

DESCRIPTION

Title of Invention

AEROBIC BIOFILM TREATMENT METHOD AND DEVICE

Technical Field

[0001] The present invention relates to a method and a device for subjecting wastewater including a pollutant that can be biologically oxidized to a biofilm treatment using a self-granulated granule, a fluidized bed carrier, a fixed bed carrier, or the like, and particularly to control of the aeration intensity thereof. In the present invention, wastewater present outside a biofilm carrying out a microbial treatment is referred to as bulk water.

Background Art

[0002] Examples of a method for treating wastewater including a pollutant that can be biologically oxidized include an activated sludge method that uses suspended sludge and a biofilm method that carries out a treatment in a form in which a microorganism is accumulated and proliferated referred to as a biofilm such as a self-granulated granule method, a fluidized bed carrier method, or a fixed bed carrier method.

[0003] In the former activated sludge method that uses suspended sludge, a microorganism is maintained in a dispersed state in a reaction tank in a form referred to as a microbial floc. By keeping the microbial biomass maintained in the reaction tank constant by the operation of extracting the microorganism that increases in association with a wastewater treatment as excess sludge, the amount of oxygen consumed

generated due to the autolytic process of the microorganism itself can be kept at a constant level. Therefore, the increase or decrease in the amount of oxygen required in the above process changes in proportion to the raw water load. By adding a constant oxygen consumption offset associated with the microbial autolytic process to the above oxygen consumption, the amount of oxygen consumed to be supplied can be determined. In the process, the microorganism is typically retained in the form of a flocculate of around 1 mm referred to as a floc, and a sufficient contact area between the microorganism and the bulk aqueous phase is secured. Because of this, the permeability and diffusivity of oxygen in the floc are not main rate-determining factors in oxygen supply. Because of this, the aeration air volume to be supplied to the device is considered to be proportional to the amount of oxygen consumed. PTL1 discloses that the load of a pollutant is measured using an instrument and based thereon, the aeration air volume is controlled.

[0004] In the activated sludge method that uses suspended sludge and the biofilm method (self-granulated granule method, fluidized bed carrier method, fixed bed carrier method, or the like), as a method for simply adjusting the amount of oxygen supplied in proportion to the load of raw water, the so-called DO control system that carries out an air volume control that keeps the dissolved oxygen concentration (hereinafter referred to as DO) in a liquid constant is widely used.

[0005] PTL2 discloses that in the self-granulated granule method and the fluidized bed carrier method, the wastewater aeration volume is controlled, using the fluidization of the microbial carrier as a criterion when the BOD volume load is smaller than a predetermined value, and

using the oxygen demand of the wastewater as a criterion when the BOD volume load is larger than the predetermined value.

Citation List

Patent Literature

[0006] PTL1: JP 2001-353496 A

PTL2: JPS 63-256185 A

[0007] In a method that carries out a treatment using a biofilm such as the self-granulated granule method, the fluidized bed carrier method, or the fixed bed carrier method, strictly speaking, it is difficult to appropriately adjust the amount of oxygen supplied based only on the inflow load determined by the product of the flow volume per unit time of raw water and the pollutant concentration of raw water, which are common indexes of the raw water load, or the tank load obtained by dividing the inflow load by the volume of the reaction tank. The reasons for this are as follows.

[0008] In the method using a biofilm, there is no means for keeping the microbial biomass retained in the form of a microbial biofilm in the reaction vessel constant, and as a result, the microbial biomass retained changes with time, and thus the amount of oxygen consumed generated due to the autolytic process of the microorganism itself also changes. Therefore, in the method using a biofilm, the amount of oxygen supplied to the device needs to be determined in consideration of the change in the amount of oxygen consumed that changes in proportion to the load of raw water and also the change in oxygen consumption associated with the change in retained microbial biomass.

[0009] Because of these factors, in the treatment scheme using a biofilm, the amount of oxygen required to oxidize raw water organic matter changes according to the load fluctuation, and the amount of oxygen that needs to be supplied also changes according to the change in the amount of the biofilm retained in the treatment device. Further, in the biofilm method, a biofilm having a film thickness of typically 3 mm or more is generally formed, and the contact area with bulk water per microorganism retained is smaller than that in a suspension method. Because of this, in supplying oxygen to the microorganism in the biofilm, the diffusion phenomenon of oxygen on the contact surface between bulk water and the biofilm is a main rate-determining factor in oxygen supply.

