

BIOLOGICAL TREATMENT METHOD AND APPARATUS FOR ORGANIC
WASTEWATER

Field of Invention

[0001]

The present invention relates to a biological treatment method and an apparatus for organic wastewater that can be utilized to treat domestic wastewater, sewage, and various concentrations of organic wastewater from food-processing plants, pulp mills, and other factories and more particularly to a biological treatment method and an apparatus for organic wastewater that can improve treatment efficiency and reduce the amount of excess sludge without deteriorating treated water quality.

Background of Invention

[0002]

Activated sludge processes for use in biological treatment of organic wastewater have been widely used in sewage treatment and industrial wastewater treatment because of their advantages including high treated water quality and ease of maintenance. The activated sludge processes require a large ground area since BOD volume loads of the activated sludge processes are generally approximately 0.5 to 0.8 kg/m³/d. Furthermore, a large amount of excess sludge is produced, since 20% to 40% of decomposed BOD is converted to

bacteria or sludge.

[0003]

One known high-load treatment method of treating organic wastewater is a fluidized bed process containing a carrier. This process can operate at a BOD volume load of 3 kg/m³/d or more. However, the amount of sludge produced in this process is approximately 30% to 50% of decomposed BOD, which is greater than the amount of sludge produced in common activated sludge processes.

[0004]

In accordance with Japanese Patent Publication S55-20649A, organic wastewater is treated with bacteria in a first treatment tank to convert an organic substance contained in wastewater by oxidative decomposition to nonagglutinating bacteria, and the nonagglutinating bacteria are predated by a sessile protozoa in a second treatment tank to reduce excess sludge. This process can operate at a high load and improve treatment efficiency of an activated sludge process.

[0005]

There are many proposed wastewater treatment methods that utilize predation by Protozoa or Metazoa, which is a group higher than bacteria.

[0006]

For example, Japanese Patent Publication 2000-210692A

proposes a measure against poor treatment performance resulting from variations in raw water quality. The poor treatment performance causes a problem in a treatment method described in Japanese Patent Publication S55-20649A.

Specific proposed methods include a method of "controlling BOD variations of water to be treated within 50% or less from the median of the average concentration", a method of "monitoring water quality in a first treatment tank and first treated water over time", and a method of "adding seed sludge or a microbial agent to the first treatment tank in the case of a decline in water quality of the first treated water".

[0007]

Japanese Patent Publication S60-23832B proposes a method of making a size of prey flocks size smaller than a size of a mouth of a predator by ultrasonication or mechanical agitation in the predation of bacteria, yeast, actinomycetes, algae, molds, or primary or excess sludge of wastewater treatment by a protozoan or metazoan.

[0008]

Japanese Patent Publications 2006-51414A, 2006-51415A, 2006-247494A, 2008-36580A, and 2009-202115A describe a multistage activated sludge process also utilizing predation by animalcules.

[0009]

Such a multistage activated sludge process utilizing predation by animalcules is practically used for organic wastewater treatment and can improve treatment efficiency and reduce sludge production by approximately 50% for some wastewater.

[0010]

Japanese Patent 3410699 describes a method that relates to multistage treatment including a fluidized bed and an activated sludge process. In accordance with this method, the activated sludge process at the second stage can be operated at a low BOD sludge load of 0.1 kg-BOD/kg-MLSS/d to cause autoxidation of sludge and thereby significantly decrease the amount of sludge withdrawal.

List of Patent Literatures

[0011]

Patent Literature 1: Japanese Patent Publication S55-20649A

Patent Literature 2: Japanese Patent Publication 2000-210692A

Patent Literature 3: Japanese Patent Publication S60-23832B

Patent Literature 4: Japanese Patent 3410699

Patent Literature 5: Japanese Patent Publication 2006-51414A

Patent Literature 6: Japanese Patent Publication 2006-

51415A

Patent Literature 7: Japanese Patent Publication 2006-
247494A

Patent Literature 8: Japanese Patent Publication 2008-
36580A

Patent Literature 9: Japanese Patent Publication 2009-
202115A

Objectand Summary of Invention

[0012]

In biological treatment, a tank load can be increased to decrease the size of a biological treatment tank. In a multistage activated sludge process utilizing predation by animalcules, however, high-load treatment results in deterioration in treated water quality. More specifically, organic substances contained in wastewater are converted to dispersed bacteria in a biological treatment tank in the first stage, and animalcules predate the dispersed bacteria in a biological treatment tank at the subsequent stage. When an amount of animalcules is small compared to an amount of dispersed bacteria, part of bacteria are not predated, and residual bacteria are sometimes not precipitated in a settling tank and flow out into treated water.

