

## DESCRIPTION

TITLE: WASTE WATER TREATMENT METHOD AND WASTE WATER TREATMENT  
DEVICE

5

## TECHNICAL FIELD

[0001]

The present disclosure relates to techniques of a wastewater treatment method and  
wastewater treatment device for biologically treating wastewater containing organic and  
10 other substances.

## BACKGROUND

[0002]

Conventional biological wastewater treatments use an activated sludge process  
15 which uses aggregates of microorganisms (aerobic biological sludge) called flocs.  
However, in the activated sludge process, as the floc settling velocity is slow when  
separating floc (aerobic biological sludge) and treated water in a settling tank, the settling  
tank may be required to have a significantly large surface area. In addition, although the  
treatment rate of the activated sludge process can be enhanced by raising the sludge  
20 concentration because the processing speed depends on the sludge concentration within a  
biological treatment tank, when the sludge concentration is raised to a range of 1,500 to  
5,000 mg/L or higher, a solid-liquid separation failure such as bulking may occur, disabling  
the maintenance of the treatment.

[0003]

25 In contrast, anaerobic biological treatments generally use aggregates called  
granules (anaerobic biological sludge) in which microorganisms converge densely to form  
granular shapes. Granules can realize a high speed treatment of wastewater because the  
settling velocity is extremely fast and microorganisms converge densely, achieving a high

concentration of the sludge in a biological treatment tank. However, anaerobic biological treatments may have disadvantages such as more limited treatable wastewater types than the aerobic biological treatments (activated sludge process) and the need to maintain treated water temperature at 30 to 35°C. Further, the anaerobic biological treatments alone cannot provide sufficiently purified water. Thus, the water needs to be further treated by aerobic biological treatments such as an activated sludge process before discharging the treated water to a river or other environments.

[0004]

In recent years, it has been discovered that not only in anaerobic biological treatments but also in aerobic biological treatments, biological sludge can be formed in granules having an excellent settleability by treating wastewater using a sequencing batch biological treatment device which intermittently supplies wastewater to a reaction tank and further by shortening the settling time of biological sludge (refer to, for example, Patent Literatures 1 to 4). By forming the biological sludge into granules, the average granule diameter becomes 0.2 mm or larger, resulting in the settling velocity of 5 m/h or higher. In a sequencing batch biological treatment device, four processes are performed in a single biological treatment tank, (1) supply of wastewater; (2) biological treatment process of target substances; (3) settlement of biological sludge; and (4) discharge of treated water. By forming the biological sludge into granules having an excellent settleability as described above, it becomes possible to maintain a high concentration of the sludge in a tank, achieving a high speed treatment.

#### CITATION LIST

[0005]

#### PATENT LITERATURE

Patent Literature 1: WO 2004/024638

Patent Literature 2: JP 2008-212878 A

Patent Literature 3: JP 4975541 B

## Patent Literature 4: JP 4804888 A

## SUMMARY

## TECHNICAL PROBLEM

5 [0006]

It should be noted that the above process (3) settlement of biological sludge is assumed to include steps of (i) re-flocculation; (ii) zone settling; (iii) transition; and (iv) compaction. In the transition step, the density of settled sludge increases, resulting in a stronger interaction between sludge granules. In the compaction process, which is the  
10 final stage of settlement, the compaction in the settled sludge further proceeds. In the transition and compaction steps, a sludge blanket having a high sludge concentration is formed.

[0007]

A sludge blanket formed in the transition and compaction steps is formed not only  
15 by biological sludge of large granule size but also by a large amount of biological sludge of small granule size which has a low settleability. When such biological sludge of small granule size is embedded in the sludge blanket, it is impossible to selectively discharge the biological sludge of small granule size from the biological treatment tank system. With a large amount of biological sludge of small granule size remaining in the biological  
20 treatment tank, a sequencing batch biological treatment cannot obtain biological sludge having a high settleability, or it would take a considerable time period to obtain biological sludge having a high settleability. As a result, a longer time is required for starting the biological treatment, disabling a high speed treatment of wastewater. It should be noted that in any of Patent Literatures 1 to 4, discharge of treated water is performed after a  
25 sludge blanket containing biological sludge of small granule size is formed.

[0008]

An object of the present invention is to provide a wastewater treatment method and a wastewater treatment device which can obtain biological sludge having a high

settleability, especially in a short period of time.

## SOLUTION TO PROBLEM

[0009]

5           (1) The present invention is a wastewater treatment method including a sequencing batch biological treatment process to biologically treat wastewater using a sequencing batch biological treatment tank containing biological sludge. The sequencing batch biological treatment process includes a biological treatment process to biologically treat the wastewater using the biological sludge by stirring the wastewater in the sequencing batch biological treatment tank under conditions where the supply of the wastewater to the sequencing batch biological treatment tank and discharge of treated water from the sequencing batch biological treatment tank are both stopped. The sequencing batch biological treatment process also includes a wastewater supply and treated water discharge process in which the supply of the wastewater to the sequencing batch biological treatment tank and the discharge of the treated water from the sequencing batch biological treatment tank are both started in a period after the stirring of the wastewater in the sequencing batch biological treatment tank has been stopped and before a sludge blanket of the biological sludge is formed in the sequencing batch biological treatment tank. The biological treatment process and the wastewater supply and treated water discharge process are sequentially repeated.

[0010]

          (2) In the wastewater treatment method described in above (1), it is preferable that, in the wastewater supply and treated water discharge process, the supply of the wastewater to the sequencing batch biological treatment tank and the discharge of the treated water from the sequencing batch biological treatment tank are both started at the same time as or immediately after the stirring of the wastewater in the sequencing batch biological treatment tank is stopped.

[0011]

(3) In the wastewater treatment method described in above (1) or (2), it is preferable that the wastewater treatment method further includes a continuous biological treatment process to biologically treat the wastewater that is continuously supplied to a continuous biological treatment tank containing biological sludge; a biological sludge supply process to supply granules formed in the sequencing batch biological treatment process to the continuous biological treatment tank; a treated water supply process to supply the treated water discharged in the sequencing batch biological treatment process to the continuous biological treatment tank; and a wastewater supply amount adjustment process to reduce an amount of wastewater supplied to the continuous biological treatment tank in response to the supply of the granules in the biological sludge supply process and the supply of the treated water in the treated water supply process.

[0012]

(4) In the wastewater treatment method described in above (3), it is preferable that, in the wastewater supply amount adjustment process, the amount of the wastewater supplied to the continuous biological treatment tank is reduced to zero in response to the supply of the granules in the biological sludge supply process and the supply of the treated water in the treated water supply process.

[0013]

(5) In the wastewater treatment method described in any one of above (1) to (4), it is preferable that the sequencing batch biological treatment tank includes a wastewater inlet for supplying the wastewater to the tank, and a treated water outlet for discharging the treated water from the tank or a sludge and treated water outlet for discharging the treated water and the granules from the tank such that the treated water outlet and the sludge and treated water outlet are disposed higher than the wastewater inlet.

[0014]

(6) The present invention is a wastewater treatment device including a sequencing batch biological treatment tank that contains biological sludge, a supply unit that supplies wastewater to the sequencing batch biological treatment tank, a discharge unit that

discharges treated water from the sequencing batch biological treatment tank, a stirring unit that stirs the wastewater in the sequencing batch biological treatment tank, a first controller that controls activation of the stirring unit; and a second controller that controls activation of the supply unit and the discharge unit. When biologically treating the wastewater with the biological sludge, the first controller activates the stirring unit to stir the wastewater in the sequencing batch biological treatment tank under conditions where the supply of the wastewater to the sequencing batch biological treatment tank and the discharge of the treated water from the sequencing batch biological treatment tank are both stopped. The second controller activates the supply unit to start the supply of the wastewater to the sequencing batch biological treatment tank, and also activates the discharge unit to start the discharge of the treated water from the sequencing batch treatment tank in a period after the stirring of the wastewater by the stirring unit has been stopped and before a sludge blanket of the biological sludge is formed in the sequencing batch biological treatment tank.

[0015]

(7) In the wastewater treatment device described in above (6), it is preferable that the second controller activates the supply unit to start the supply of the wastewater to the sequencing batch biological treatment tank and also activates the discharge unit to start the discharge of the treated water from the sequencing batch biological treatment tank at the same time as or immediately after the stirring of the wastewater by the stirring unit is stopped.

[0016]

(8) In the wastewater treatment device described in above (6) or (7), it is preferable that the second controller controls the supply unit and the discharge unit such that an amount of the wastewater supplied to the sequencing batch biological treatment tank and an amount of the treated water discharged from the sequencing batch biological treatment tank are equal to each other.

[0017]

(9) In the wastewater treatment device according to any one of above (6) to (8), it is preferable that the sequencing batch biological treatment tank includes a wastewater inlet for supplying the wastewater to the tank and a treated water outlet for discharging the treated water from the tank, such that the wastewater inlet is disposed lower than the treated water outlet.

[0018]

(10) In the wastewater treatment device according to above (9), it is preferable that the treated water outlet is disposed at a water surface level of the wastewater in the sequencing batch biological treatment tank when the discharge of the treated water is stopped.

[0019]

(11) In the wastewater treatment device according to any one of above (6) to (10), it is preferable that the wastewater treatment device further includes a continuous biological treatment device that biologically treats continuously supplied wastewater, a biological sludge supply unit that supplies granules formed in the sequencing batch biological treatment tank to the continuous biological treatment device, a treated water supply unit that supplies the treated water discharged from the sequencing batch biological treatment tank to the continuous biological treatment device, and a wastewater supply amount adjustment unit that adjusts an amount of the wastewater supplied to the continuous biological treatment device such that the water supply amount adjustment unit reduces an amount of the wastewater supplied to the continuous biological treatment device in response to the supply of the granules by the biological sludge supply unit and the supply of the treated water by the treated water supply unit.

[0020]

(12) In the wastewater treatment device according to above (11), it is preferable that the wastewater supply amount adjustment unit reduces the amount of the wastewater supplied to the continuous biological treatment device to zero in response to the supply of the granules by the biological sludge supply unit and the supply of the treated water by the

treated water supply unit.

[0021]

(13) In the wastewater treatment device according to any one of above (6) to (8), it is preferable that the sequencing batch biological treatment tank includes a wastewater inlet for supplying the wastewater to the tank, and a treated water outlet for discharging the treated water from the tank or a sludge and treated water outlet for discharging the treated water and the granules from the tank such that the treated water outlet and the sludge and treated water outlet are disposed higher than the wastewater inlet.

## ADVANTAGEOUS EFFECTS OF INVENTION

[0022]

According to the present disclosure, it is possible to provide a wastewater treatment method and a wastewater treatment device which can obtain biological sludge having a high settleability, especially in a short period of time.

## BRIEF DESCRIPTION OF DRAWINGS

[0023]

FIG. 1 is a schematic diagram showing an example of a structure of a sequencing batch biological treatment device according to an embodiment of the present disclosure;

FIG. 2 is a schematic diagram showing another example of a structure of a sequencing batch biological treatment device according to an embodiment of the present disclosure;

FIG. 3 is a graph showing an example of a settlement curve;

FIG. 4 is a schematic diagram showing an example of a structure of a wastewater treatment device according to an embodiment of the present disclosure;

FIG. 5 is a schematic diagram showing an example of a structure of a sequencing batch biological treatment device used in an embodiment of the present disclosure;

FIG. 6 is a schematic diagram showing another example of a structure of a

wastewater treatment device according to an embodiment of the present disclosure;

FIG. 7 is a schematic diagram showing another example of a structure of a wastewater treatment device according to an embodiment of the present disclosure;

FIG. 8 is a schematic diagram showing another example of a structure of a wastewater treatment device according to an embodiment of the present disclosure;

FIG. 9A is a schematic diagram showing another example of a structure of a sequencing batch biological treatment device used in an embodiment of the present disclosure;

FIG. 9B is a schematic diagram showing another example of a structure of a sequencing batch biological treatment device used in an embodiment of the present disclosure; and

FIG. 10 is a graph showing variations in SVI5 values in an example of the present invention and a comparison example.