[0010] The diffusion rate of oxygen in the biofilm depends on the DO level of bulk water, and thus it is necessary to adjust the DO level in order to adjust the amount of oxygen supplied. In addition, from the viewpoint of the aeration system, the required aeration air volume changes depending on the difference in the DO level even if the amount of oxygen supplied is the same. It is widely known that when the DO level is high, the required aeration volume increases, and when the DO level is low, the required aeration volume decreases.

[0011] Therefore, when the load increases, the amount of oxygen required to oxidize organic matter in raw water increases. The amount of oxygen that needs to be supplied is determined by taking into account the amount of oxygen consumed due to the autolytic process, which changes according to the change in the microbial biomass retained as the biofilm. It is necessary to adjust the DO of bulk water to be higher according to the increase in the amount of oxygen that needs to be

supplied, and also to increase the aeration air volume in order to achieve the target DO.

[0012] On the contrary, when the load decreases, the amount of oxygen required to oxidize organic matter in raw water decreases. The amount of oxygen that needs to be supplied is determined by taking into account the amount of oxygen consumed due to the autolytic process, which changes according to the change in the microbial biomass retained as the biofilm. The DO of bulk water can be kept lower according to the decrease in the amount of oxygen that needs to be supplied, and the aeration air volume for achieving the target DO also decreases.

[0013] For these reasons, when carrying out an operation that does not adjust or control according to the load of the aeration air volume, it is necessary to carry out a constant air volume operation in a state in which the aeration air volume is excessively increased so that the DO of bulk water can be kept high and the amount of oxygen supplied can be maintained even at the time of a high load.

[0014] Under the constant air volume operation that can maintain the high DO required at the time of a high load, a waste of energy consumption occurs because the air volume is not suppressed according to the decrease in the amount of oxygen consumed when the load decreases. Even when DO control is carried out by assuming oxygen supply at the time of a high load and setting a high DO target value, the DO level can be lowered when the load decreases by a biofilm treatment device, and thus if the target DO level of DO control is lowered, the aeration air volume can be further reduced. However, the normal DO control does not suppress the air volume due to such a decrease in the DO target, and thus a waste of energy consumption still occurs.

[0015] For this reason, the waste of energy consumption becomes particularly remarkable when the load fluctuation is large. However, even if there is a situation in which such a waste of energy consumption occurs, it is difficult to carry out the operation of adjusting the DO level that does not worsen the treated water quality according to the load fluctuation and adjustment of the air volume according to the target DO level by a conventional technique. Even when the operator appropriately adjusts the air volume, conventionally, even if the load is low, excessive DO level setting and aeration are often carried out in order to supply more oxygen than necessary with some margin. Because of this, a waste of energy often occurs.

[0016] When a flow rate load or a tank load, which is a common index of the raw water load, is used, the influence of the change in the microbial biomass retained in the biofilm cannot be taken into account. In addition, it is not possible to consider the influence of the contact area between the biofilm and bulk water, and it is difficult to appropriately control the aeration volume. Because of these, conventionally, it is common to set a large aeration air volume without considering the influence of the contact area between the biofilm and bulk water on the premise of the amount of oxygen consumed assuming a situation in which a large microbial biomass is retained. For this reason as well, a waste of energy often occurs.

Summary of Invention

Technical Problem

[0017] An object of the present invention is to provide a method and a device for appropriately controlling aeration in a wastewater treatment using an aerobic biofilm.

Solution to Problem

[0018] The aerobic biofilm treatment method of the present invention is a method comprising supplying raw water to an aeration tank, aerating the aeration tank using an aeration device, and subjecting a substance to be removed in the raw water to an aerobic biological treatment using a biofilm retaining carrier or granule packed in the aeration tank, wherein a relationship between a raw water biofilm load, which is a raw water load per carrier or granule, and a corresponding DO target value and/or a corresponding aeration intensity set value is set in advance, the DO target value and/or the aeration intensity set value is adjusted based on the relationship according to a fluctuation of a measured value of the raw water biofilm load, and the aeration device is controlled such that the DO becomes the target value or the aeration intensity becomes the set value.