[0013]

Animalcules that contribute to a decrease in the amount of sludge include filter-type predators and aggregate

predators. Since animalcules of the aggregate predators can gnaw sludge flocks in predation, dominance of the animalcules of the aggregate predators results in deterioration in treated water quality. Thus, in order to improve treated water quality, it is effective to make dominant animalcules of the filter-type predators. However, there is no proposed method of controlling the growth of animalcules of the filter-type and the growth of animalcules of the aggregate predators. In particular, when the amount of sludge is decreased by using animalcules in high-load wastewater treatment, unexpected deterioration in treated water quality occurs under some operating conditions.

[0014]

It is an object of the present invention to dissolve problems described above and provide a biological treatment method and apparatus for organic wastewater using a multistage activated sludge process utilizing predation by animalcules. The biological treatment method and apparatus make dominant actively animalcules of the filter-type predators and reduce the growth of animalcules of the aggregate predators that deteriorate treated water quality in high-load treatment at a COD_{Cr} volume load of $1.0 \text{ kg/m}^3/\text{d}$ or more or a BOD volume load of $0.5 \text{ kg/m}^3/\text{d}$ or more, thereby improving treatment efficiency, decreasing the sludge volume, and improving treated water quality.

[0015]

As a result of extensive studies to dissolve problems described above, the present inventors found that stable high-load treatment by a multistage activated sludge process utilizing predation by animalcules can be achieved by providing a transient organic substance treatment tank in a biological treatment tank in the first stage to produce dispersed bacteria, actively makes dominant necessary animalcules in a biological treatment tank at the subsequent stage, withdrawing sludge at a retention time of not less than the growth rate of the animalcules of the aggregate (flock) predators in the biological treatment tank in the subsequent stage to reduce the growth of the animalcules of the aggregate predators that deteriorate treated water quality, and providing the biological treatment tank with a carrier for supporting animalcules to allow efficient predation of the dispersed bacteria and support sessile animalcules of the filter-type predators that contribute to improved solid-liquid separation of sludge and treated water quality.

[0016]

The present invention is based on such findings.

[0017]

The present invention provides a biological treatment method of treating organic wastewater under aerobic

conditions, in which an entire load of all biological treatment tanks has a COD_{Cr} volume load of $1.0 \text{ kg/m}^3/\text{d}$ or more or a BOD volume load of $0.5 \text{ kg/m}^3/\text{d}$ or more, wherein aerobic biological treatment tanks at multiple stages of two stages or more are provided; the organic wastewater is fed to a first biological treatment tank and treated biologically by bacteria therein; first biologically treated water containing dispersed bacteria is transferred from the first biological treatment tank to a subsequent biological treatment tank including a second biological treatment tank and treated biologically by bacteria therein; treated water from the subsequent biological treatment tank including the second biological treatment tank is subjected to solid-liquid separation in a settling tank; and part of separated sludge is returned to the subsequent biological treatment tank including the second biological treatment tank, and wherein the subsequent biological treatment tank including the second biological treatment tank contains a carrier for supporting animalcules.

[0018]

The present invention provides a biological treatment apparatus for treating organic wastewater under aerobic conditions, in which an entire load of biological treatment tanks has a COD_{Cr} volume load of $1.0 \text{ kg/m}^3/\text{d}$ or more or a BOD volume load of $0.5 \text{ kg/m}^3/\text{d}$ or more, wherein aerobic

biological treatment tanks at multiple stages of two stages or more are provided; the organic wastewater is fed to a first biological treatment tank and treated biologically by bacteria therein; first biologically treated water containing dispersed bacteria is transferred from the first biological treatment tank to a subsequent biological treatment tank including a second biological treatment tank and treated biologically by bacteria therein; treated water from the subsequent biological treatment tank including the second biological treatment tank is subjected to solid-liquid separation in a settling tank; and part of separated sludge is returned to the subsequent biological treatment tank including the second biological treatment tank, and wherein the subsequent biological treatment tank including the second biological treatment tank contains a carrier for supporting animalcules.

[0019]

The soluble BOD sludge load in the subsequent biological treatment tank including the second biological treatment tank is preferably in the range of 0.025 to 0.050 kg/kg-MLSS/d.

[0020]

At least part of the carrier in the subsequent biological treatment tank including the second biological treatment tank is preferably fixed to the biological

treatment tank directly or with a fastening device.

[0021]

Part of the organic wastewater may be introduced into the subsequent biological treatment tank including the second biological treatment tank without through the first biological treatment tank.

[0022]

Sludge retention time (SRT) in the subsequent biological treatment tank including the second biological treatment tank is preferably 50 days or less, particularly preferably in the range of 10 to 50 days.