## DESCRIPTION OF EMBODIMENTS

[0024]

Embodiments of the present invention are described below. It should be noted that the embodiments are merely examples of the present invention. The present invention should not be limited to the embodiments.

[0025]

FIG. 1 is a schematic diagram showing an example of a structure of a sequencing batch biological treatment device according to the present disclosure. As shown in FIG. 1, a sequencing batch biological treatment device 1 includes a sequencing batch biological treatment tank 10, a wastewater supply device 12, a distributor 14, a treated water discharger 16, a stirring system, and a controller 20.

[0026]

The sequencing batch biological treatment tank 10 according to the present embodiment contains biological sludge so as to treat wastewater using the biological

sludge. The sequencing batch biological treatment tank 10 according to the present embodiment includes a wastewater inlet 22 for supplying wastewater, and a treated water outlet 24 for discharging treated water. The wastewater inlet 22 is positioned lower than the treated water outlet 24.

5 [0027]

The wastewater supply device 12 according to the present embodiment includes a wastewater supply line 26, a wastewater pump 28, and a wastewater side solenoid valve 30. The wastewater supply line 26 is connected to the wastewater inlet 22 from outside the sequencing batch biological treatment tank 10. The wastewater supply line 26 is provided  
10 with the wastewater pump 28 and the wastewater side solenoid valve 30. The wastewater pump 28 and the wastewater side solenoid valve 30 are electrically connected to the controller 20. The wastewater supply device 12 is not limited to the device structure described above as long as the device can supply wastewater to the sequencing batch biological treatment tank 10 from the wastewater inlet 22. For example, the wastewater  
15 supply device 12 may be formed with the wastewater supply line 26, the wastewater pump 28, and other elements. It should be noted that in the present embodiment, the distributor 14 is disposed inside the sequencing batch biological treatment tank 10 such that the distributor 14 is connected to the wastewater inlet 22 from inside the sequencing batch biological treatment tank 10. In other words, the wastewater supply line 26 and the  
20 distributor 14 are connected to each other via the wastewater inlet 22.

[0028]

The treated water discharger 16 according to the present embodiment includes a treated water discharge line 32 and a treated water side solenoid valve 34. The treated water discharge line 32 is connected to the treated water outlet 24 from outside the  
25 sequencing batch biological treatment tank 10. The treated water discharge line 32 is provided with the treated water side solenoid valve 34, which is electrically connected to the controller 20. The treated water discharger 16 is not limited to the device structure described above as long as the device can discharge treated water in the sequencing batch

biological treatment tank 10 from the treated water outlet 24. For example, the treated water discharger 16 may be formed with the treated water discharge line 32, a treated water pump, the treated water side solenoid valve 34, and other elements.

[0029]

5           The stirring system according to the present embodiment includes a stirring device 36 and an aerator 38. The stirring device 36 according to the present embodiment includes a motor 40, a stirring blade 42, and other elements. The wastewater in the sequencing batch biological treatment tank 10 is stirred by the stirring blade 42 which rotates along with rotation of the motor 40. The aerator 38 according to the present  
10           embodiment includes a diffuser pump 44, a diffuser pipe 46, and other elements. Aeration gas such as oxygen and air is fed to the diffuser pipe 46 by the diffuser pump 44. The wastewater in the sequencing batch biological treatment tank 10 is moved and stirred by the aeration gas supplied from the diffuser pipe 46 to the sequencing batch biological treatment tank 10. The motor 40 and the diffuser pump 44 are electrically connected to  
15           the controller 20.

[0030]

FIG. 2 is a schematic diagram showing another example of a structure of a sequencing batch biological treatment device according to an embodiment of the present disclosure. The stirring system is not limited to any system configurations as long as the  
20           stirring system can stir the wastewater in the sequencing batch biological treatment tank 10. For example, in an aerobic biological treatment, the stirring device 36 is not required as it is in a sequencing batch biological treatment device 2 in FIG. 2. Such a stirring system may be formed with the aerator 38 such that the wastewater is stirred by supplying aerobic gas to the sequencing batch biological treatment tank 10 to obtain an aerobic condition  
25           inside the sequencing batch biological treatment tank 10. In an anaerobic biological treatment, for example, the aerator 38 is not required. Such a stirring system may be formed with the stirring device 36 such that the wastewater is stirred by the stirring device 36.

[0031]

The controller 20 is configured with a CPU for executing programs, a microcomputer which is formed with a ROM and a RAM for storing programs and operation results, and electronic circuits. The controller 20 serves as a first controller  
5 which controls activation of the stirring device 36 and the aerator 38, and also as a second controller which controls activation of the wastewater supply device 12 and the treated water discharger 16. Although a single controller functioning as the first controller and the second controller is described in the present embodiment as an example, the present invention is not limited to this configuration. The first controller and the second  
10 controller may be provided as separate controllers.

[0032]

Example operations of the sequencing batch biological treatment device 1 according to the present embodiment are described below.

[0033]

15 The controller 20 opens the wastewater side solenoid valve 30 and activates the wastewater pump 28 to supply wastewater from the wastewater inlet 22 to the sequencing batch biological treatment tank 10 through the wastewater supply line 26. In this embodiment, the wastewater is supplied from the distributor 14 disposed in the sequencing batch biological treatment tank 10 such that the flow linear velocity of wastewater  
20 becomes uniform.

[0034]

After closing the wastewater side solenoid valve 30 and stopping the wastewater pump 28, the controller 20 activates the motor 40 and the diffuser pump 44. In this way, the stirring blade 42 is rotated and aeration gas is supplied from the diffuser pipe 46 to the  
25 sequencing batch biological treatment tank 10 such that the wastewater and biological sludge in the sequencing batch biological treatment tank 10 are stirred. Then, the wastewater is biologically treated by the biological sludge such that target substances in the wastewater are dissolved (biological treatment process).

[0035]

After performing the biological treatment for a predetermined time period while the wastewater is stirred, the controller 20 stops the motor 40 and the diffuser pump 44. In other words, the stirring of the wastewater in the sequencing batch biological treatment tank 10 is stopped. When the stirring of the wastewater is stopped, the biological sludge starts to settle. In this process, while the settlement of the biological sludge proceeds, a sludge blanket of the biological sludge is formed in the sequencing batch biological treatment tank 10.

[0036]

In the present embodiment, in a time period after the stirring of wastewater is stopped and before a sludge blanket of biological sludge is formed, the controller 20 activates the wastewater pump 28 and opens the wastewater side solenoid valve 30 to start supply of wastewater from the wastewater inlet 22 and also opens the treated water side solenoid valve 34 to start discharge of treated water from the treated water outlet 24 (wastewater supply and treated water discharge process). By supplying the wastewater from the wastewater inlet 22 which is positioned lower than the treated water outlet 24 and discharging the treated water from the treated water outlet 24 which is positioned higher than the wastewater inlet 22 as described above, biological sludge of small granule size and biological sludge having a settling velocity lower than the flow linear velocity (m/h) of the wastewater supply to the sequencing batch biological treatment tank 10 are also discharged from the system together with the treated water. In contrast, if the wastewater is supplied from the wastewater inlet 22 which is positioned lower than the treated water outlet 24 and the treated water is discharged from the treated water outlet 24 which is positioned higher than the wastewater inlet 22 after the sludge blanket of biological sludge is formed in the sequencing batch biological treatment tank 10, it would not be possible to discharge the biological sludge of small granule size together with the treated water because the biological sludge of small granule size would be embedded in the sludge blanket. However, before the sludge blanket of biological sludge is formed, because the

biological sludge of small granule size mainly floats near the water surface, it can be assumed that the biological sludge of small granule size is discharged with the treated water in the wastewater supply and treated water discharge process. Further, regarding the biological sludge of small granule size floating near the bottom of the reaction tank when the stirring of wastewater is stopped, such biological sludge can be assumed to be selectively discharged from the sequencing batch biological treatment tank by starting the supply of the wastewater and the discharge of the treated water before the re-flocculation process proceeds to form the sludge blanket. By sequentially repeating the biological treatment process and the wastewater supply and treated water discharge process, biological sludge having a high settling velocity (biological sludge of large granule size) is selectively left in the sequencing batch biological treatment tank 10. Therefore, biological sludge having a high settleability can be obtained. Further, because the supply of wastewater and discharge of treated water are performed together, the treatment cycle can be shortened.

[0037]

The wastewater inlet 22 for supplying the wastewater to the sequencing batch biological treatment tank 10 is preferably positioned lower than the treated water outlet 24 for discharging the treated water from the sequencing batch biological treatment tank 10. The wastewater inlet 22 is preferably positioned between the bottom of the sequencing batch biological treatment tank 10 and 1/2 height of the water surface in the sequencing batch biological treatment tank 10. The treated water outlet 24 is preferably positioned between 1/2 the height of the water surface in the sequencing batch biological treatment tank 10 and the top of the sequencing batch biological treatment tank 10, more preferably at the height of the water surface in the sequencing batch biological treatment tank 10. It should be noted that the height of water in the sequencing batch biological treatment tank 10 means the height of the water surface when the wastewater supply and treated water discharge process is finished. By widening the distance between the wastewater inlet 22 and the treated water outlet 24 by positioning the wastewater inlet 22 between the bottom

of the sequencing batch biological treatment tank 10 and 1/2 the height of the water surface in the sequencing batch biological treatment tank 10, and positioning the treated water outlet 24 between 1/2 the height of the water surface in the sequencing batch biological treatment tank 10 and the top of the sequencing batch biological treatment tank 10, as described above, it becomes possible to allow a large portion of the biological sludge to receive the effect of the flow linear velocity of the wastewater. Therefore, more biological sludge having a low settling velocity can be discharged from the treated water outlet 24. Further, by positioning the treated water outlet 24 at the height of the water surface in the sequencing batch biological treatment tank 10, the treated water can be pushed out from the sequencing batch biological treatment tank 10 at the same time as the wastewater is supplied to the sequencing batch biological treatment tank 10. In this way, the amount of water in the sequencing batch biological treatment tank 10 can be maintained at a constant level.

[0038]

Although the wastewater inlet 22 is preferably positioned lower than the treated water outlet 24 to selectively discharge sludge of small granule size from the sequencing batch biological treatment tank, a structure to form biological sludge having a high settleability is not limited to the above structure. For example, the wastewater inlet 22 may be positioned higher than the treated water outlet 24 or at the same height. In either case, sludge having a high settleability can be formed by starting the supply of wastewater and discharge of treated water in a period after the stirring of the wastewater is stopped and before the sludge blanket is formed, because in this way, sludge of small granule size is discharged from the sequencing batch biological treatment tank. It should be noted that when positioning the wastewater inlet 22 at the same height or higher than the treated water outlet 24, the amount of water in the sequencing batch biological treatment tank 10 is preferably maintained at a constant level by adjusting the supply amount using a valve, a pump or other device in order to suppress the discharge of a large amount of biological sludge having a high settleability from the system.