[0019] The aerobic biofilm treatment device of the present invention is an aerobic biological treatment device including an aeration tank to which raw water is supplied, an aeration device that aerates the aeration tank, a biofilm-attached carrier or granule packed in the aeration tank, and a controller that controls the aeration device, wherein the device further includes: a setting unit that sets in advance a relationship between a raw water biofilm load, which is a raw water load per carrier or granule, and a corresponding DO target value and/or a corresponding aeration intensity set value; and an adjusting unit that adjusts the DO target value and/or the aeration intensity set value based on the

relationship according to a fluctuation of a measured value of the raw water biofilm load, and wherein the controller controls the aeration device such that the DO becomes the target value or the aeration intensity becomes the set value.

[0020] In one embodiment of the present invention, the raw water biofilm load is any of the load of a substance to be removed per packing volume of the carrier, the load of a substance to be removed per total surface area of a carrier group, the load of a substance to be removed per packing volume of the granule, and the load of a substance to be removed per total surface area of a granule group.

[0021] In one embodiment of the present invention, the substance to be removed is organic matter, a nitrogen compound, or an ammonium ion, and the raw water biofilm load is calculated from a calculated value of the concentration converted from a measured value of the concentration of the substance to be removed or a measured value of the absorbance, a measured value of the raw water flow rate, and a measured value or a calculated value of the packing volume or the surface area of the carrier or the granule.

[0022] In one embodiment of the present invention, the aeration intensity is controlled by controlling the aeration air volume, the aeration stop time, or the aeration suppression time.

[0023] In one embodiment of the present invention, the relationship is set using any of an experimental result, an operation result of an actual machine, and a mechanism model considering the diffusivity of oxygen in the biofilm.

Advantageous Effects of Invention

[0024] In the present invention, a necessary and sufficient oxygen supply suitable for a property of the carrier or the granule in the aeration tank, which changes with time, is estimated using the raw water biofilm load instead of the flow rate load or the volume load, and the DO target value or the aeration intensity set value itself is changed and controlled, and thus the aeration can be appropriately controlled.

Brief Description of Drawings

[0025] [Fig. 1] Fig. 1 is a block diagram of a biological treatment device to which the present invention is applied.

[Fig. 2] Fig. 2 is a graph showing results of an Example and a Comparative Example.

[Fig. 3] Fig. 3 is a graph showing results of an Example and a Comparative Example.

[Fig. 4] Fig. 4 is a graph showing results of an Example and a Comparative Example.

[Fig. 5] Fig. 5 is a graph showing the TOC load of raw water.

[Fig. 6] Fig. 6 is a block diagram of a biological treatment device to which the present invention is applied.

Description of Embodiments

[0026] Fig. 1 is a block diagram of a biological treatment device to which the present invention is applied.

[0027] Wastewater to be treated (raw water) is introduced into an aeration tank 2 through a pipe 1. A carrier C supporting a biofilm is packed in the aeration tank 2. A diffuser tube 3 is disposed at the

bottom of the aeration tank 2, and air is supplied from a blower 4 through a pipe 5 to carry out aeration.

[0028] The water that has been subjected to an aerobically biological treatment by the biofilm passes through a screen 2a and is taken out as treated water from a pipe 6.

[0029] This biological treatment device is provided with a flow rate meter 7 and a concentration meter 8 for measuring the flow rate and the concentration of the substance to be treated of raw water flowing through the pipe 1, a DO meter 9 for measuring the DO in the tank 2, and an air volume meter 10 for measuring the volume of air supplied from the blower 4 to the diffuser tube 3, as measurement means, and values detected by these are input to a controller 11. The aeration intensity is controlled by causing the blower 4 to be controlled by the controller 11.

[0030] Examples of the concentration meter 8 include a TOC meter, an ammoniacal nitrogen meter, and a UV absorbance meter (for determining TOC/N).

[0031] The present inventors have carried out various studies and found that one of the causes for which appropriate aeration control may be difficult even though the raw water load is the same when the flow rate load or the tank load is used as the raw water load is that the state of the carrier or the granule packed in the aeration tank changes.

[0032] For example, when an aeration tank in which a fluidized bed carrier is packed is operated for a long period of time, the carrier is scraped to have a smaller particle size and flows out of the aeration tank through a gap in the screen, the carrier packing ratio in the aeration tank decreases, the carrier packing ratio in the tank decreases, and the contact

area between the biofilm surface and bulk water decreases, which may reduce the treatment performance.

[0033] In the case of an operation for a long period of time, the microbial biomass retained on the carrier may increase and the amount of oxygen consumed due to microbial autolysis may increase.