Advantageous Effects of Invention

[0023]

The present invention employs a multistage activated sludge process utilizing predation by animalcules. The biological treatment tank containing animalcules is provided with a carrier for supporting the animalcules. Sludge is withdrawn at a retention time of not less than the growth rate of animalcules of the aggregate predators in order to reduce the growth of the animalcules of the aggregate predators that deteriorate treated water quality. As a result thereof, sessile animalcules of the filter-type predators that can efficiently predate dispersed bacteria and contribute to improved solid-liquid separation of sludge, whereby treated water quality can be stably held in the

biological treatment tank even in high-load treatment at a COD_{Cr} volume load of $1.0 \text{ kg/m}^3/\text{d}$ or more or a BOD volume load of $0.5 \text{ kg/m}^3/\text{d}$ or more.

[0024]

Thus, the present invention allows efficient biological treatment of organic wastewater and has the following advantages.

1) A significant decrease in the amount of sludge produced in wastewater treatment.

2) Improved treatment efficiency due to high-load operation.

3) Consistent treated water quality.

Brief Description of Drawings

[0025]

Fig. 1 is a system diagram of a biological treatment method and apparatus for organic wastewater according to an embodiment of the present invention.

Fig. 2 is a system diagram of a biological treatment method and apparatus for organic wastewater according to another embodiment of the present invention.

Description of Embodiments

[0026]

A biological treatment method and apparatus for organic wastewater according to an embodiment of the present invention will be described in detail below with reference

to the accompanying drawings.

[0027]

Figs. 1 and 2 are system diagrams of a biological treatment method and apparatus for organic wastewater according to an embodiment of the present invention.

In Figs. 1 and 2, 1 denotes a first biological treatment tank, 2 denotes a second biological treatment tank, 3 denotes a settling tank, 11 and 21 denote aeration tubes, and 22 denotes a carrier for supporting animalcules. Each same reference numeral designate the same member in Figs. 1 and 2.

[0028]

In the embodiment described in Fig. 1, raw water (organic wastewater) is introduced into the first biological treatment tank 1, in which 70% or more, desirably 80% or more, more desirably 85% or more of an organic component (soluble BOD) is oxidatively decomposed by dispersive bacteria (nonagglutinating bacteria). The pH of the first biological treatment tank 1 is 6 or more, preferably 8 or less. The pH of the first biological treatment tank 1 may be 8 or more for raw water having a high oil content, such as food manufacturing wastewater, or raw water containing a large amount of organic solvent or detergent, such as semiconductor manufacturing wastewater or liquid crystal manufacturing wastewater.

[0029]

Water flow through the first biological treatment tank 1 is preferably transient. When the first biological treatment tank 1 has a BOD volume load of $1 \text{ kg/m}^3/\text{d}$ or more, for example, 1 to $20 \text{ kg/m}^3/\text{d}$, and a hydraulic retention time (HRT) of 24 h or less, preferably 8 h or less, for example, 0.5 to 8 h, treated water contains dispersive bacteria as dominant bacteria. Furthermore, a decrease in HRT allows wastewater having a low BOD concentration to be treated at a high load.

[0030]

High-load treatment at a BOD volume load of $5 \text{ kg/m}^3/\text{d}$ or more in the first biological treatment tank 1 can be performed by returning part of sludge from the biological treatment tank at the second stage to the first biological treatment tank 1, constituting the first biological treatment tank 1 having a multistage structure composed of two or more tanks, or adding a carrier to the first biological treatment tank 1.

[0031]

In the case that a carrier is added to the first biological treatment tank 1, the carrier may have any shape, such as a sphere, pellet, hollow tube, thread, or sheet, and a diameter in the range of approximately 0.1 to 10 mm. The material of the carrier may be any material including a

natural material, inorganic material, or polymer material. The material may be a gel substance. A high packing rate of the first biological treatment tank 1 with the carrier results in the production of no dispersed bacteria and the deposition of bacteria on the carrier or the growth of filamentous bacteria. When the packing rate of the first biological treatment tank 1 with the carrier is 10% or less, desirably 5% or less, dispersed bacteria that are ready for predation can be produced independently of concentration variations.

[0032]

The dissolved oxygen (DO) concentration in the first biological treatment tank 1 may be controlled to 1 mg/L or less, preferably 0.5 mg/L or less, to suppress the growth of filamentous bacteria.

[0033]

Complete decomposition of soluble organic substances in the first biological treatment tank 1 results in the formation of no flock, a deficiency of nutrition for the growth of animalcules, and dominant formation of low-density sludge in the second biological treatment tank 2. Thus, the decomposition rate of an organic component in the first biological treatment tank 1 is not 100%, but is preferably 95% or less, more preferably in the range of 85% to 90%.

[0034]

Treated water (first biologically treated water) in the first biological treatment tank 1 is transferred to the second biological treatment tank 2 at the second stage to perform oxidative decomposition of residual organic components, autolysis of dispersive bacteria, and reduction of the amount of excess sludge due to predation by animalcules.