[0039]

For example, as operation conditions of the wastewater treatment to repeat the biological treatment process and the wastewater supply and treated water discharge process according to the present embodiment, when the biochemical oxygen demand (BOD) concentration of wastewater is set at 100 to 1,000 mg/L and the BOD load is set at 0.5 to 3.0 kg/m<sup>3</sup>/day, it is preferable to set the wastewater supply/treated water discharge time within a range of 15 to 120 minutes; reaction time of biological treatment within a range of 60 to 400 minutes; and the total time period of one cycle in a range of 2.0 to 8.0 hours.

[0040]

Each treatment process is described below in detail.

[0041]

#### Biological Treatment Process

The biological treatment reaction in the sequencing batch biological treatment tank 10 may be performed under either one of anaerobic (no oxygen) and aerobic conditions, or alternative operations between anaerobic and aerobic conditions. However, the biological treatment under aerobic conditions is more preferable because of higher proliferation rate of biological sludge and higher formation rate of granules.

[0042]

The wastewater suitable for the biological treatments according to embodiments of the present invention is wastewater which contains biodegradable substances, for example, food processing factory wastewater, chemical factory wastewater, semiconductor factory wastewater, machine factory wastewater, sewage, urine, and river water. The biodegradable substances are, for example, organic matter and nitrogen-containing substances, such as ammonia nitrogen and nitrate nitrogen. For example, when biologically treating wastewater containing organic matter, the organic matter in the wastewater is dissolved down to carbon dioxide by contact with biological sludge (microorganism). Further, for example, when biologically treating wastewater containing nitrogen-containing substances, the nitrogen-containing substances in the wastewater are

dissolved down to nitrogen gas by contact with biological sludge (microorganism).

[0043]

In the biological treatment process, the sludge concentration of the biological sludge in the sequencing batch biological treatment tank 10 is preferably set in a range of, for example, 3,000 to 30,000 mg/L in order to maintain soundness (such as settleability and activity) of the sludge. Further, the sludge load is preferably maintained in a range of 0.05 to 0.60 kg-BOD/kg-MLSS/day in order to maintain soundness (such as settleability and activity) of the sludge, and more preferably in a range of 0.1 to 0.5 kg-BOD/kg-MLSS/day. If the sludge load or the sludge concentration becomes higher than the above mentioned ranges, it is desired to reduce the biological sludge in the sequencing batch biological treatment tank 10.

[0044]

The pH in the sequencing batch biological treatment tank 10 is desirably set in a range suitable for general microorganisms, for example, preferably at 6 to 9, more preferably at 6.5 to 7.5. When the pH is out of this range, the pH is preferably controlled by adding acid or alkali. The dissolved oxygen (DO) in the sequencing batch biological treatment tank 10 is preferably set to 0.5 mg/L or higher, more preferably 1 mg/L or higher, under aerobic conditions.

[0045]

## 20 Wastewater Supply and Treated Water Discharge Process

In the wastewater supply and treated water discharge process, the supply of wastewater from the wastewater inlet 22 and the discharge of treated water from the sequencing batch biological treatment tank are both started in a period after stirring of the wastewater is stopped and before a sludge blanket of biological sludge is formed. It should be noted that the starting of the supply of the wastewater and the discharge of the treated water in the above period includes not only the case where the wastewater supply and the treated water discharge are started at the same time, but also the case where the discharge of the treated water is started after the wastewater supply is started and before the wastewater

supply is stopped in a period after stirring of the wastewater is stopped and before the sludge blanket of biological sludge is formed.

[0046]

The period before the sludge blanket of biological sludge is formed means a  
 5 period after stirring of the wastewater is stopped and before (ii) a zone settlement process in the biological sludge settlement process is finished. As described above, the sludge blanket has been formed before (iii) a transition process in the biological sludge settlement process. Therefore, the time period after stirring of wastewater is stopped and before the zone settlement process is finished (hereinafter referred to as “zone settlement finish time  
 10 of the sequencing batch biological treatment tank”) is the period after stirring of wastewater is stopped and before the sludge blanket of biological sludge is formed. In the present embodiment, the zone settlement finish time of the sequencing batch biological treatment tank is obtained by, for example, the methods described below.

[0047]

15 For example, 1L of a sample (wastewater) is entered into a graduated cylinder and slowly stirred until the mixed liquor suspended solids (MLSS) becomes uniform. After stopping stirring, the volume (mL) of settled sludge is measured at 5, 10, 15, 20, 30, 45, and 60 minutes later to draw a settlement curve by obtaining a percentage with respect to the total amount (1L) of the sample for each time. The settlement curve varies depending  
 20 on the settleability of the sludge. Therefore, for sludge having a high settleability (for example, for the sludge having a 5-minute sludge volumetric index (SVI5), indicative of the sludge settleability, of 100 mL/g or lower), it would be preferable to draw a settlement curve by measuring the settled sludge volume at more frequent interval, for example, at 0.5,  
 1, 1.5, 2, 2.5, 3, 3.5, 4, 5, 10, 15, 20, and 30 minutes after stopping stirring in the graduated  
 25 cylinder.

[0048]

FIG. 3 shows an example of the settlement curve. As shown in FIG. 3, the settlement curve includes at least two inflection points A, B. The time period between the

settling time 0 and the first inflection point A is the time period after the stirring of wastewater is stopped and before (i) a re-flocculation process is finished. The time period between the settling time 0 and the second inflection point B is the time period after the stirring of the wastewater is stopped and (ii) a zone settlement process is finished. It should be noted that the period after the inflection point B in the settlement curve is (iii) a transition process and (iv) a compaction process.

[0049]

The time period after the stirring of wastewater is stopped and before (ii) a zone settlement process is finished obtained from the settlement curve is the time which is measured using the graduated cylinder (hereinafter referred to as “zone settlement finish time measured using a graduated cylinder”). Therefore, the zone settlement finish time of the sequencing batch biological treatment tank can be obtained by multiplying the zone settlement finish time measured using a graduated cylinder by the ratio of the height of the actual sequencing batch biological treatment tank and the height of the graduated cylinder. A specific equation is shown below.

[0050]

Zone settlement finish time of a treatment device = Zone settlement finish time measured using a graduated cylinder x (height of sequencing batch biological treatment tank / height of graduated cylinder).

[0051]

In the present embodiment, the supply of wastewater and the discharge of treated water are both started before the zone settlement finish time of the sequencing batch biological treatment tank obtained by the equation above.

[0052]

Further, it is also possible to supply wastewater during the zone settlement by disposing an ultrasonic sludge interface meter in the sequencing batch biological treatment tank. Specifically, after stirring of wastewater is stopped, variations in height of sludge interface from the bottom of the reaction tank in the settlement process are recorded

by the ultrasonic sludge interface meter. The zone settlement finish time of the sequencing batch biological treatment tank can be obtained by drawing a settlement curve similar to the one in FIG. 3 based on the recorded variation in the height of the sludge interface.

5 [0053]

In the wastewater supply and treated water discharge process, it is preferable to start the wastewater supply from the wastewater inlet 22 and the treated water discharge from the treated water outlet 24 at the same time as or immediately after the stirring of wastewater is stopped. In this way, although an increase in the amount of biological  
10 sludge discharged from the treated water outlet 24 is a concern, the time period of one cycle can be further shortened. "Immediately after the stirring of wastewater is stopped" indicates immediately after the power distribution to the stirring system (such as the stirring device 36 and the aerator 38) is stopped. This means within one minute, more preferably within 30 minutes, after the stirring of wastewater is stopped (actually, after  
15 power distribution to the wastewater stirring device is stopped). Therefore, within one minute after the stirring of wastewater is stopped, the supply of wastewater and the discharge of treated water are started at the same time, or the discharge of treated water is started in a period after the supply of wastewater is started and before the supply of wastewater is stopped. In this way, sludge of small granule size having a slow settling  
20 velocity can be forcibly discharged from the system and a shortened cycle time can also be achieved.

[0054]

Although sufficient time to stop the supply of wastewater and the discharge of treated water depends on the wastewater supply amount and the supply flow velocity, the  
25 supply of wastewater and the discharge of treated water may be stopped after the sludge blanket of biological sludge is formed. However, once a sludge interface of biological sludge is formed, because biological sludge of small granule size and biological sludge having a slow settling velocity is embedded in the sludge blanket, it becomes impossible

for the sludge of small granule size or the like to be discharged from the system. Therefore, in order to shorten the cycle time, it is preferable to finish the supply of wastewater and the discharge of treated water (the supply of wastewater and the discharge of treated water are both finished) and to proceed to the biological treatment process before the sludge blanket of biological sludge is formed.

[0055]

The wastewater supply ratio (the ratio of the wastewater supply amount to the water volume in the sequencing batch biological treatment tank 10 in one cycle) is preferably set in a range of, for example, 10% to 100%. The granulation of biological sludge is assumed to be stimulated when the biological sludge is repeatedly exposed to a very high concentration (for example, the concentration of organic matter) of the target subject (feast conditions immediately after the supply of wastewater) and a very low concentration (for example, the concentration of organic matter) of the target subject (famine conditions in the final stage of the biological treatment). Therefore, in order to form granules, it is better to set the wastewater supply ratio as high as possible. However, a higher wastewater supply ratio requires a larger capacity wastewater pump 28, resulting in a higher cost. Consequently, a more preferable wastewater supply ratio is in a range from 20% to 80%.

[0056]

Although a preferable flow linear velocity of wastewater (the supply amount with respect to the cross-sectional area of the sequencing batch biological treatment tank) depends on the sludge concentration or other conditions, the flow linear velocity of wastewater is preferably set at, for example, 1 to 10 m/h. When the flow linear velocity of wastewater falls within this range of 1 to 10 m/h, it becomes easier to retain biological sludge having a fast settling velocity while discharging biological sludge having a slow settling velocity among the sludge in the sequencing batch biological treatment tank 10 than in a case where the flow linear velocity of wastewater does not fall within the above mentioned range.

[0057]

The flow linear velocity of wastewater is preferably increased along with the sludge granulation. Specifically, when the sequencing batch biological treatment tank 10 contains less biological sludge having a high settling velocity (for example, granular biological sludge), the wastewater is supplied at a low linear velocity. The flow linear velocity is increased as the ratio of the biological sludge having a high settling velocity (for example, granular biological sludge) increases. Such control of the flow linear velocity is preferably performed while measuring, for example, the average granule size of biological sludge using a granule size distribution meter. Specifically, when the average granule size of the biological sludge in the sequencing batch biological treatment tank 10 is 0.05 mm or smaller, the wastewater is preferably supplied at the flow linear velocity of 1 to 2 m/h. Then, the flow linear velocity is preferably increased along with the increase in the average granule size of the biological sludge such that the flow linear velocity is increased to 2 to 10 m/h after the average granule size reaches 0.2 mm or larger (after granulation). Alternatively, the flow linear velocity of wastewater may be increased along with an increase in the settling velocity by actually measuring the setting velocity of the biological sludge in the sequencing batch biological treatment tank 10 based on the zone settling velocity.

[0058]

The treated water discharged in the wastewater supply and treated water discharge process may be supplied to another treatment device by disposing, subsequent to the sequencing batch biological treatment tank 10 according to an embodiment of the present invention, a physical and chemical treatment unit, such as a settling tank and a pressurized flotation device, and a biological treatment unit, such as a membrane bioreactor (MBR), a fluidized bed carrier processor, and an activated sludge processor. In this way, because the treated water discharged in the wastewater supply and treated water discharge process is sufficiently treated by another treatment device, the water quality deterioration of the final treated water can be suppressed.

