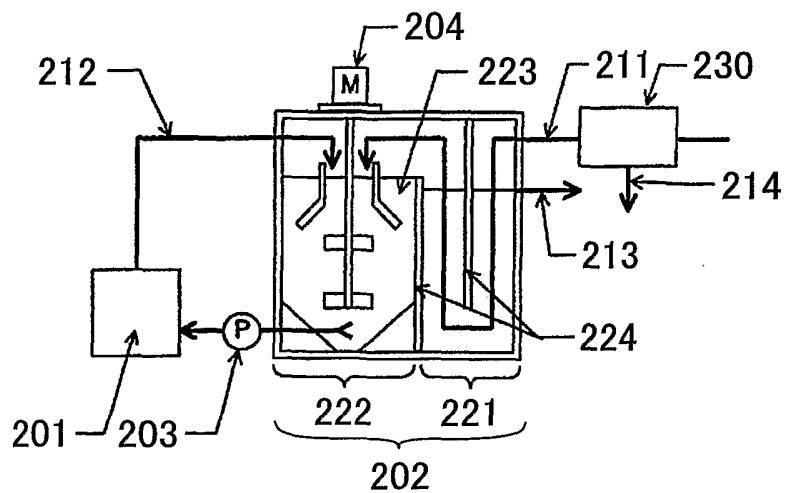
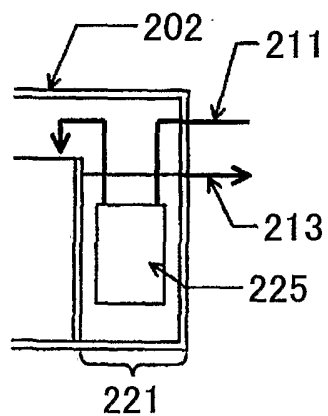
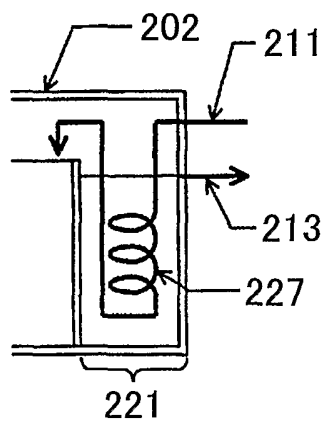
Fig. 10*Fig. 11**Fig. 12*