[0035]

In the second biological treatment tank 2, in order to utilize the function of the animalcules that has a lower growth rate than the bacteria and the autolysis of the bacteria, the operating conditions and treatment apparatus should be such that the animalcules and the bacteria remain in the system. Thus, it is desirable to employ an activated sludge process involving sludge return in the second biological treatment tank 2. The second biological treatment tank 2 may have a multistage structure composed of two or more tanks.

[0036]

In the present invention, the second biological treatment tank 2 contains a carrier 22 for supporting animalcules. When the soluble BOD sludge load is in the range of 0.025 to 0.050 kg/kg-MLSS/d, this increases the amount of animalcules, particularly sessile animalcules of the filter-type predators, retained in the tank that

efficiently predate dispersed bacteria and contribute to improved solid-liquid separation of sludge and treated water quality.

[0037]

Namely, not only animalcules of the filter-type predators that predate dispersed bacteria but also animalcules of the aggregate predators that predate sludge flocks grow in the second biological treatment tank 2. Since the animalcules of the aggregate predators can predate flocks while swimming, when they become dominant, a lot of sludge is eaten greedily, and fine half-eaten flocks are dispersed in the tank. These fine flocks deteriorate treated water quality. Thus, in the present invention, the soluble BOD sludge load in the second biological treatment tank 2 is in the range of 0.025 to 0.050 kg/kg-MLSS/d. In order to replace tank sludge at regular intervals, that is, in order to thin out animalcules and excrement, the sludge retention time (SRT) in the second biological treatment tank 2 is desirably set constant at 50 days or less, particularly 45 days or less, more particularly 40 days or less, and desirably 10 days or more, particularly 20 days or more.

$$\text{SRT} = (\text{suspended sludge concentration of tank} \cdot \text{aeration tank volume}) / (\text{withdrawn sludge concentration} \cdot \text{amount of withdrawal per day}).$$

[0038]

In addition, in order to retain animalcules of the filter-type predators that predate dispersed bacteria in the second biological treatment tank 2, the second biological treatment tank 2 contains the carrier 22 for supporting the animalcules. While the animalcules of this type are adhered to sludge flocks and are retained in the system, sludge is withdrawn to the outside of the system in a certain retention time. Thus, the system must include a supply source of the animalcules. When the carrier is granular or angular and forms a fluidized bed, the carrier can not be stably held at a high concentration because of shear force due to fluidization. The carrier filling rate must be increased accordingly.

[0039]

Thus, in the present invention, the carrier in the second biological treatment tank 2 is preferably not a fluidizing carrier but a fixed carrier, at least part of which is fixed directly or with a fastening device to a bottom, a side surface, or an upper portion of the second biological treatment tank 2. The carrier 22 may have any shape including a thread, sheet, or strip. The material of the carrier 22 may be any material including a natural material, inorganic material, polymer material, and a gel substance. It is preferable that the material of the carrier 22 is synthetic resin foam, such as porous

polyurethane foam. The carrier is preferably a sheet or strip having a thickness in the range of 0.5 to 5 cm. The length of a first side of the sheet or strip is preferably in the range of 100 to 400 cm, and the length of a second side of the sheet or strip perpendicular to the first side is preferably in the range of 5 to 200 cm. In the embodiment illustrated in Fig. 1, the left and right ends of a sheet-like fixed carrier are fixed to two rod-like fastening devices 23, which are vertical and fixed to the bottom of the second biological treatment tank 2 with a certain distance between the fastening devices 23.

[0040]

The second biological treatment tank 2 requires a large number of scaffolds to hold animalcules. An excessively high carrier packing rate, however, results in insufficient agitation in the tank or putrefaction of the sludge. Thus, the carrier packing rate is preferably in the range of approximately 0.1% to 20%.

[0041]

In the present invention, when a large amount of organic substances remain in the first biologically treated water which is transferred to the second biological treatment tank 2, they are oxidatively decomposed in treatment tanks at the subsequent stages. When organic substances are oxidatively decomposed with bacteria in the

second biological treatment tank 2 containing a large amount of animalcules, it is known that the bacteria grow in such a form that the bacteria are difficult to be predated in order to escape from predation by the animalcules. The resulting bacteria escaped from the predation by the animalcules are decomposed only by autodigestion. This reduces the effect of decreasing sludge production. Thus, as described above, most of the organic substances, specifically 70% or more, desirably 80% or more of BOD in the raw water should be decomposed and converted to bacteria in the first biological treatment tank. A tank sludge load in the biological treatment tank at the subsequent stage is preferably in the range of 0.025 to 0.050 kg/kg-MLSS/d in terms of soluble BOD. When the soluble BOD sludge load with respect to a tank sludge is more than 0.050 kg/kg-MLSS/d, this reduces the effect of decreasing the amount of sludge. When the soluble BOD sludge load is less than 0.025 kg/kg-MLSS/d, sludge is sometimes not settled in a settling tank. The tank sludge is the total of suspended sludge and sludge adhering to the carrier.