[0034] In the case of an aeration tank provided with an expanded bed using a precipitating carrier, which is a kind of fixed bed treatment, it is necessary to periodically backwash the same to discharge excess sludge and SS between the carriers. At this time, the carriers are worn due to a collision and a shear force between the carriers, the carrier packing ratio gradually decreases, the carrier packing ratio in the tank decreases, and the contact area between the biofilm surface and bulk water decreases, which may reduce the treatment performance.

[0035] In the case of an operation for a long period of time, the microbial biomass retained in the carrier and between the carriers may increase and the amount of oxygen consumed due to microbial autolysis may increase.

[0036] In a biological treatment tank using a self-granulated granule, the number and the particle size of the self-granulated granule fluctuate with time, and the amount of the biofilm in the aeration tank increases or decreases, thereby the contact area between the biofilm and bulk water changes, and thereby the oxygen diffusivity to the biofilm changes, which causes a phenomenon in which the aeration air volume required for a wastewater treatment changes even if the organic matter load is the same.

[0037] In the present invention, the relationship between the raw water biofilm load and the corresponding DO target value and/or the

corresponding aeration intensity set value is set in advance, and the corresponding DO target value and/or aeration intensity set value is adjusted based on the above relationship according to the fluctuation in a measured value of the raw water biofilm load.

[0038] Then, the aeration device is controlled such that the DO becomes the target value or the aeration intensity becomes the set value.

[0039] As the raw water biofilm load, the load of the substance to be removed per packing volume of the carrier (carrier volume load) or the load of the substance to be removed per total surface area of the carrier group (all carriers in the tank) (carrier surface area load), the load of the substance to be removed per packing volume of the granule (granule volume load), or the load of the substance to be removed per total surface area of the granule group (all granules in the tank) (granule surface area load) is preferable.

[0040] <Raw water load>

The raw water load is calculated by the following expression.

[0041] $\text{Load} = Q \cdot \text{Conc}$

Load: Raw water load [kg/d]

Q: Raw water flow rate [m^3/d]

Conc: Raw water concentration [kg/m^3]

Examples of the raw water concentration include the concentration of TOC, ammoniacal nitrogen, or TOC/N estimated from a UV absorbance.

[0042] <Carrier volume load>

The carrier volume load is calculated by the following expression.

[0043] $\text{Load}_{\text{CarrierVol}} = \text{Load} / V_{\text{Carrier}}$

$\text{Load}_{\text{CarrierVol}}$: Carrier volume load [$\text{kg}/(\text{m}^3 \cdot \text{d})$]

V_{Carrier} : Carrier packing volume in aeration tank [m^3]

[0044] <Carrier surface area load>

The carrier surface area load is calculated by the following expression.

[0045] $\text{Load}_{\text{CarrierSurf}} = \text{Load} / S_{\text{Carrier}}$

$\text{Load}_{\text{CarrierSurf}}$: Carrier surface area load [$\text{kg}/(\text{m}^2 \cdot \text{d})$]

S_{Carrier} : Total surface area of the carrier group in the aeration tank [m^2]

[0046] In the aeration tank, the raw water load may fluctuate with time rapidly on a minute basis, but the change with time in a property of the carrier (carrier packing volume in the aeration tank or the total surface area of the carrier group in the aeration tank) changes relatively slowly on a daily to monthly basis. Because of this, it is preferable to frequently update a calculated value of the raw water load. In addition, the carrier packing volume in the aeration tank or the total surface area of the carrier group in the aeration tank is analyzed by sampling the carrier periodically (for example, at a frequency of about once every 1 to 3 months), and data on the carrier packing volume or the total surface area data of the carrier group may be updated.

[0047] [Control using oxygen consumption rate as control index]

[Method for calculating oxygen consumption rate]

In one embodiment of the present invention, the oxygen consumption rate of the treatment device is monitored as an index for monitoring the consumption of oxygen that needs to be supplied by the treatment device as the sum of the amount of oxygen required to oxidize an organic substance of raw water and the amount of oxygen consumed derived from the self-oxidation of a microorganism retained in the biofilm, and the aeration intensity is controlled based on the oxygen consumption

rate. That is, under a low load condition where the oxygen consumption rate is equal to or less than the predetermined value, the aeration intensity is set to the specified intensity or more in order to maintain the stirring intensity in the treated water tank, and when the oxygen consumption rate is equal to or more than the predetermined value, the aeration intensity is adjusted according to the oxygen consumption level. As described above, a method for calculating the oxygen consumption rate when the oxygen consumption rate is used as a control index will be described with reference to Fig. 6.