[0059]

Further, when treating wastewater containing, for example, non-biodegradable substances, the wastewater may be supplied to a physical and chemical treatment device by disposing, before the sequencing batch biological treatment tank 10 according to an embodiment of the present invention, a physical and chemical treatment device such as a flotation device, a coagulated pressurized flotation device, an absorption device, a Fenton treatment device, and an ozone treatment device. The use of the physical and chemical treatment device enables conversion of non-biodegradable substances to biodegradable substances. For example, when oils and fats which are often included in food processing factory wastewater are supplied to a biological treatment device without physical and chemical treatment, the oils and fats attach to biological sludge, causing adverse effects to the biological treatment. Therefore, it is desirable to supply the oils and fats to the sequencing batch biological treatment tank 10 after removing the oils and fats down to an extraction concentration of normal hexane of about 150 mg/L or lower with the above mentioned physical and chemical treatment device.

[0060]

In order to stimulate granulation of biological sludge, it is preferable to add ions that form hydroxide, such as  $\text{Fe}^{2+}$ ,  $\text{Fe}^{3+}$ , and  $\text{Ca}^{2+}$ , and  $\text{Mg}^{2+}$ , to the wastewater in the sequencing batch biological treatment tank 10 or the wastewater before being supplied to the sequencing batch biological treatment tank 10. Typical wastewater contains fine particles which can serve as a granule core. Formation of the core can be stimulated by adding the above-listed ions.

[0061]

A wastewater treatment is described below in which granules formed in the above-described sequencing batch biological treatment device are supplied to a continuous biological treatment device for biological treatment. The sequencing batch biological treatment devices shown in FIGs. 4 to 9 are variations of the above-described sequencing batch biological treatment device. In other words, it should be understood that the

sequencing batch biological treatment device shown in FIGs. 1 and 2 can be applied to the wastewater treatment devices described below. It should be further understood that, although descriptions of the processes to form granules by repeating the above-described biological treatment process and the wastewater supply and treated water discharge process are omitted to avoid redundancy, such processes are also performed as required in the devices described below. For example, in the sequencing batch biological treatment device described below, it is preferable to form granules by repeatedly performing the biological treatment process and the wastewater supply and treated water discharge process in the place of typically performed sequencing batch biological treatment when granule formation is required in cases such as at the start of the biological treatment (at the startup of the device) or when the granule concentration in the tank has dropped significantly.

[0062]

FIG. 4 shows a schematic diagram showing an example of a structure of a wastewater treatment device according to an embodiment of the present disclosure. A wastewater treatment device 3 shown in FIG. 4 includes a continuous biological treatment device 48, a sequencing batch biological treatment device 50, a solid-liquid separator 52, and a wastewater storage tank 54.

[0063]

The wastewater treatment device 3 shown in FIG. 4 includes wastewater supply lines 56a, 56b, 56c, treated water discharge lines 58a, 58b, a sludge return line 60, a sludge discharge line 62, and a biological sludge supply line 64. The wastewater treatment device 3 shown in FIG. 4 further includes a first wastewater supply pump 66, a second wastewater supply pump 70, a treated water discharge pump 72, a sludge supply pump 74, and a sludge return pump 76. The first wastewater supply pump 66 is disposed in the wastewater supply line 56a. The second wastewater supply pump 70 is connected to the wastewater supply line 56b. The sludge supply pump 74 is connected to the biological sludge supply line 64. The sludge return pump 76 is connected to the sludge return line 60. In addition, the sludge discharge line 62 includes a solenoid valve 78.

[0064]

One end of the wastewater supply line 56a is connected to a wastewater inlet of the wastewater storage tank 54 and the other end is connected to a wastewater inlet of the continuous biological treatment device 48. One end of the wastewater supply line 56b is  
5 connected to a wastewater inlet of the wastewater storage tank 54 and the other end is connected to a wastewater inlet of the sequencing batch biological treatment device 50. One end of the wastewater supply line 56c is connected to a wastewater outlet of the continuous biological treatment device 48 and the other end is connected to a wastewater inlet of the solid-liquid separator 52. The treated water discharge line 58a is connected to  
10 a treated water outlet of the solid-liquid separator 52. One end of the sludge return line 60 is connected to a sludge outlet of the solid-liquid separator 52 and the other end is connected to a sludge inlet of the continuous biological treatment device 48. The sludge discharge line 62 is connected to the sludge return line 60. One end of the biological sludge supply line 64 is connected to a sludge outlet of the sequencing batch biological  
15 treatment device 50, and the other end is connected to a sludge supply port of the continuous biological treatment device 48. One end of the treated water discharge line 58b is connected to a treated water outlet of the sequencing batch biological treatment device 50, and the other end is connected to a treated water inlet of the continuous biological treatment device 48.

[0065]

FIG. 5 is a schematic diagram showing an example of a structure of a sequencing batch biological treatment device used in an embodiment of the present disclosure. As described below, the sequencing batch biological treatment device 50 shown in FIG. 5 repeatedly performs four processes: (1) wastewater is supplied, (2) target substances such  
25 as organic matter are biologically treated, (3) biological sludge is settled, and (4) treated water is discharged. The sequencing batch biological treatment device 50 shown in FIG. 5 includes a sequencing batch biological treatment tank 80, in or around which the sequencing batch biological treatment device 50 further includes a second wastewater

supply pump 70, a treated water discharge pump 72, a stirring device 86, an air pump 88, a diffuser 90, and a sludge supply pump 74. The diffuser 90 is connected to the air pump 88 such that the air supplied from the air pump 88 is supplied to the tank via the diffuser 90. The stirring device 86 includes, for example, a motor, a stirring blade, and a shaft  
5 connecting between the motor and the blade. The sequencing batch biological treatment device 50 includes a wastewater inlet 50a, a treated water outlet 50b, and a sludge outlet 50c such that the wastewater supply line 56b is connected to the wastewater inlet 50a, the treated water discharge line 58b is connected to the treated water outlet 50b, and the biological sludge supply line 64 is connected to the sludge outlet 50c.

10 [0066]

The wastewater supply line 56b and the second wastewater supply pump 70 shown in FIG. 5 serve as a wastewater supply device on a sequencing batch type side which intermittently supplies wastewater to the sequencing batch biological treatment device 50. Although the intermittent supply of wastewater is performed by activating and  
15 stopping the second wastewater supply pump 70 in the present embodiment, the intermittent supply of wastewater may be performed, for example, by opening and closing a solenoid valve disposed in the wastewater supply line 56b.

[0067]

The biological sludge supply line 64 and the sludge supply pump 74 shown in FIG.  
20 5 serve as a biological sludge supply device which supplies granules to the continuous biological treatment device 48. A solenoid valve or other elements may be disposed as required in the biological sludge supply line 64.

[0068]

The treated water discharge line 58b and the treated water discharge pump 72  
25 serve as a treated water supply device which supplies treated water to the continuous biological treatment device 48. A solenoid valve or other elements may be disposed as required in the treated water discharge line 58b.

[0069]

The wastewater supply line 56a and the first wastewater supply pump 66 shown in FIG. 4 serve as a wastewater supply device on a continuous supply side which supplies wastewater to the continuous biological treatment device 48. The first wastewater supply pump 66 shown in FIG. 4 adjusts the wastewater supply amount to the continuous biological treatment device 48 in response to the granules supplied by the above described biological sludge supply device and the treated water supplied by the above described treated water supply device. Specifically, the first wastewater supply pump 66 is electrically connected to the treated water discharge pump 72 and the sludge supply pump 74. When the treated water discharge pump 72 or the sludge supply pump 74 is activated, output signals from these pumps are sent to the first wastewater supply pump 66. When the first wastewater supply pump 66 receives the output signal, the output of the first wastewater supply pump 66 is lowered to reduce the supply of wastewater by a predetermined amount. Alternatively, when the first wastewater supply pump 66 receives the output signal, the first wastewater supply pump 66 is stopped to reduce the wastewater supply to zero (in other words, the supply of wastewater from the wastewater supply line 56a is stopped). It is preferable that the wastewater supply amount is restored by returning the output of the first wastewater supply pump 66 to the original level when the treated water discharge pump 72 or the sludge supply pump 74 is stopped and the transmission of the output signal is stopped.

[0070]

The continuous biological treatment device 48 in the present embodiment is an aerobic reaction tank for biologically treating continuously supplied wastewater. The continuous biological treatment device 48 shown in FIG. 4 includes devices (not shown) such as a stirring device, an air pump, and a diffuser connected to the air pump such that the liquid in the tank is stirred by the stirring device and the air supplied from the air pump is supplied to the tank via the diffuser.

[0071]

The solid-liquid separator 52 according to the present embodiment is a separator

which separates biological sludge and treated water from water including biological sludge. The separator is, for example, a settlement separator, a pressurized flotation device, a filter, or a membrane separator.

[0072]

5           Example operations of the wastewater treatment device 3 according to an embodiment of the present disclosure are described below.

[0073]

10           The wastewater storage tank 54 shown in FIG. 4 contains target wastewater to be treated. The target wastewater is, for example, food processing factory wastewater, chemical factory wastewater, semiconductor factory wastewater, machine factory wastewater, sewage, urine, and river water. Wastewater generally contains substances such as biodegradable organic matter. When the wastewater contains non-biodegradable organic matter, it is preferable to remove the non-biodegradable organic matter by applying a physical and chemical treatment in advance using a flotation separator, a coagulated  
15           pressurized flotation device, an absorption device or other devices.

[0074]

20           First, the first wastewater supply pump 66 is activated to supply the target wastewater from the wastewater storage tank 54 to the continuous biological treatment device 48 through the wastewater supply line 56a. The continuous biological treatment device 48 applies, to the wastewater, a biological treatment using biological sludge under aerobic conditions. Treated water which has been treated by the continuous biological treatment device 48 is supplied to the solid-liquid separator 52 through the wastewater supply line 56c where biological sludge is separated from the treated water.

[0075]

25           When activating the sequencing batch biological treatment device 50, the second wastewater supply pump 70 is activated (with the first wastewater supply pump 66 kept in operation) to supply the target wastewater from the wastewater storage tank 54 to the sequencing batch biological treatment device 50 (the sequencing batch biological treatment

tank 80 shown in FIG. 5) through the wastewater supply line 56b ((1) wastewater supply process). After supplying a predetermined amount of the wastewater to the sequencing batch biological treatment tank 80, the second wastewater supply pump 70 is stopped. Then, the wastewater is biologically treated by activating the air pump 88 to supply air from the diffuser 90 to start supply of air to the sequencing batch biological treatment tank 80 and by also activating the stirring device 86 to stir the wastewater in the sequencing batch biological treatment tank 80 ((2) target substance biological treatment process). Then, the biological treatment is finished after a predetermined time period by stopping the air pump 88 to stop the supply of air and by stopping the stirring device 86. After the biological treatment process is finished, the biological sludge in the sequencing batch biological treatment tank 80 settles for a predetermined time period to separate biological sludge and treated water in the sequencing batch biological treatment tank 80 ((3) biological sludge settlement process). Then, the treated water discharge pump 72 is activated to discharge treated water from the sequencing batch biological treatment tank 80 through the treated water discharge line 58b ((4) treated water discharge process) to supply the treated water to the continuous biological treatment device 48 through the treated water discharge line 58b. Then, the processes (1) to (4) are sequentially repeated. By repeating the processes (1) to (4), granules are formed in the sequencing batch biological treatment tank 80. However, at the start of the biological treatment (at the startup of the device) or when the granule concentration in the tank has dropped significantly, it is more preferable to form granules by repeating the above described biological treatment process and the wastewater supply and treated water discharge process in place of the above processes (1) to (4).