Fig. 13

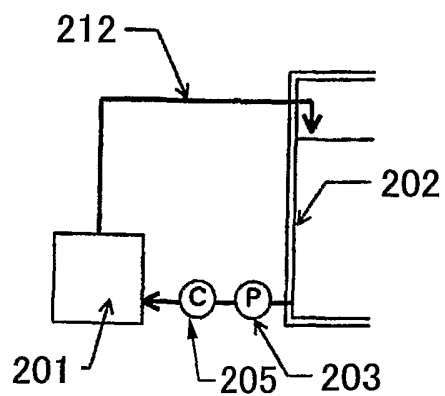


Fig. 14

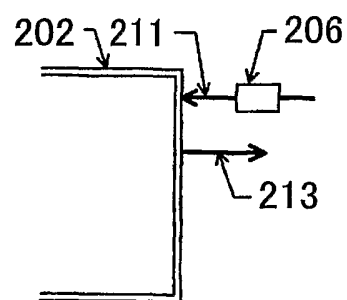


Fig. 15

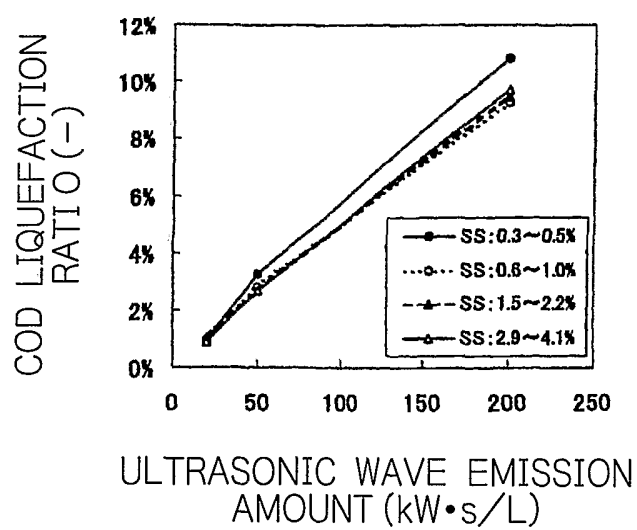