[0048] In the biological treatment device of Fig. 6, wastewater to be treated (raw water) is introduced into an aeration tank 2 through a pipe 1. A carrier C supporting a biofilm is packed in the aeration tank 2. Diffuser tubes 3a, 3b, and 3c are disposed at the bottom of the aeration tank 2, and air is supplied from a blower 4 through a pipe 5 and branch pipes 5a, 5b, and 5c to carry out aeration. The aeration tank 2 is provided with a top cover 2r.

[0049] The water that has been subjected to an aerobically biological treatment by the biofilm passes through a screen 2a and is taken out as treated water from a pipe 6.

[0050] This biological treatment device is provided with an exhaust gas meter 24 for measuring the oxygen concentration of the gas phase portion gas in the upper portion of the aeration tank 2 and below the top cover 2r, a DO meter 19 for measuring the DO in the aeration tank 2, and an air volume meter 20 for measuring the volume of air supplied from the blower 4 to the diffuser tubes 3a to 3c, as measurement means.

[0051] <Case 1: Method for calculating oxygen consumption rate from air volume meter and exhaust gas meter>

The aeration air volume and the oxygen concentration of the exhaust gas are measured, and the oxygen consumption rate q_{O_2} is directly calculated by the following expression.

[0052]

$$OTE = \frac{Z_0 - Z}{Z_0} \quad \cdot \cdot \cdot (1)$$

[0053]

$$q_{O_2} = \frac{G_v \cdot Z_0 \cdot OTE}{v_m} \quad \cdot \cdot \cdot (2)$$

[0054] OTE: Oxygen transfer efficiency [-]

Z_0 : Mole fraction of oxygen in blown air [-]

Z : Mole fraction of oxygen in exhaust gas [-]

q_{O_2} : Oxygen consumption rate [kg/d]

G_v : Blowing flow rate of aeration air converted to standard state

[Nm³/d]

v_m : Specific volume of oxygen [Nm³/kg]

[0055] <Case 2: Method for calculating oxygen consumption rate from DO meter and aeration air volume>

The aeration air volume and the DO are measured, and the oxygen consumption rate q_{O_2} is indirectly estimated.

(i) (Provision before mounting control device) The oxygen solubility index ϕ required to estimate the oxygen consumption rate is calculated by the following expression.

[0056]

$$OTE = \frac{Z_0 - Z}{Z_0} \quad \cdot \cdot \cdot (3)$$

[0057]

$$\phi = \frac{v_m \cdot h \cdot (C_s - C)}{Z_0 \cdot OTE} \quad \cdot \cdot \cdot (4)$$

[0058] OTE: Oxygen transfer efficiency [-]

Z_0 : Mole fraction of oxygen in blown air [-]

Z : Mole fraction of oxygen in exhaust gas [-]

ϕ : Oxygen solubility index [m]

v_m : Specific volume of oxygen [Nm³/kg]

h : Water depth of diffusion device [m]

C_s : Saturated dissolved oxygen concentration [kg/m³]

C : Dissolved oxygen concentration of mixed liquid [kg/m³]

[0059] (ii) (When the device is in operation) Changes with time in oxygen consumption rate are continuously measured.

[0060] The oxygen consumption rate qO_2 is continuously estimated by the following expression from continuous measurement data from the DO meter and on the aeration air volume, and the oxygen solubility index ϕ determined in advance.

[0061]

$$qO_2 = \frac{G_v \cdot h \cdot (C_s - C)}{\phi} \quad \cdot \cdot \cdot (5)$$

[0062] qO_2 : Oxygen consumption rate [kg/d]

Gv: Blowing flow rate of aeration air converted to standard state
[Nm³/h]

h: Water depth of diffusion device [m]

Cs: Saturated dissolved oxygen concentration [kg/m³]

C: Dissolved oxygen concentration of mixed liquid [kg/m³]

φ: Oxygen solubility index [m]

[0063] [Relationship between raw water biofilm load and DO target value or aeration intensity set value according to raw water biofilm load]

In the embodiment of the present invention, the oxygen consumption rate (q_{O_2}) is regarded as the raw water load (Load), the "carrier volume load" or the "carrier surface area load" is calculated, the calculation result thereof is regarded as the "raw water biofilm load," an appropriate DO target value or aeration intensity set value is found from a prediction or an actual result of the treated water quality when the DO target value or the aeration intensity is changed, the relationship between the raw water biofilm load and the appropriate DO target value or aeration intensity set value according to the raw water biofilm load is found and utilized in the control system.