[0042]

In Fig. 1, treated water from the second biological treatment tank 2 is subjected to solid-liquid separation in the settling tank 3. Separated water flows out as treated water. Part of separated sludge is returned to the second

biological treatment tank 2 or the upstream thereof, and the remainder is eliminated as excess sludge from the system.
[0043]

The embodiment illustrated in Fig. 2 is the same as the embodiment illustrated in Fig. 1 except that part, for example, 5% to 50%, particularly approximately 5% to 20%, of raw water is directly introduced into the second biological treatment tank 2 without passing through the first biological treatment tank 1. Direct introduction of part of raw water into the second biological treatment tank 2 can effectively avoid load deficiency in the second biological treatment tank caused by raw water variations (a decrease in load).
[0044]

Figs. 1 and 2 illustrate an embodiment of the present invention, and the present invention is not limited to these embodiments. For example, the first biological treatment tank and the second biological treatment tank may have a multistage structure composed of two or more tanks, and a biological treatment tank in the present invention may be of three or more stages.
[0045]

In accordance with any embodiment of the present invention, in high-load treatment in which the entire biological treatment tank load is a COD_{Cr} volume load of 1.0

kg/m³/d or more or a BOD volume load of 0.5 kg/m³/d or more, the subsequent biological treatment tank including the second biological treatment tank contain a carrier for supporting animalcules, and the soluble BOD sludge load is in the range of 0.025 to 0.050 kg/kg-MLSS/d. This can suppress dominance of animalcules of the aggregate predators, can realize both a decreased amount of sludge and improved treated water quality, and allows stable high-load treatment.

EXAMPLES

[0046]

The present invention will be more specifically described in the following examples and comparative examples.

[0047]

[EXAMPLE 1]

An experimental apparatus illustrated in Fig. 1 and including a first biological treatment tank 1 with 36 liters volume, a second biological treatment tank 2 with 150 liters volume, and a settling tank 3 with 50 liters volume was used to treat organic wastewater according to the present invention. The raw water contained a synthesized substrate at a COD_{Cr} of 2000 mg/L and a BOD of 1280 mg/L.

The following are treatment conditions for each biological treatment tank.

[0048]

<First Biological Treatment Tank>

DO: 0.5 mg/L

BOD volume load: 7.7 kg-BOD/m³/d

HRT: 4 h

pH: 7.0

<Second Biological Treatment Tank>

DO: 4 mg/L

Carrier packing rate: 2%

HRT: 17 h

SRT: 25 days

pH: 7.0

[0049]

The carrier 22 of the second biological treatment tank 2 was polyurethane foam sheets (100 cm x 30 cm x 1 cm/sheet). The carriers 12 were fixed at their bottom, left and right side walls of the tank at a position opposite the aeration tube 21 with respect to the central vertical surface of the tank.

The BOD volume load of the entire apparatus was 1.5 kg-BOD/m³/d. The HRT of the entire apparatus was 21 h. The soluble BOD sludge load in the second biological treatment tank 2 was 0.046 kg/kg-MLSS/d.

[0050]

As a result, sessile animalcules of the filter-type predators (Vorticella, Bdelloidea) became dominant on sludge flocks and the carriers in the second biological treatment

tank 2. The sludge conversion ratio was 0.10 kg-MLSS/kg-COD_{Cr}.

Treated water (separated water from the settling tank 3) had quality in which the soluble COD_{Cr} concentration was less than 50 mg/L, and SS was less than 20 mg/L. Thus, the quality of treated water was satisfactory throughout the test period.

[0051]

[COMPARATIVE EXAMPLE 1]

Treatment was performed under the same conditions as Example 1 except that the second biological treatment tank contained no carrier.

The raw water quality, the treatment conditions for the first and second biological treatment tanks, and the entire BOD volume load and HRT were the same as in Example 1.

As a result, the sludge conversion ratio was 0.10 kg-MLSS/kg-COD_{Cr}. Because of a dominant amount of animalcules of the aggregate predators, however, the treated water had inferior quality in which the soluble COD_{Cr} was 80 mg/L or more, and SS was 50 mg/L or more throughout the test period.

[0052]

[EXAMPLE 2]

Treatment was performed under the same conditions as Example 1 except that the raw water contained a synthesized substrate at a COD_{Cr} of 670 mg/L and a BOD of 430 mg/L, the

BOD volume load in the first biological treatment tank was 2.6 kg-BOD/m³/d, the entire BOD volume load was 0.5 kg-BOD/m³/d (0.78 kg-COD_{Cr}/m³/d), the HRT was 21 h, and the soluble BOD sludge load in the second biological treatment tank was 0.025 kg/kg-MLSS/d.