[0076]

In the treated water discharge process (4), when the first wastewater supply pump 66 receives the output signal indicating that the treated water discharge pump 72 has been activated, the output from the first wastewater supply pump 66 is reduced by a predetermined amount such that the wastewater supply to the continuous biological

treatment device 48 decreases. Alternatively, the first wastewater supply pump 66 may be stopped to reduce the wastewater supply amount to the continuous biological treatment device 48 to zero. If treated water is supplied from the sequencing batch biological treatment device 50 (the sequencing batch biological treatment tank 80 shown in FIG. 5) without reducing the wastewater supply amount to the continuous biological treatment device 48, the water supply amount to the continuous biological treatment device 48 increases significantly, causing an increase in the amount of biological sludge in the treated water to be discharged from the continuous biological treatment device 48. In that case, because the supply load of the solid-liquid separator 52 tentatively increases, biological sludge in the solid-liquid separator 52 may not be sufficiently separated and a large amount of biological sludge may be discharged with the treated water. However, in the present embodiment, the wastewater supply amount to the continuous biological treatment device 48 is lowered or reduced to zero in response to the supply of treated water from the sequencing batch biological treatment tank 80 to the continuous biological treatment device 48, as described above, and the increase in the water supply amount to the continuous biological treatment device 48 can be suppressed. As a result, the increase in the amount of biological sludge in the treated water to be discharged from the continuous biological treatment device 48 is suppressed, and thereby the tentative increase in the supply load of the solid-liquid separator 52 can be suppressed. Consequently, the amount of biological sludge discharged with treated water can be suppressed. In order to return to the wastewater supply process (1) by stopping the treated water discharge pump 72 after a predetermined time period, it is preferable to return the output of the first wastewater supply pump 66 to the original level to restore the wastewater supply amount to the continuous biological treatment device 48.

[0077]

In a process to supply treated water to the continuous biological treatment device 48, the wastewater supply amount to the continuous biological treatment device 48 is preferably reduced by an amount greater than the wastewater supply amount from the

sequencing batch biological treatment tank 80, more preferably to zero, in order to suppress the increase in the water supply amount to the continuous biological treatment device 48. For example, when the wastewater supply amount to the continuous biological treatment device 48 before starting the supply of water to be treated to the sequencing batch biological treatment tank 80 is 100 L/h and the amount of treated water supplied from the sequencing batch biological treatment tank 80 is 30L/h, the wastewater supply amount to the continuous biological treatment device 48 after starting the supply of treated water to the continuous biological treatment device 48 is preferably set to 70 L/h or lower, more preferably at 0 L/h. It should be noted that even when the first wastewater supply pump 66 is stopped to reduce the wastewater supply amount to the continuous biological treatment device 48 through the wastewater supply line 56a to zero (the wastewater supply from the wastewater supply line 56a is stopped), treated water discharged from the sequencing batch biological treatment tank 80 is still supplied to the continuous biological treatment device 48 through the treated water discharge line 58b. Therefore, the continuous supply of wastewater to the continuous biological treatment device 48 is maintained.

[0078]

Further, by activating the sludge supply pump 74, the granules formed in the sequencing batch biological treatment tank 80 are supplied to the continuous biological treatment device 48 through the biological sludge supply line 64. The supply of the granules from the sequencing batch biological treatment tank 80 may be performed in (3) the biological sludge settlement process, (2) the target substance biological treatment process, or (4) the treated water discharge process. In any case, the output of the first wastewater supply pump 66 is lowered when the granules are supplied to the continuous biological treatment device 48, specifically when the first wastewater supply pump 66 receives the output signal from the sludge supply pump 74. Alternatively, the first wastewater supply pump 66 may be stopped to reduce the wastewater supply to the continuous biological treatment device 48 to zero. In this way, the increase in the water

supply amount to the continuous biological treatment device 48 can be suppressed. As a result, the increase in the amount of biological sludge in the treated water to be discharged from the continuous biological treatment device 48 is suppressed, and thereby the tentative increase in the supply load of the solid-liquid separator 52 can be suppressed.

5 Consequently, the amount of biological sludge discharged with the treated water can be suppressed.

[0079]

In a process to supply granular sludge to the continuous biological treatment device 48, the wastewater supply amount to the continuous biological treatment device 48

10 is preferably reduced by greater than the granular supply amount from the sequencing batch biological treatment tank 80, more preferably to zero, in order to suppress the increase in the water supply amount to the continuous biological treatment device 48. For example, when the wastewater supply amount to the continuous biological treatment device 48 before starting the supply of water to be treated to the sequencing batch

15 biological treatment tank 80 is 100 L/h and the granule supply amount from the sequencing batch biological treatment tank 80 is 10 L/h, the wastewater supply amount to the continuous biological treatment device 48 after starting the supply of granules to the continuous biological treatment device 48 is preferably set to 90 L/h or lower, more preferably to 0 L/h. Further, when the treated water and the granules are supplied at the

20 same time, the amount of wastewater is preferably reduced to less than the total amount of the treated water and the granules supplied from the sequencing batch biological treatment tank 80. It should be noted that even when the first wastewater supply pump 66 is stopped to reduce the wastewater supply amount to the continuous biological treatment device 48 through the wastewater supply line 56a to zero (the wastewater supply from the

25 wastewater supply line 56a is stopped), the granules discharged from the sequencing batch biological treatment tank 80 contains treated water and this treated water is supplied to the continuous biological treatment device 48 through the biological sludge supply line 64. Therefore, the continuous supply of wastewater to the continuous biological treatment

device 48 is maintained.

[0080]

The granules formed in the sequencing batch biological treatment tank 80 are sludge in which self-granulation proceeds such that the average granule size of the sludge is 0.2 mm or larger or an SVI5 value indicating that the sludge settleability is 80 mL/g or lower. In the present embodiment, whether granules have been formed is determined by measuring, for example, SVI indicative of the sludge settleability. Specifically, it can be determined that granules have been formed when the SVI value calculated based on the volume ratio five minutes after the settlement drops to a predetermined value or lower (for example, 80 mL/g or lower) by periodically measuring the SVI values in a settleability test of the sludge in the sequencing batch biological treatment tank 80. Alternatively, it can be determined that granules have been formed when the average granule size reaches a predetermined value or larger (for example, 0.2 mm or larger) by measuring the granule size distribution of the sludge in the sequencing batch biological treatment tank 80. (It should be noted that a lower SVI value and a larger average granule size indicate better granular sludge.) Then, by activating the sludge supply pump 74, the granules formed in the sequencing batch biological treatment tank 80 are supplied to the continuous biological treatment device 48 through the biological sludge supply line 64.

[0081]

As described above, because the present embodiment suppresses the increase in the supply load of the solid-liquid separator 52, the biological sludge discharged with the treated water from the solid-liquid separator 52 can be suppressed. Further, the treated water discharged from the solid-liquid separator 52 is discharged from the system through the treated water discharge line 58a. Furthermore, the sludge return pump 76 is activated to supply a portion of the biological sludge separated by the solid-liquid separator 52 to the continuous biological treatment device 48 through the sludge return line 60. In addition, by opening the solenoid valve 78, a portion of the biological sludge discharged from the solid-liquid separator 52 is discharged from the system through the sludge discharge line

62.

[0082]

Variations of the present embodiment are described below.

[0083]

5           Although the sequencing batch biological treatment device 50 in FIG. 4 is described as performing the biological treatment under aerobic conditions, the biological treatment is not particularly limited to this example and other conditions can be applied such as anaerobic (no oxygen) conditions only, aerobic conditions only, or alternative operations between anaerobic (no oxygen) conditions and aerobic conditions. However, 10 because aerobic conditions can accelerate the growth rate of the biological sludge, it is preferable to include the aerobic conditions in consideration of the granule formation rate. When forming granules, it is preferable to sufficiently control the settling time and wastewater supply ratio per batch. The settling time for settling of the sludge after stopping stirring (including aeration stirring) is calculated based on the distance between 15 the water surface and the sludge discharge portion, and the sludge settling velocity. The settling time is preferably set between 4 min/m to 15 min/m, more preferably between 5 min/m to 10 min/m. The wastewater supply ratio (the ratio of supplied water to the effective volume during reaction) is preferably set in a range, for example, from 20% to 120%, more preferably from 40% to 100%. The granulation of sludge is assumed to be 20 stimulated when the sludge is repeatedly exposed to a very high concentration of target organic matter (feast conditions immediately after the wastewater supply process) and a very low concentration of the target organic matter (famine conditions in the final stage of the biological treatment process). Therefore, in order to form granules, it is better to set the wastewater supply ratio as high as possible. However, a higher wastewater supply 25 ratio requires a larger capacity wastewater supply pump, resulting in a higher cost. Consequently, in consideration of granule formation and cost reduction, a preferable wastewater supply ratio is in a range from 40% to 100%.

[0084]

The sequencing batch biological treatment device 50 is desirably operated with the sludge concentration in the tank in a range of 2,000 to 20,000 mg/L. It is desirable to reduce biological sludge from the tank when the sludge concentration exceeds a predetermined concentration. Further, in order to maintain soundness (such as settleability and activity) of the biological sludge, biological sludge is desirably reduced such that the sludge load is maintained at a sufficient level, preferably in a range of 0.05 to 0.60 kgBOD/MLSS/day, more preferably at 0.1 to 0.5 kgBOD/MLSS/day.

[0085]

The pH in the sequencing batch biological treatment tank 80 is preferably adjusted to a range of 6 to 9 pH, which is appropriate for general biological treatments, more preferably in a range of 6.5 to 7.5 pH. When the pH becomes out of this range, it is preferable to adjust the pH by adding acid or alkali. When adjusting the pH of the sequencing batch biological treatment tank 80, in order to appropriately measure the pH values, it is more desirable to adjust the pH while the wastewater in the sequencing batch biological treatment tank 80 is stirred than otherwise. The dissolved oxygen (DO) in the sequencing batch biological treatment tank 80 is preferably set to 0.5 mg/L or higher, which is appropriate for general biological treatments, and more preferably 1 mg/L or higher.

[0086]

The sequencing batch biological treatment device 50 may perform supply of separated water and discharge of treated water at the same time. Specifically, the sequencing batch biological treatment device 50 according to embodiments of the present invention may repeat three processes, (1) a separated water supply/treated water discharge process, (2) a target substance biological treatment process, and (3) a biological sludge settlement process. An example of a wastewater treatment device using a sequencing batch biological treatment device which repeats these three processes is described below.

[0087]

Although the continuous biological treatment device 48 shown in FIG. 4 is

described in an example as performing a biological treatment using a general activated sludge method targeting organic matter or other substances, the present invention is not limited to this example. For example, the device may perform biological treatments using a nutrient salt removal system (system with a no oxygen treatment tank, or an anaerobic treatment tank) such as an anaerobic-anoxic-oxic (A2O) system and an anaerobic-oxic (AO) system, and a system using an oxidation ditch method, a non-continuous supply type multi-step activated sludge method, or other methods. Further, the device may perform biological treatments in the presence of a carrier such as polyurethane, plastic, and resin.