The relationship between the raw water biofilm load and the DO target value or the aeration intensity set value is set using data on a result of a preliminary experiment, data on an operation result of an actual machine, a simulation result of a mechanism model considering the diffusivity of oxygen in the biofilm, or the like.

[0064] The method for expressing the relationship between the raw water biofilm load and the DO target value or the aeration intensity set value may be any of a functional expression (an approximate function for obtaining an appropriate DO target value or an appropriate aeration

intensity according to the raw water biofilm load), a control table (the relationship between the raw water biofilm load and an appropriate DO target value or an appropriate aeration intensity organized in tabular format), and the like.

[0065] [Biofilm mechanism model for creating the relationship between raw water biofilm load and DO target value and/or aeration intensity set value]

As one method for finding the relationship between the raw water biofilm load and the DO target value and/or the aeration intensity set value, a dynamic model that estimates a decrease in a pollutant and an increase or a decrease in the activated sludge microbiomass in a biofilm when the biofilm comes into contact with the bulk aqueous phase in a fluid state including the pollutant and oxygen (hereinafter sometimes referred to as a biofilm mechanism model) can be used. Such a dynamic model needs to be built also in consideration of a situation in which microbe proliferation and pollutant consumption/oxygen consumption occur simultaneously in the biofilm, and a phenomenon in which oxygen is dissolved in bulk water by diffusion of dissolved oxygen in the bulk aqueous phase into the biofilm and aeration. In addition, the expansion and contraction of the biofilm occur because of an increase and a decrease in the volume of the microbial population associated with the proliferation and the death of a microbe, or the attachment of the microbe from bulk water and the detachment of the microbe to the bulk water. When using a dynamic model for a biofilm utilization treatment, these phenomena need to be mathematically modeled. Such phenomena are phenomena that originally occur in a three-dimensional space, and thus the model expression is complicated, but the simulation can be carried

out relatively easily by expressing the expansion and contraction of the biofilm by a one-dimensional model expression that considers a change only in the thickness direction. As a mathematical model for simulating a wastewater treatment with activated sludge, for example, a series of mathematical models proposed by a Task Group of the International Water Association [Reference 1] can be utilized. [Reference 2] and the like can be used as an example of a mathematical model for a biofilm.

[Reference 1] M Henze; IWA. Task Group on Mathematical Modeling for Design and Operaton of Biological Wastewater Treatment; et al

[Reference 2] Boltz, J.P., Johnson, B.R., Daigger, G.T., Sandino, J., (2009a). "Modeling Integrated Fixed-Film Activated Sludge and Moving Bed Biofilm Reactor Systems I: Mathematical Treatment and Model Development". Water Environment Research, 81(6), 555-575

[0066] By using a mathematical model, for example, a mathematical model of a fluidized bed carrier can be built. In general, such a mathematical model is often described in the form of simultaneous ordinary differential equations, and a dynamic behavior of the target process can be simulated using numerical integration software for ordinary differential simultaneous equations. For example, it is possible to predict the treated water quality according to the DO situation of the bulk aqueous phase, which changes depending on a specific device configuration, load assumption, or aeration intensity.

[0067] By using a mathematical model, it is possible to predict, for example, the TOC concentration of the treated water when the treatment is carried out with various aeration intensities under various load conditions. Based on a simulation result, the minimum DO target value and aeration intensity adjustment that does not worsen the treatment

can be studied, and a table that organizes the simulation result can be created and utilized for the control table used in the control system of the present patent.

[0068] [Control of aeration intensity]

The aeration intensity can be controlled, for example, by changing the aeration air volume (supply air flow rate), or the aeration stop time or the aeration suppression time (weak aeration time) for each fixed time cycle. The aeration stop time refers to the time during which aeration is stopped within a fixed time cycle in the so-called intermittent aeration. The aeration suppression time is the time of weak aeration in an operation in which strong aeration and weak aeration are alternately repeated.