As a result, sessile animalcules of the filter-type predators (Vorticella, Bdelloidea) became dominant on sludge flocks and the carrier in the second biological treatment tank. The sludge conversion ratio was 0.08 kg-MLSS/kg-COD_{Cr}. Treated water had quality of the soluble COD_{Cr} concentration less than 30 mg/L, and SS less than 10 mg/L. Thus, the treated water quality was satisfactory throughout the test period.

[0053]

[COMPARATIVE EXAMPLE 2]

Treatment was performed under the same conditions as Example 2 except that the second biological treatment tank contained no carrier.

The raw water quality, the treatment conditions for the first and second biological treatment tanks, and the entire BOD volume load and HRT were the same as in Example 2.

As a result, the sludge conversion ratio was 0.08 kg-MLSS/kg-COD_{Cr}. However, since animalcules of the aggregate predators became dominant at regular intervals, the treated water quality became inferior to Example 2. The soluble

COD_{Cr} of treated water was 50 mg/L or more, and treated water SS was 30 mg/L or more, throughout more than half of the test period.

[0054]

[EXAMPLE 3]

Treatment was performed under the same conditions as Example 1 except that the raw water contained an artificial substrate at a COD_{Cr} of 6700 mg/L and a BOD of 4350 mg/L, the BOD volume load in the first biological treatment tank was 17.5 kg-BOD/m³/d, the entire BOD volume load was 5 kg-BOD/m³/d, the HRT in the first biological treatment tank was 6 h, the HRT in the second biological treatment tank was 15 h, the carrier filling rate of the second biological treatment tank was 5%, the SRT was 50 days, and the soluble BOD sludge load in the second biological treatment tank was 0.05 kg/kg-MLSS/d.

As a result, sessile animalcules of the filter-type predators (Vorticella, Bdelloidea) became dominant on sludge flocks and the carrier in the second biological treatment tank. The sludge conversion ratio was 0.09 kg-MLSS/kg-COD_{Cr}. Treated water had quality of the soluble COD_{Cr} concentration less than 60 mg/L, and SS less than 30 mg/L. Thus, the treated water quality was almost satisfactory throughout the test period.

[0055]

Example 3 shows that the wastewater was well treated even at a high volume load.

[0056]

[COMPARATIVE EXAMPLE 3]

Treatment was performed under the same conditions as Example 1 except that the second biological treatment tank contained no carrier, the raw water contained a synthesized substrate at a COD_{Cr} of 550 mg/L and a BOD of 350 mg/L, the BOD volume load in the first biological treatment tank was 2.1 kg-BOD/m³/d, the entire BOD volume load was 0.4 kg-BOD/m³/d, and the soluble BOD sludge load in the second biological treatment tank was 0.025 kg/kg-MLSS/d.

As a result, sessile animalcules of the filter-type predators (Vorticella, Bdelloidea) became dominant on sludge flocks and the carrier in the second biological treatment tank. The sludge conversion ratio was 0.08 kg-MLSS/kg- COD_{Cr} . Treated water had quality of the soluble COD_{Cr} concentration less than 30 mg/L, and SS less than 10 mg/L. Thus, the treated water quality was satisfactory throughout the test period.

[0057]

Comparative Example 3 shows that when the entire BOD volume load was low, the treated water quality was satisfactory even in the absence of the carrier.

[0058]

[EXAMPLE 4]

Treatment was performed using the raw water described in Example 1 under the same conditions as Example 1 except that the HRT in the first biological treatment tank was 5.7 h, the HRT in the second biological treatment tank was 17 h, the BOD volume load in the first biological treatment tank was 5.4 kg-BOD/m³/d, the entire BOD volume load was 1.5 kg-BOD/m³/d, and the soluble BOD sludge load in the second biological treatment tank was 0.06 kg/kg-MLSS/d while 30% of the raw water was bypassed.

As a result, sessile animalcules of the filter-type predators (Vorticella, Bdelloidea) became dominant on sludge flocks and the carrier in the second biological treatment tank. The sludge conversion ratio was 0.11 kg-MLSS/kg-COD_{Cr}. Treated water had quality of the soluble COD_{Cr} concentration less than 60 mg/L, and SS less than 30 mg/L. Thus, the treated water quality was almost satisfactory throughout the test period.

[0059]

Example 4 shows that the treated water quality was satisfactory even at a high sludge load.

[0060]

[EXAMPLE 5]

Treatment was performed under the same conditions as Example 1 except that the carrier in the second biological

treatment tank was a fluidized bed sponge carrier (the carrier packing rate was 2%), the SRT in the second biological treatment tank was 30 days, and the soluble BOD sludge load in the second biological treatment tank was 0.04 kg/kg-MLSS/d.