Fig. 16

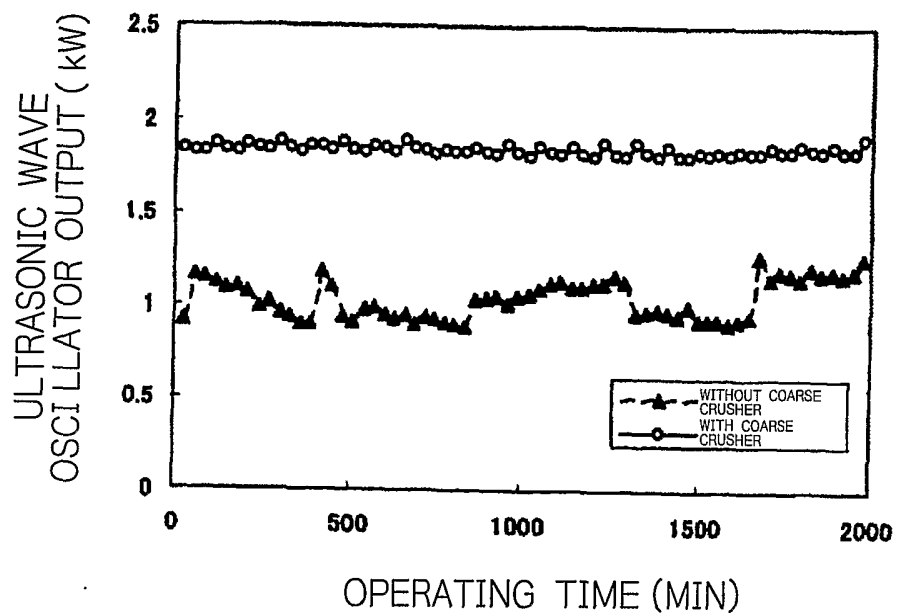


Fig. 17

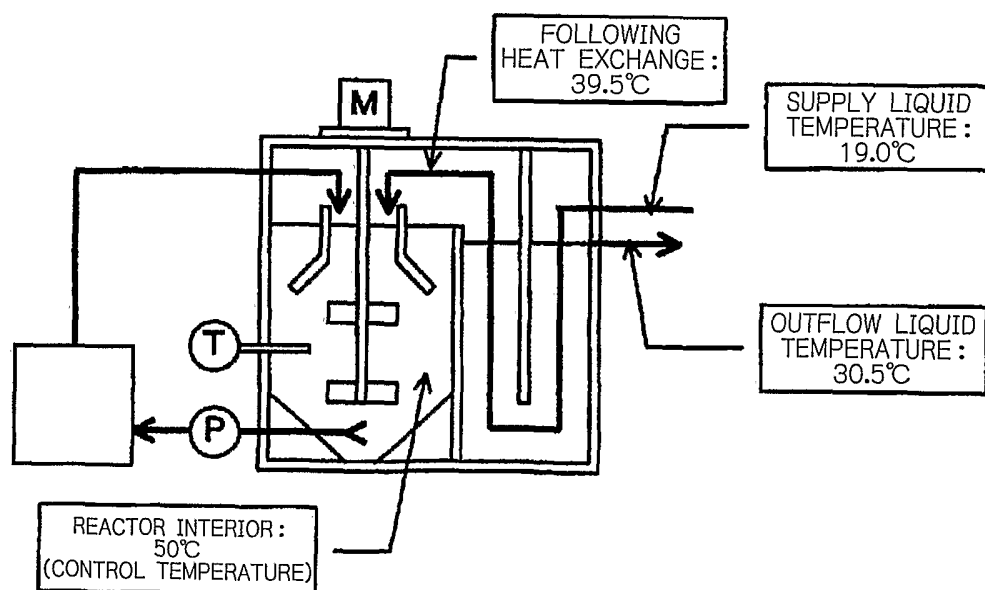