[0069] The aeration air volume, the aeration stop time, and the aeration suppression time are controlled continuously or stepwise according to the raw water load.

[0070] [Biological treatment other than fluidized bed]

Although a biological treatment using a fluidized bed carrier has been illustrated in Fig. 1, the present invention can be practiced by the same method even when a fixed bed carrier or a granule is used. For example, in the case of a raw water granule load, the volume or the surface area of the carrier or the carrier group may be read as the volume or the surface area of the granule or the granule group in expressions (2) and (3).

[0071] Although in the present embodiment, use of the present invention when wastewater including organic matter is treated by an aerobic biofilm treatment involving aeration, additionally, even when carrying out a biological treatment including an aerobic treatment step

using a biofilm in an aeration tank, such as a biological nitrification and denitrification treatment using a biofilm, the present invention can be practiced by the same method.

Example

[0072] <Device configuration>

One example of a method for controlling the DO and the weak aeration time by monitoring the raw water load with the carrier volume load of TOC on the fluidized bed carrier using the device of Fig. 1 will be described below.

[0073] A controller 11 includes a mechanism for adjusting the aeration volume in order to set a DO value according to the DO target value, and an intermittent aeration mechanism for periodically carrying out weak aeration at a designated air volume.

[0074] As a carrier C, a cubic urethane sponge carrier having a side length of 3 mm was used.

[0075] <Biofilm mechanism model>

Actually, the diffusion phenomenon of a pollutant and oxygen generated between the inside of the carrier having a three-dimensional structure and bulk water is expressed by a one-dimensional simple model, and this one-dimensional model was built as a model assuming a completely mixed compartment having a total of four layers consisting of bulk water and three biofilm layers.

[0076] The microbe proliferates by consuming substrates, that is, the pollutant and oxygen in the bulk aqueous phase and the biofilm and autolyzes at a constant proportion. Attachment and/or detachment of the proliferated microbe occurs according to the difference in microbial concentration in the bulk aqueous phase. In general, the microbial

concentration in the biofilm is higher than the microbial concentration in the bulk aqueous phase, and thus a situation in which the amount of the microbe proliferated in the biofilm detached is more than the amount of the microbe present in the aqueous phase adhered to the biofilm is modeled.

[0077] A situation in which the substrate, that is, the pollutant to be treated, is supplied from inflow wastewater, a part thereof flows out together with the treated water, and the rest diffuses into the biofilm according to the concentration difference between the bulk aqueous phase and the biofilm, and is reduced by undergoing oxidative decomposition associated with microbial proliferation in the bulk aqueous phase and the biofilm is modeled. In the model, the rate of oxidative decomposition of the pollutant in association with the microbial proliferation decreases as the oxygen concentration and the substrate, that is, pollutant concentration decreases.

[0078] Most of oxygen is supplied to the bulk aqueous phase by a diffusion device, but a part thereof is also supplied as oxygen included in the inflow wastewater. In addition, a situation in which a part of the supplied oxygen flows out together with the treated water, and the rest diffuses into the biofilm according to the difference between the oxygen concentration of the bulk aqueous phase and the oxygen concentration of the biofilm, and consumed in association with microbial proliferation and autolysis in the bulk aqueous phase and the biofilm is modeled. In the model, the rate of decrease in oxygen consumed in association with microbial proliferation of the pollutant decreases as the oxygen concentration and the substrate, that is, pollutant concentration decreases.

[0079] <Relationship between raw water biofilm load and DO target value and/or aeration intensity set value>

Using the mathematical expression of the one-dimensional diffusion model of a biofilm built, the treated water quality under a treatment condition was predicted by numerical integration simulation, and an appropriate control condition was exploratively determined, and summarized in the following control table.

[0080] In this case, the control table of Table 1 was used as the relationship between the raw water biofilm load and the DO target value and/or the aeration intensity set value according to the raw water biofilm load.