[0088]

The continuous biological treatment device 48 is desirably operated with the sludge concentration in the tank in a range of 2,000 to 20,000 mg/L. In order to maintain soundness (such as settleability and activity) of the biological sludge, the sludge load is preferably maintained in a range of 0.05 to 0.6 kgBOD/MLSS/day, more preferably in a range of 0.1 to 0.5 kgBOD/MLSS/day.

[0089]

The pH in the continuous biological treatment device 48 is preferably adjusted to a range of 6 to 9 pH, which is appropriate for general biological treatments, more preferably in a range of 6.5 to 7.5 pH. The dissolved oxygen (DO) in the continuous biological treatment device 48 is preferably set to 0.5 mg/L or higher, which is appropriate for general biological treatments, more preferably 1 mg/L or higher.

[0090]

Although the wastewater treatment device 3 in FIG. 4 is described in an example with the solid-liquid separator 52, the solid-liquid separator 52 is not always required. However, in order to enhance efficiency of the wastewater treatment using circulating granules, the wastewater treatment device 3 preferably includes the solid-liquid separator 52 which separates biological sludge in the treated water discharged from the continuous biological treatment device 48 and further includes the sludge return line 60 for returning the biological sludge discharged from the solid-liquid separator 52 to the continuous

biological treatment device 48.

[0091]

FIG. 6 is a schematic diagram showing another example of a structure of a wastewater treatment device according to an embodiment of the present disclosure. The elements in the wastewater treatment device 4 in FIG. 6 which are similar to those of the wastewater treatment device 3 in FIG. 4 are represented by identical reference numerals and their descriptions are omitted. The wastewater treatment device 4 in FIG. 6 includes a wastewater supply pump 68 and a first solenoid valve 82 in a wastewater supply line 56a, and a second solenoid valve 84 in a wastewater supply line 56b. One end of the wastewater supply line 56b is connected to the wastewater supply line 56a between the wastewater supply pump 68 and the first solenoid valve 82, and the other end is connected to a wastewater inlet of a sequencing batch biological treatment device 50. The first solenoid valve 82 shown in FIG. 6 adjusts the wastewater supply amount to a continuous biological treatment device 48 in response to the granule supply and the treated water supply. Specifically, the first solenoid valve 82 is electrically connected to a treated water discharge pump 72 and a sludge supply pump 74. When the treated water discharge pump 72 or the sludge supply pump 74 is activated, output signals from these pumps are sent to the first solenoid valve 82. When the first solenoid valve 82 receives the output signal, the opening of the first solenoid valve 82 is narrowed to reduce the wastewater supply amount by a predetermined amount. Alternatively, when the first solenoid valve 82 receives the output signal, the first solenoid valve 82 is closed to reduce the wastewater supply to zero (in other words, the supply of wastewater from the wastewater supply line 56a is stopped). It is desirable that the wastewater supply amount is restored by adjusting the first solenoid valve 82 to open at the original level when the treated water discharge pump 72 or the sludge supply pump 74 is stopped and the transmission of the output signal is stopped.

[0092]

Example operations of the wastewater treatment device 4 according to the present

embodiment are described below.

[0093]

First, the wastewater supply pump 68 is activated and the first solenoid valve 82 is opened to supply the target wastewater from the wastewater storage tank 54 to the continuous biological treatment device 48 through the wastewater supply line 56a. The continuous biological treatment device 48 applies a biological treatment to the wastewater as described above. Then, treated water is supplied to the solid-liquid separator 52 through a wastewater supply line 56c.

[0094]

When activating the sequencing batch biological treatment device 50, the wastewater supply pump 68 is activated and the second solenoid valve 84 is opened with the first solenoid valve 82 left opened so as to supply the target wastewater from the wastewater storage tank 54 to the sequencing batch biological treatment device 50 through the wastewater supply line 56b ((1) wastewater supply process). After a predetermined amount of the wastewater has been supplied to the sequencing batch biological treatment tank 80, the second solenoid valve 84 is closed.

[0095]

Then, the wastewater is biologically treated by activating the air pump 88 to supply air from the diffuser 90 to start supply of air to the sequencing batch biological treatment device 50 and by activating the stirring device 86 to stir the wastewater in the sequencing batch biological treatment device 50 ((2) target substance biological treatment process). Then, the biological treatment is finished after a predetermined time period by stopping the air pump 88 to stop the supply of air and by stopping the stirring device 86. After the biological treatment is finished, the biological sludge in the sequencing batch biological treatment device 50 is settled for a predetermined time period to separate biological sludge and treated water in the sequencing batch biological treatment device 50 ((3) biological sludge settlement process). Then, a treated water discharge pump 72 is activated to discharge treated water in the sequencing batch biological treatment device 50

through the treated water discharge line 58b ((4) treated water discharge process) to supply the treated water to the continuous biological treatment device 48 through the treated water discharge line 58b. Then, the processes (1) to (4) are repeated. By repeating the processes (1) to (4), granules are formed in the sequencing batch biological treatment device 50. However, at the start of the biological treatment (at the startup of the device) or when the granule concentration in the tank has dropped significantly, it is more preferable to form granules by sequentially repeating the above described biological treatment process and the wastewater supply and treated water discharge process in place of the above processes (1) to (4).

10 [0096]

In the treated water discharge process (4), when the first solenoid valve 82 receives the output signal indicating that the treated water discharge pump 72 has been activated, the opening of the first solenoid valve 82 is narrowed to reduce the wastewater supply amount to the continuous biological treatment device 48. Alternatively, the first solenoid valve 82 is closed to reduce the wastewater supply amount to the continuous biological treatment device 48 to zero (the wastewater supply from the wastewater supply line 56a is stopped). After a predetermined time period, the treated water discharge pump 72 is stopped and the process returns to the wastewater supply process (1). In the wastewater supply process, it is preferable to return the opening degree of the first solenoid valve 82 to the original level to restore the wastewater supply amount to the continuous biological treatment device 48. It should be noted that although the wastewater supply amount is reduced by adjusting the opening degree of the first solenoid valve 82 in the present embodiment, the wastewater supply amount may be reduced by lowering the output of the wastewater supply pump 68 similarly to the wastewater treatment device 3 in FIG. 4.

25

[0097]

As described above, in the wastewater treatment device 4 according to the present embodiment, because the wastewater supply amount to the continuous biological treatment

device 48 is lowered or reduced to zero in response to the supply of the treated water from the sequencing batch biological treatment device 50 to the continuous biological treatment device 48, the increase in the water supply amount to the continuous biological treatment device 48 can be suppressed. As a result, the increase in the amount of biological sludge in the treated water to be discharged from the continuous biological treatment device 48 is suppressed, and thereby the tentative increase in the supply load of the solid-liquid separator 52 can be suppressed. Consequently, the amount of biological sludge discharged with treated water can be suppressed.

[0098]

Further, by activating the sludge supply pump 74, the granules formed in the sequencing batch biological treatment device 50 are supplied to the continuous biological treatment device 48 through the biological sludge supply line 64. When the first solenoid valve 82 receives the output signal from the sludge supply pump 74, the opening of the sludge supply pump 74 is narrowed to reduce the wastewater supply amount to the continuous biological treatment device 48. Alternatively, the first solenoid valve 82 is closed to reduce the wastewater supply to the continuous biological treatment device 48 to zero. In this way, the water supply amount to the continuous biological treatment device 48 can be suppressed. As a result, the increase in the biological sludge contained in the treated water discharged from the continuous biological treatment device 48 is suppressed, and thereby the tentative increase in the supply load of the solid-liquid separator 52 can be suppressed. Consequently, the amount of biological sludge discharged with treated water can be suppressed.

[0099]

Further, as in the wastewater treatment device 4 in the present embodiment, the device type which uses the same pump to supply the wastewater both to the continuous biological treatment device 48 and the sequencing batch biological treatment device 50 can suppress the initial and running costs to lower than the device type which uses separate pumps to respectively supply wastewater to the continuous biological treatment device 48

and the sequencing batch biological treatment device 50.

[0100]

Example operations of the wastewater treatment device 4 using the sequencing batch biological treatment device 50 to which wastewater is supplied and from which treated water is discharged are described below. Specifically, the sequencing batch biological treatment device 50 repeats three processes, (1) a separated water supply/treated water discharge process, (2) a target substance biological treatment process, and (3) a biological sludge settlement process. By repeating the processes (1) to (3), granules are formed in the sequencing batch biological treatment device 50. However, for example, at the start of the biological treatment (at the startup of the device) or when the granule concentration in the tank has dropped significantly, it is more preferable to form granules by sequentially repeating the above described biological treatment process and the wastewater supply and treated water discharge process in place of the processes (1) to (3).

[0101]

First, the wastewater supply pump 68 is activated and the first solenoid valve 82 is opened to supply the target wastewater from the wastewater storage tank 54 to the continuous biological treatment device 48 through the wastewater supply line 56a. After the continuous biological treatment device 48 has applied a biological treatment to the wastewater, the treated water is supplied to the solid-liquid separator 52 through the wastewater supply line 56c. When activating the sequencing batch biological treatment device 50, the second solenoid valve 84 is opened and the treated water discharge pump 72 is activated to supply the wastewater to the sequencing batch biological treatment device 50 through the wastewater supply line 56a and to supply the treated water to which the biological treatment has been applied in the sequencing batch biological treatment device 50 to the continuous biological treatment device 48 through the treated water discharge line 58b ((1) separated water supply/treated water discharge process). During this process in the present embodiment, when the first solenoid valve 82 receives the output signal indicating that the treated water discharge pump 72 has been activated, the opening of the

first solenoid valve 82 is narrowed to reduce the wastewater supply amount to the continuous biological treatment device 48. Alternatively, the first solenoid valve 82 is closed to reduce the wastewater supply amount to the continuous biological treatment device 48 to zero (the wastewater supply is stopped).

5 [0102]

After a predetermined time period, the treated water discharge pump 72 is stopped and the second solenoid valve 84 is closed. During this process, it is desirable to return the opening degree of the first solenoid valve 82 to the original level to restore the wastewater supply amount to the continuous biological treatment device 48. Then, the wastewater is biologically treated by activating the air pump 88 to supply air from the diffuser 90 to start supply of air to the sequencing batch biological treatment device 50 and by activating the stirring device 86 to stir the wastewater in the sequencing batch biological treatment device 50 ((2) target substance biological treatment process). Then, the biological treatment is finished after a predetermined time period by stopping the air pump 88 to stop the supply of air and by stopping the stirring device 86. After the biological treatment is finished, the biological sludge in the sequencing batch biological treatment device 50 is settled for a predetermined time period to separate biological sludge and treated water in the sequencing batch biological treatment device 50 ((3) biological sludge settlement process). Then, the process returns to (1) wastewater supply process. Alternatively, when supplying granules formed in the sequencing batch biological treatment device 50 to the continuous biological treatment device 48, the wastewater supply amount to the continuous biological treatment device 48 is lowered or reduced to zero by narrowing the opening of the first solenoid valve 82 when the output signal is received from the sludge supply pump 74, as described above.

25 [0103]

As described above, in the wastewater treatment device 4 according to the present embodiment, because the wastewater supply amount to the continuous biological treatment device 48 is reduced in response to the supply of the treated water and granules from the

sequencing batch biological treatment device 50 to the continuous biological treatment device 48, the increase in the water supply amount to the continuous biological treatment device 48 can be suppressed. As a result, the increase in the amount of biological sludge in the treated water to be discharged from the continuous biological treatment device 48 is suppressed, and thereby the tentative increase in the supply load of the solid-liquid separator 52 can be suppressed. Consequently, the amount of biological sludge discharged with treated water can be suppressed.