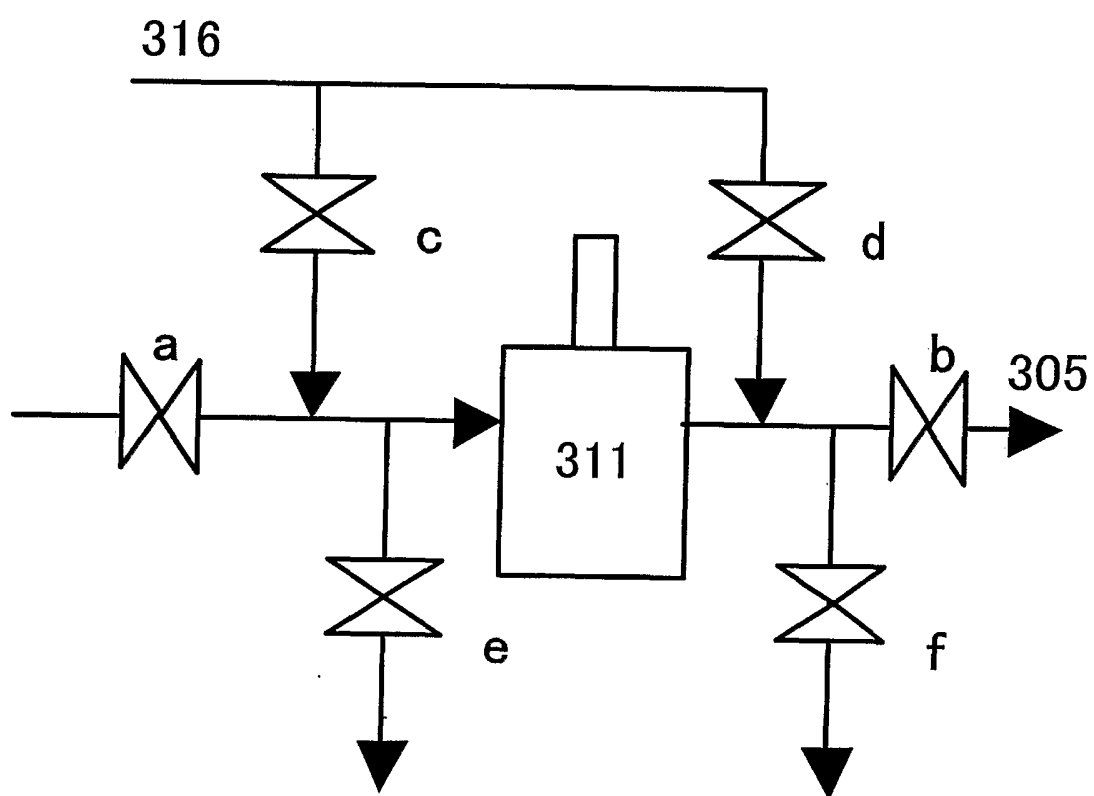
Fig. 18

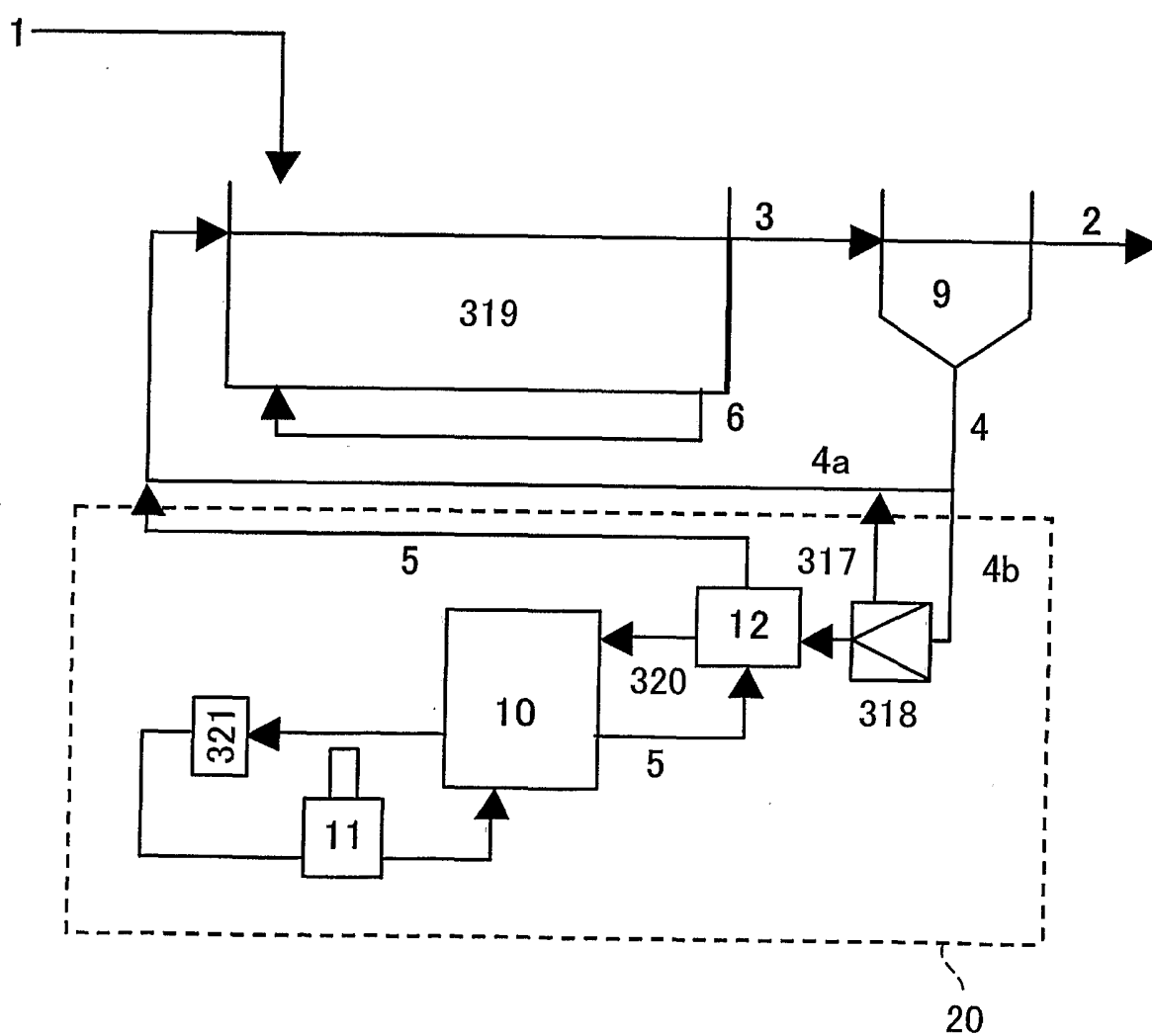
Fig. 19

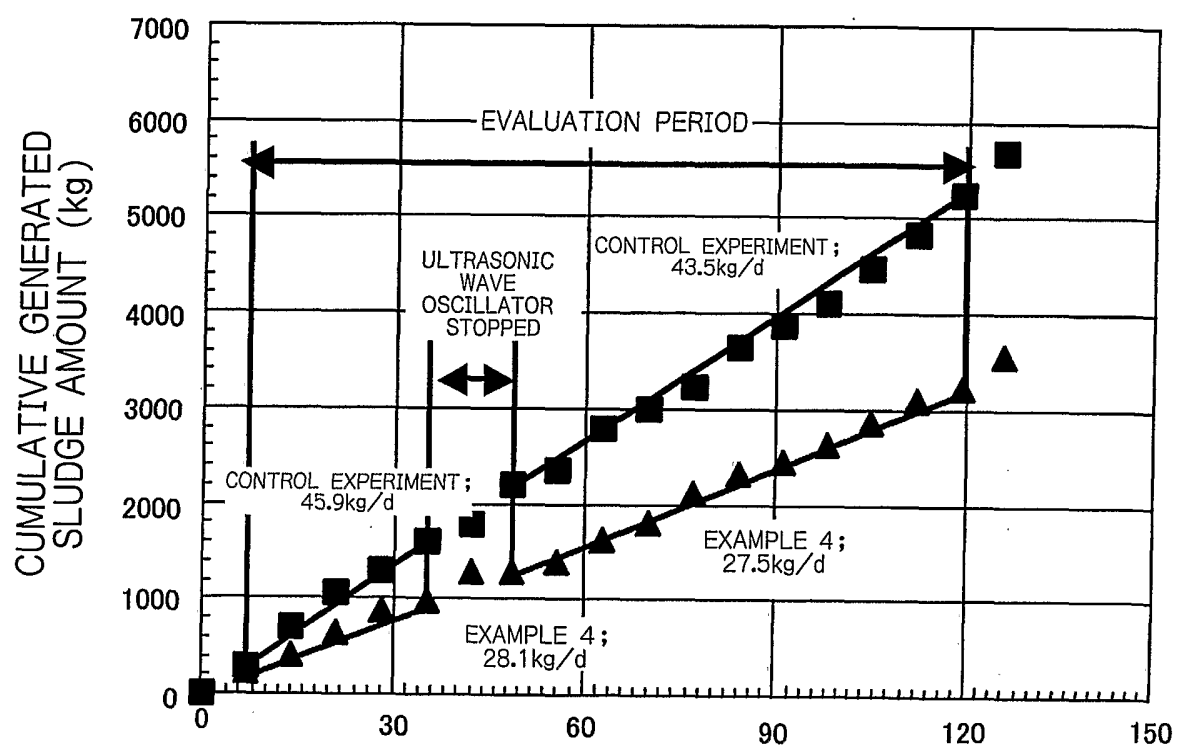
Fig. 20

Fig. 21