As a result, sessile animalcules of the filter-type predators (Vorticella, Bdelloidea) became dominant on sludge flocks and the carrier in the second biological treatment tank. The sludge conversion ratio was 0.11 kg-MLSS/kg-COD_{Cr}. Treated water had quality of the soluble COD_{Cr} concentration less than 50 mg/L, and SS less than 30 mg/L. Thus, the treated water quality was almost satisfactory throughout the test period.

[0061]

Example 5 shows that although the wastewater was treated almost satisfactorily, the amount of animalcules fixed on the carrier was small.

[0062]

[EXAMPLE 6]

Treatment was performed under the same conditions as in Example 2 except that 10% of raw water was directly supplied to the second biological treatment tank, and the SRT in the second biological treatment tank was 45 days.

As a result, sessile animalcules of the filter-type predators (Vorticella, Bdelloidea) became dominant on sludge

flocks and the carrier in the second biological treatment tank. The sludge conversion ratio was 0.07 kg-MLSS/kg-COD_{Cr}. Treated water had quality of the soluble COD_{Cr} concentration less than 30 mg/L, and SS less than 10 mg/L. Thus, the treated water quality was satisfactory throughout the test period.

[0063]

Example 6 shows that even when part of the raw water was bypassed, the treated water had water quality equal to or better than the water quality in the case that the raw water was not bypassed.

[0064]

[EXAMPLE 7]

Treatment was performed using the raw water described in Example 1 under the same conditions as Example 1 except that the HRT in the first biological treatment tank was 4 h, the HRT in the second biological treatment tank was 17 h, the SRT in the second biological treatment tank was 60 days, and the soluble BOD sludge load in the second biological treatment tank was 0.03 kg/kg-MLSS/d.

As a result, sessile animalcules of the filter-type predators (Vorticella, Bdelloidea) became dominant on sludge flocks and the carrier in the second biological treatment tank. The sludge conversion ratio was 0.08 kg-MLSS/kg-COD_{Cr}. Treated water had quality of the soluble COD_{Cr} concentration

less than 70 mg/L, and SS less than 50 mg/L. Thus, the treated water quality was substantially satisfactory throughout the test period. However, the amount of animalcules fixed on the carrier was smaller than that in Example 1.

[0065]

Although the present invention has been described in detail with reference to particular embodiments, it is apparent to a person skilled in the art that various modifications can be made therein without departing from the spirit and scope of the present invention.

The present application is based on Japanese Patent Application 2011-058035 filed on March 16, 2011 and Japanese Patent Application 2012-001290 filed on January 6, 2012, which are incorporated herein by reference in their entirety.

CLAIMS

1 A biological treatment method of treating organic wastewater under aerobic conditions, in which an entire load of all biological treatment tanks has a COD_{Cr} volume load of 1.0 kg/m³/d or more or a BOD volume load of 0.5 kg/m³/d or more,

wherein aerobic biological treatment tanks at multiple stages of two stages or more are provided; the organic wastewater is fed to a first biological treatment tank and treated biologically by bacteria therein; first biologically treated water containing dispersed bacteria is transferred from the first biological treatment tank to a subsequent biological treatment tank including a second biological treatment tank and treated biologically by bacteria therein; treated water from the subsequent biological treatment tank including the second biological treatment tank is subjected to solid-liquid separation in a settling tank; and part of separated sludge is returned to the subsequent biological treatment tank including the second biological treatment tank, and

wherein the subsequent biological treatment tank including the second biological treatment tank contains a carrier for supporting animalcules, wherein the carrier packing rate is in the range of 0.1% to 20%,

wherein at least part of the carrier in the subsequent biological treatment tank including the second biological treatment tank is fixed to the biological treatment tank

directly or with a fastening device,

wherein the carrier in the subsequent biological treatment tank is a sheet or strip having a thickness in a range between 0.5 and 5 cm, a length of a first side in a range between 100 and 400 cm, and a length of a second side perpendicular to the first side in a range between 5 and 200 cm, and that the carrier is vertical and fixed to the biological treatment tank with the fastening device, and

wherein the soluble BOD sludge load in the subsequent biological treatment tank including the second biological treatment tank is in the range of 0.025 to 0.050 kg/kg-MLSS/d.

2 The biological treatment method of treating organic wastewater according to Claim 1, wherein part of the organic wastewater is introduced into the subsequent biological treatment tank including the second biological treatment tank without flowing through the first biological treatment tank.

3 The biological treatment method of treating organic wastewater according to Claim 1, wherein sludge retention time (SRT) in the subsequent biological treatment tank including the second biological treatment tank is 50 days or less.