[0104]

FIG. 7 is a schematic diagram showing another example of a structure of a wastewater treatment device according to an embodiment of the present disclosure. The elements in a wastewater treatment device 5 in FIG. 7 which are similar to those of the wastewater treatment device 4 in FIG. 6 are represented by the identical reference numerals and their descriptions are omitted. The wastewater treatment device 5 in FIG. 7 includes a third solenoid valve 92 in the treated water discharge line 58b (no treated water discharge pump 72 is provided). The wastewater treatment device 5 in FIG. 7 operates in the identical manner to the wastewater treatment device 4 in FIG. 6 except that the supply and stop of the treated water is performed by opening and closing the third solenoid valve 92 in place of activating and stopping the treated water discharge pump 72 in FIG. 6. The wastewater treatment device 5 in FIG. 7 is configured with further reduced number of pumps than the wastewater treatment device 4 in FIG. 6, resulting in even lower initial and running costs of the device.

[0105]

FIG. 8 is a schematic diagram showing another example of a structure of a wastewater treatment device according to an embodiment of the present disclosure. The elements in a wastewater treatment device 6 in FIG. 8 which are similar to those of the wastewater treatment device 4 in FIG. 6 are represented by the identical reference numerals and their descriptions are omitted. The wastewater treatment device 6 in FIG. 8 includes a sludge and treated water supply line 94 for supplying the treated water and granules

discharged from the sequencing batch biological treatment device 50 to the continuous biological treatment device 48. The sludge and treated water supply line 94 is provided with a third solenoid valve 96. The sludge and treated water supply line 94 serves as a treated water supply device which supplies the treated water discharged from the sequencing batch biological treatment device 50 to the continuous biological treatment device 48 and also as a biological sludge supply device which supplies granules to the continuous biological treatment device 48. The third solenoid valve 96 and the first solenoid valve 82 are electrically connected to each other. The first solenoid valve 82 receives an output signal from the third solenoid valve 96 when the third solenoid valve 96 is opened. When the first solenoid valve 82 receives the output signal, the opening of the first solenoid valve 82 is narrowed to reduce the wastewater supply amount for a predetermined amount. Alternatively, the first solenoid valve 82 may be closed to reduce the wastewater supply to zero when the first solenoid valve 82 receives the output signal (specifically, the wastewater supply from the wastewater supply line 56a is stopped). It is desirable that the opening degree of the first solenoid valve 82 is returned to the original level to restore the wastewater supply amount by configuring that the transmission of the output signal is stopped when the third solenoid valve 96 is closed.

[0106]

The wastewater treatment device 6 shown in FIG. 8 uses the sequencing batch biological treatment device 50 to which wastewater is supplied and from which treated water and granules are discharged while liquid (the treated water and granules) in the sequencing batch biological treatment device 50 is stirred. Example operations of the wastewater treatment device 6 shown in FIG. 8 are described below.

[0107]

First, the wastewater supply pump 68 is activated and the first solenoid valve 82 is opened to continuously supply the target wastewater from the wastewater storage tank 54 to the continuous biological treatment device 48 through the wastewater supply line 56a. After the wastewater is biologically treated in the continuous biological treatment device

48, the treated water is supplied to the solid-liquid separator 52 through the wastewater supply line 56c. When activating the sequencing batch biological treatment device 50, the second solenoid valve 84 and the third solenoid valve 96 are opened such that the wastewater is supplied to the sequencing batch biological treatment device 50 through the wastewater supply line 56b and the treated water in the sequencing batch biological treatment device 50 is continuously supplied to the continuous biological treatment device 48 through the sludge and treated water supply line 94 ((1) a wastewater supply and treated water discharge process). During this process in the present embodiment, when the first solenoid valve 82 receives an output signal indicating that the third solenoid valve 96 is opened, the opening of the first solenoid valve 82 is narrowed to reduce the wastewater supply amount to the continuous biological treatment device 48. Alternatively, the first solenoid valve 82 is closed to reduce the wastewater supply amount to the continuous biological treatment device 48 to zero (a wastewater supply stop process). Then, with the opening degree of each valve being maintained, the stirring device 86 is activated. The treated water and granules which have been stirred by the stirring device in the sequencing batch biological treatment device 50 are supplied to the continuous biological treatment device 48 through the sludge and treated water supply line 94 ((1.5) a granular sludge supply process).

[0108]

After a predetermined time period, the second solenoid valve 84 and the third solenoid valve 96 are closed. It is desirable that the opening degree of the first solenoid valve 82 is returned to the original level at this point to restore the wastewater supply amount to the continuous biological treatment device 48. Next, the wastewater is biologically treated by activating the air pump 88 without stopping the stirring device 86 to supply air from the diffuser 90 to start air supply to the sequencing batch biological treatment device 50 ((2) biological treatment process). The biological treatment is finished after a predetermined time period by stopping the stirring device 86 and the air pump 88 to stop the supply of air. After the biological treatment is finished, the

biological sludge in the sequencing batch biological treatment device 50 is allowed to be settled for a predetermined time period to separate the biological sludge and the treated water in the sequencing batch biological treatment device 50 ((3) biological sludge settlement process). Then, the process returns to (1) the wastewater supply/treated water discharge process. The (1.5) granular sludge supply process is not required to be performed in each cycle. This process may be performed once in some cycles.

[0109]

Another example of operations of the wastewater treatment device 6 shown in FIG. 8 is described below.

[0110]

First, the wastewater supply pump 68 is activated, and the first solenoid valve 82 is opened to continuously supply target wastewater from the wastewater storage tank 54 to the continuous biological treatment device 48 through the wastewater supply line 56a. After a biological treatment is applied to the wastewater by the continuous biological treatment device 48, the treated water is supplied to the solid-liquid separator 52 through the wastewater supply line 56c. When activating the sequencing batch biological treatment device 50, the second solenoid valve 84 and the third solenoid valve 96 are opened and the stirring device 86 is activated to supply the wastewater to the sequencing batch biological treatment device 50 through the wastewater supply line 56b, and at the same time, the treated water and granules which have been stirred by the stirring device in the sequencing batch biological treatment device 50 are supplied to the continuous biological treatment device 48 through the sludge and treated water supply line 94 ((1) wastewater supply and treated water discharge process). During this process in the present embodiment, when the first solenoid valve 82 receives the output signal indicating that the third solenoid valve 96 is opened, the opening of the first solenoid valve 82 is narrowed to reduce the wastewater supply amount to the continuous biological treatment device 48. Alternatively, the first solenoid valve 82 is closed to reduce the wastewater supply to the continuous biological treatment device 48 to zero (the wastewater supply is

stopped).

[0111]

After a predetermined time period, the second solenoid valve 84 and the third solenoid valve 96 are closed. In this process, it is desirable that the opening degree of the first solenoid valve 82 is returned to the original level to restore the wastewater supply amount to the continuous biological treatment device 48. Then, the wastewater is biologically treated by activating the air pump 88 without stopping the stirring device 86 to supply air from the diffuser 90 to start air supply to the sequencing batch biological treatment device 50 ((2) biological treatment process). Then, the biological treatment is finished after a predetermined time period by stopping the air pump 88 to stop the supply of air. Next, with the stirring device 86 in operation (in other words, with the liquid in the sequencing batch biological treatment device 50 being stirred), wastewater is supplied to the sequencing batch biological treatment device 50 and treated water and granules are discharged from the sequencing batch biological treatment device 50 again ((1) a wastewater supply and treated water discharge process).

[0112]

Application of the sludge and treated water supply line 94, which serves as a treated water supply device for supplying treated water discharged from the sequencing batch biological treatment device 50 to the continuous biological treatment device 48 and also as a biological sludge supply device for supplying granules to the continuous biological treatment device 48, is not limited to the wastewater treatment device shown in FIG. 8 but is applicable to all the embodiments described above.

[0113]

FIGs. 9A and 9B are schematic diagrams showing other examples of structures of a sequencing batch biological treatment device used in embodiments of the present disclosure. The elements in a sequencing batch biological treatment device 98 in FIG. 9 which are similar to those of the sequencing batch biological treatment device 50 shown in FIG. 5 are represented by identical reference numerals and their descriptions are omitted.

In the sequencing batch biological treatment device 98 in FIG. 9A, the treated water outlet 50b for discharging treated water is provided higher than the wastewater inlet 50a for supplying wastewater. Further, the sequencing batch biological treatment device 98 in FIG. 9B is the sequencing batch biological treatment device 50 which is used as the wastewater treatment device in FIG. 8. A sludge and treated water outlet 50d for discharging the treated water and granules is provided higher than the wastewater inlet 50a for supplying wastewater. In this way, because it is possible to suppress a wastewater shortcut which would allow the supplied wastewater to be discharged from the sequencing batch biological treatment device 98 without being treated, it becomes possible to efficiently form granules with the sequencing batch biological treatment device 98. Further, because the treated water in the sequencing batch biological treatment device 98 is discharged by being pushed up by the supplied wastewater, biological sludge having a low settleability can be forcibly discharged from the system. Because sludge having a high settleability remains in the sequencing batch biological treatment device 50 as a result, granules can be formed more effectively. It should be noted that although deterioration in the quality of treated water may be a concern because treated water discharged from the sequencing batch biological treatment device 98 is mixed with wastewater before the treatment, the deterioration in the quality of treated water which can be finally achieved is limited because the treated water discharged from the sequencing batch biological treatment device 98 is supplied to the continuous biological treatment device 48 where a biological treatment is applied to the treated water.

#### EXAMPLE

[0114]

Although an example of the present invention is given below to describe the present invention in more detail, the present invention is not limited to this example.

[0115]

In an example of the present invention, the sequencing batch biological treatment

device shown in FIG. 2 was used to treat artificial wastewater under the conditions below. In this example, a sequencing batch biological treatment tank (dimensions of the sequencing batch biological treatment tank: 0.15 m in width x 0.2 m in length x 0.4 m in height) was used in which a wastewater inlet was positioned at 1/4 the height of the water surface in the sequencing batch biological treatment tank (0.4 m above the bottom of the tank) and a treated water outlet was positioned at the water level (0.2 m below the top of the tank) such that the treated water outlet was positioned higher than the wastewater inlet. The artificial wastewater which mainly contained fish meat extract and peptone was used. [0116]

The artificial wastewater supplied in the sequencing batch biological treatment tank was biologically treated by supplying air to the artificial wastewater for a predetermined time (150 minutes) using an aerator disposed near the bottom of the sequencing batch biological treatment tank (biological treatment process). At the same time as supply of wastewater was started from the wastewater inlet 30 seconds after stopping the aerator (within the zone settlement time obtained using a graduated cylinder), discharge of treated water from a treated water outlet was started (wastewater supply and treated water discharge process). The flow linear velocity of the wastewater was set to 1 m/h with respect to the water surface area of the sequencing batch biological treatment device. The wastewater supply amount was set such that 75% of actual volume of the sequencing batch biological treatment device was filled in 18 minutes. In this way, the biological treatment process and the wastewater supply and treated water discharge process were repeatedly performed.