4 The biological treatment method of treating organic wastewater according to Claim 1, wherein the sludge retention time (SRT) in the subsequent biological treatment tank

including the second biological treatment tank is in the range of 10 to 50 days.

5 A biological treatment apparatus for treating organic wastewater under aerobic conditions, in which an entire load of biological treatment tanks has a COD_{Cr} volume load of 1.0 $kg/m^3/d$ or more or a BOD volume load of 0.5 $kg/m^3/d$ or more,

wherein aerobic biological treatment tanks at multiple stages of two stages or more are provided; the organic wastewater is fed to a first biological treatment tank and treated biologically by bacteria therein; first biologically treated water containing dispersed bacteria is transferred from the first biological treatment tank to a subsequent biological treatment tank including a second biological treatment tank and treated biologically by bacteria therein; treated water from the subsequent biological treatment tank including the second biological treatment tank is subjected to solid-liquid separation in a settling tank; and part of separated sludge is returned to the subsequent biological treatment tank including the second biological treatment tank, and

wherein the subsequent biological treatment tank including the second biological treatment tank contains a carrier for supporting animalcules, wherein the carrier packing rate is in the range of 0.1% to 20%,

wherein at least part of the carrier in the subsequent biological treatment tank including the second biological treatment tank is fixed to the biological treatment tank

directly or with a fastening device,

wherein the carrier in the subsequent biological treatment tank is a sheet or strip having a thickness in a range between 0.5 and 5 cm, a length of a first side in a range between 100 and 400 cm, and a length of a second side perpendicular to the first side in a range between 5 and 200 cm, and that the carrier is vertical and fixed to the biological treatment tank with the fastening device, and

wherein the soluble BOD sludge load in the subsequent biological treatment tank including the second biological treatment tank is in the range of 0.025 to 0.050 kg/kg-MLSS/d.

6 The biological treatment apparatus for treating organic wastewater according to Claim 5, wherein the apparatus further comprises means for introducing part of the organic wastewater into the subsequent biological treatment tank including the second biological treatment tank without flowing through the first biological treatment tank.

7 The biological treatment apparatus for treating organic wastewater according to Claim 5, wherein the sludge retention time (SRT) in the subsequent biological treatment tank including the second biological treatment tank is 50 days or less.

8 The biological treatment method of treating organic wastewater according to Claim 1, wherein the first biological

treatment tank1 has a hydraulic retention time (HRT) of 0.5 to 8h.

9 The biological treatment method of treating organic wastewater according to Claim 1, wherein the first biological treatment tank contains a carrier at a packing rate of 10% or less, and

wherein the subsequent biological treatment tank including the second biological treatment tank contains the carrier at a packing rate of 0.1 to 20%.

10 The biological treatment method of treating organic wastewater according to Claim 1, wherein the carrier in the subsequent biological treatment tank including the second biological treatment tank has a shape of a thread, sheet, or strip.

11 The biological treatment method of treating organic wastewater according to Claim 10, wherein the length of a first side of the sheet or strip is in the range of 100 to 400 cm, the length of a second side of the sheet or strip perpendicular to the first side is in the range of 5 to 200 cm, and the thickness of the sheet strip is in the range of 0.5 to 5 cm.

12 The biological treatment method of treating organic wastewater according to Claim 1, wherein the carrier in the subsequent biological treatment tank including the second

biological treatment tank consists of porous polymer material.

13 The biological treatment method of treating organic wastewater according to Claim 12, wherein the porous polymer material is porous polyurethane foam.

14 The biological treatment apparatus for treating organic wastewater according to Claim 5, wherein the first biological treatment tank1 has a hydraulic retention time (HRT) of 0.5 to 8h.

15 The biological treatment apparatus for treating organic wastewater according to Claim 5, wherein the first biological treatment tank contains a carrier at a packing rate of 10% or less, and

wherein the subsequent biological treatment tank including the second biological treatment tank contains the carrier at a packing rate of 0.1 to 20%.

16 The biological treatment apparatus for treating organic wastewater according to Claim 5, wherein the carrier in the subsequent biological treatment tank including the second biological treatment tank has a shape of a thread, sheet or strip.

17 The biological treatment apparatus for treating organic wastewater according to Claim 16, wherein the length of a first side of the sheet or strip is in the range of 100 to 400

cm, the length of a second side of the sheet or strip perpendicular to the first side is in the range of 5 to 200 cm, and the thickness of the sheet strip is in the range of 0.5 to 5 cm.

18 The biological treatment apparatus for treating organic wastewater according to Claim 5, wherein the carrier in the subsequent biological treatment tank including the second biological treatment tank consists of porous polymer material.

19 The biological treatment apparatus for treating organic wastewater according to Claim 18, wherein the porous polymer material is porous polyurethane foam.