[0117]

## Comparative Example

In a comparative example, the above described treatment of artificial wastewater was performed under the conditions described below. In the comparative example, a sequencing batch biological treatment tank (dimensions of the sequencing batch biological

treatment tank: 0.15 m in width x 0.2 m in length x 0.4 m in height) was used in which a wastewater inlet was positioned at 1/4 the height of the water surface in the sequencing batch biological treatment tank (0.4 m above the bottom of the tank) and a treated water outlet was positioned at 1/2 the height of the water surface in the sequencing batch biological treatment tank (0.2 m above the bottom of the tank).

[0118]

In the comparative example, a conventional sequencing batch treatment was performed. First, (1) in a wastewater supply process, raw water was supplied to the sequencing batch biological treatment tank from a wastewater inlet for 10 minutes. (2) In a biological treatment process of the target substances, artificial wastewater was biologically treated by supplying air to the artificial wastewater using an aerator disposed near the bottom of the sequencing batch biological treatment tank for 95 minutes. (3) In a biological sludge settlement process, biological sludge was allowed to settle for 15 minutes after stopping the aerator. (4) In a treated water discharge process, the treated water was discharged from the treated water outlet for 10 minutes. Processes (1) to (4) were repeated.

[0119]

In both the example of the present invention and the comparative example, daily SVI5 values of biological sludge in the sequencing batch biological treatment tank were measured. The SVI5 value which is an indicator of sludge settleability can be obtained as described here. First, sludge (1L) was supplied in a 1L graduated cylinder and stirred. After allowing 5 minutes, the sludge interface was measured. Then, the volume ratio (%) of the sludge in the graduated cylinder was calculated. Then, MLSS (mg/L) was measured. The SVI5 value was calculated by inserting these values into the equation below. A smaller SVI5 value indicates a higher settleability of the sludge.

$$\text{SVI5 (mL/g)} = \text{volume of sludge} \times 10,000/\text{MLSS}$$

[0120]

Table 1 shows an example of representative treated water quality on the 26th day

from the start of water supply in the example of the present invention and the comparative example. FIG. 10 is a graph showing daily variations in the SVI5 values of the example and the comparative example. Regarding the treated water quality, the soluble BOD was suppressed to 10 mg/L or lower and SS was also excellent. At the start of the tests, the SVI5 values in Example 1 and the comparative example were both about 50 mL/g. However, while the SVI5 value decreased as days passed and dropped down to a very low value of 26 mL/g on the 26th day from the start of the test in the example of the present invention, the SVI5 values did not significantly change as days passed in the comparative example and was 47 mL/g on the 26th day from the start of the test. Therefore, as shown in the example of the present invention, by repeating the biological treatment process in which wastewater was biologically treated while the wastewater was stirred with the supply of wastewater and the discharge of the treated water being stopped, and the wastewater supply and treated water discharge process in which the supply of wastewater from the wastewater inlet positioned lower than the treated water outlet and the discharge of treated water from the treated water outlet were both started in a period after the stirring of the wastewater was stopped and before the sludge interface of the biological sludge was formed, biological sludge having a higher settleability was obtained, especially in a shorter time, than with the conventional sequencing batch treatment as in the comparative example.

[0121]

Table 1. Treated Water Quality on 26th Day after Water Supply.

|             | Example of Present Invention | Comparative Example |
|-------------|------------------------------|---------------------|
| Soluble BOD | 8 mg/L                       | 3 mg/L              |
| SS          | 15 mg/L                      | 20 mg/L             |

## REFERENCE NUMERALS

[0122]

1, 2, 50, 98 sequencing batch biological treatment device, 3 to 6 wastewater treatment device, 10 sequencing batch biological treatment tank, 12 wastewater supply

device, 14 distributor, 16 treated water discharger, 20 controller, 22 wastewater inlet, 24 treated water outlet, 26 wastewater supply line, 28 wastewater pump, 30 wastewater side solenoid valve, 32 treated water discharge line, 34 treated water side solenoid valve, 36, 86 stirring device, 38 aerator, 40 motor, 42 stirring blade, 44 diffuser pump, 46 diffuser pipe, 5 48 continuous biological treatment device, 50a wastewater inlet, 50b treated water outlet, 50c sludge outlet, 50d sludge and treated water outlet, 52 solid-liquid separator, 54 wastewater storage tank, 56a, 56b, 56c wastewater supply line, 58a, 58b treated water discharge line, 60 sludge return line, 62 sludge discharge line, 64 biological sludge supply line, 66 first wastewater supply pump, 68 wastewater supply pump, 70 second wastewater 10 supply pump, 72 treated water discharge pump, 74 sludge supply pump, 76 sludge return pump, 78 solenoid valve, 80 sequencing batch biological treatment tank, 82 first solenoid valve, 84 second solenoid valve, 88 air pump, 90 diffuser, 92, 96 third solenoid valve, and 94 sludge and treated water supply line.

## CLAIMS

1. A wastewater treatment method comprising a sequencing batch biological treatment process to biologically treat wastewater using a sequencing batch biological treatment tank containing biological sludge, the sequencing batch biological treatment process comprising:

a biological treatment process to biologically treat the wastewater using the biological sludge by stirring the wastewater in the sequencing batch biological treatment tank under conditions where supply of the wastewater to the sequencing batch biological treatment tank and discharge of treated water from the sequencing batch biological treatment tank are both stopped; and

a wastewater supply and treated water discharge process in which

(a) the supply of the wastewater to the sequencing batch biological treatment tank and the discharge of the treated water from the sequencing batch biological treatment tank are started at the same time; or

(b) the supply of the wastewater to the sequencing batch biological treatment tank is started and the discharge of the treated water from the sequencing batch biological treatment tank is started in a period after the supply of the wastewater is started and before the supply of the wastewater is stopped,

wherein (a) or (b) takes place in a period after the stirring of the wastewater in the sequencing batch biological treatment tank has been stopped and before a sludge blanket of the biological sludge is formed in the sequencing batch biological treatment tank,

wherein the biological treatment process and the wastewater supply and treated water discharge process are sequentially repeated.

2. The wastewater treatment method according to claim 1, wherein in the wastewater

supply and treated water discharge process, the supply of the wastewater to the sequencing batch biological treatment tank and the discharge of the treated water from the sequencing batch treatment tank are both started at the same time as or immediately after the stirring of the wastewater in the sequencing batch biological treatment tank is stopped.

5

3. The wastewater treatment method according to claim 1 or 2, wherein the wastewater treatment method further comprises:

a continuous biological treatment process to biologically treat the wastewater that is continuously supplied to a continuous biological treatment tank containing biological  
10 sludge;

a biological sludge supply process to supply granules formed in the sequencing batch biological treatment process to the continuous biological treatment tank;

a treated water supply process to supply the treated water discharged in the sequencing batch biological treatment process to the continuous biological treatment tank;

15 and

a wastewater supply amount adjustment process to reduce an amount of the wastewater supplied to the continuous biological treatment tank in response to the supply of the granules in the biological sludge supply process and the supply of the treated water in the treated water supply process.

20

4. The wastewater treatment method according to claim 3, wherein, in the wastewater supply amount adjustment process, the amount of the wastewater supplied to the continuous biological treatment tank is reduced to zero in response to the supply of the granules in the biological sludge supply process and the supply of the treated water in the  
25 treated water supply process.

5. The wastewater treatment method according to any one of claims 1 to 4, wherein the sequencing batch biological treatment tank comprises:

a wastewater inlet for supplying the wastewater to the tank; and

a treated water outlet for discharging the treated water from the tank or a sludge  
and treated water outlet for discharging the treated water and the granules from the tank,  
the treated water outlet and the sludge and treated water outlet being disposed higher than  
5 the wastewater inlet.

6. A wastewater treatment device comprising:

a sequencing batch biological treatment tank that contains biological sludge;

a supply unit that supplies wastewater to the sequencing batch biological  
10 treatment tank;

a discharge unit that discharges treated water from the sequencing batch biological  
treatment tank;

a stirring unit that stirs the wastewater in the sequencing batch biological  
treatment tank;

15 a first controller that controls activation of the stirring unit; and

a second controller that controls activation of the supply unit and the discharge  
unit,

wherein, when biologically treating the wastewater with the biological sludge, the  
first controller activates the stirring unit to stir the wastewater in the sequencing batch  
20 biological treatment tank under conditions where the supply of the wastewater to the  
sequencing batch biological treatment tank and the discharge of the treated water from the  
sequencing batch biological treatment tank are both stopped; and

the second controller activates

(a) the supply unit and the discharge unit to start the supply of the wastewater  
25 to the sequencing batch biological treatment tank and the discharge of the  
treated water from the sequencing batch biological treatment tank at the  
same time, or

(b) the supply unit to start the supply of the wastewater to the sequencing

batch biological treatment tank, and the discharge unit to start the discharge of the treated water from the sequencing batch biological treatment tank in a period after the supply of the wastewater is started and before the supply of the wastewater is stopped,

5            wherein (a) or (b) takes place in a period after the stirring of the wastewater by the stirring unit has been stopped and before a sludge blanket of the biological sludge is formed in the sequencing batch biological treatment tank.

7. The wastewater treatment device according to claim 6, wherein the second controller  
10           activates the supply unit to start the supply of the wastewater to the sequencing batch biological treatment tank and the discharge unit to start the discharge of the treated water from the sequencing batch biological treatment tank at the same time as or immediately after the stirring of the wastewater by the stirring unit is stopped.

15           8. The wastewater treatment device according to claim 6 or 7, wherein the second controller controls the supply unit and the discharge unit such that an amount of the wastewater supplied to the sequencing batch biological treatment tank and an amount of the treated water discharged from the sequencing batch biological treatment tank are equal to each other.

20           9. The wastewater treatment device according to any one of claims 6 to 8, wherein  
                 the sequencing batch biological treatment tank comprises a wastewater inlet for supplying the wastewater to the tank and a treated water outlet for discharging the treated water from the tank; and

25           the wastewater inlet is disposed lower than the treated water outlet.

10. The wastewater treatment device according to claim 9, wherein the treated water outlet is disposed at a water surface level of the wastewater in the sequencing batch biological

treatment tank when the discharge of the treated water is stopped.

11. The wastewater treatment device according to any one of claims 6 to 10,

wherein the wastewater treatment device further comprises:

5                   a continuous biological treatment device that biologically treats continuously supplied wastewater;

                  a biological sludge supply unit that supplies granules formed in the sequencing batch biological treatment tank to the continuous biological treatment device;

                  a treated water supply unit that supplies the treated water discharged from  
10 the sequencing batch biological treatment tank to the continuous biological treatment device; and

                  a wastewater supply amount adjustment unit that adjusts an amount of the wastewater supplied to the continuous biological treatment device, and

                  the wastewater supply amount adjustment unit reduces an amount of the  
15 wastewater supplied to the continuous biological treatment device in response to the supply of the granules by the biological sludge supply unit and the supply of the treated water by the treated water supply unit.

12. The wastewater treatment device according to claim 11, wherein the wastewater supply  
20 amount adjustment unit reduces the amount of the wastewater supplied to the continuous biological treatment device to zero in response to the supply of the granules by the biological sludge supply unit and the supply of the treated water by the treated water supply unit.

25 13. The wastewater treatment device according to any one of claims 6 to 8, wherein the sequencing batch biological treatment tank comprises:

                  a wastewater inlet for supplying the wastewater to the tank; and

                  a treated water outlet for discharging the treated water from the tank or a sludge

and treated water outlet for discharging the treated water and the granules from the tank, the treated water outlet and the sludge and treated water outlet being disposed higher than the wastewater inlet.