[0081] [Table 1]

TOC carrier volume load	[kgC/(m ³ •d)]	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
DO target value	[mg/L]	3.1	3.1	3.1	3.1	3.1	3.8	3.9	3.9	4.4	4.8
Weak aeration time set value	[minutes/2 hours]	110	90	80	60	20	0	0	0	0	0

[0082] In this control table, for example, when the TOC carrier volume load (kgC/(m³•d), hereinafter, the unit may be omitted) is 0.1 or more and less than 0.6, a DO target value of 3.1 mg/L is set,

when the TOC carrier volume load is 0.6 or more and less than 0.7, a DO target value of 3.8 mg/L is set,

when the TOC carrier volume load is 0.7 or more and less than 0.9, a DO target value of 3.9 mg/L is set,

when the TOC carrier volume load is 0.9 or more and less than 1.0, a DO target value of 4.4 mg/L is set, and

when the TOC carrier volume load is 1.0 or more, a DO target value of 4.8 mg/L is set,

as an appropriate value,
when the TOC carrier volume load is 0.1 or more and less than 0.2, a weak aeration time set value of 110 minutes every 2 hours is set, and
when the TOC carrier volume load is 0.2 or more and less than 0.3, a weak aeration time set value of 90 minutes every 2 hours is set, when the TOC carrier volume load is 0.3 or more and less than 0.4, a weak aeration time set value of 80 minutes every 2 hours is set, when the TOC carrier volume load is 0.4 or more and less than 0.5, a weak aeration time set value of 60 minutes every 2 hours is set, and when the TOC carrier volume load is 0.5 or more and less than 0.6, a weak aeration time set value of 20 minutes every 2 hours is set as an appropriate value, and
when the TOC carrier volume load is 0.6 ($\text{kgC}/(\text{m}^3 \cdot \text{d})$) or more, the weak aeration time set value is set to zero (that is, no intermittent aeration was carried out).

[0083] [Example 1]

Raw water whose TOC load fluctuated as shown in Fig. 5 was used as wastewater to be treated.

[0084] Based on the 2-hour moving average of the carrier volume load, once every 2 hours the DO target value was adjusted and the weak aeration time in a 2-hour cycle was adjusted based on the control table in Table 1, and a low air volume ($3 \text{ m}^3/(\text{m}^2 \text{ of bottom area} \cdot \text{hr})$) was fixed during the weak aeration, and the blower motor rotation speed was controlled in such a way as to reach the set DO target value during the time period other than during the weak aeration.

[0085] The changes with time in the duration of the weak aeration time are shown in Fig. 2, and the changes with time in DO are shown in Fig. 3.

In addition, the changes with time in the electric power consumption by the blower are shown in Fig. 4.

[0086] [Comparative Example 1]

The conditions were the same as in Example 1 except that the DO target value was fixed at 3.5 mg/L and the weak aeration time was kept constant at 10 minutes/2 hours. Results are shown in Figs. 2 to 4.

[0087] <Discussion>

In Example 1, the DO target value and the weak aeration time were adjusted according to the load per carrier, and thus the amount of electric power used by the blower is smaller than that in Comparative Example 1. That is, the electric power consumption of Comparative Example 1 was about 1150 kWh/day, whereas the electric power consumption of Example 1 was about 950 kWh/day, which is about 17% less.

[0088] There was almost no difference in the treated water quality between Example 1 and Comparative Example 1.

[0089] Although the present invention has been described in detail using specific embodiments, it will be apparent to those skilled in the art that various modifications can be made without departing from the intent and scope of the invention.

The present application is based on Japanese Patent Application No. 2020-063031 filed on March 31, 2020, which is incorporated herein by reference in its entirety.

Reference Signs List

[0090] 2 Aeration tank

3 Diffuser tube

- 4 Blower
- 7 Flow rate meter
- 8 Concentration meter
- 9 DO meter
- 10 Air volume meter
- 11 Controller

CLAIMS

[Claim 1]

An aerobic biofilm treatment method comprising supplying raw water to an aeration tank, aerating the aeration tank using an aeration device, and subjecting a substance to be removed in the raw water to an aerobic biological treatment using a biofilm retaining carrier in the aeration tank, wherein

a relationship between a raw water biofilm load, which is a raw water load per carrier, and a corresponding DO target value and/or a corresponding aeration intensity set value is set in advance,

the DO target value and/or the aeration intensity set value is adjusted based on the relationship according to a fluctuation of a measured value of the raw water biofilm load, and

the aeration device is controlled such that the DO becomes the target value or the aeration intensity becomes the set value, and

wherein the raw water biofilm load is any of the load of a substance to be removed per packing volume of the carrier, and the load of a substance to be removed per total surface area of a carrier group.

[Claim 2]

The aerobic biofilm treatment method according to claim 1, wherein the substance to be removed is organic matter, a nitrogen compound, or an ammonium ion, and

the raw water biofilm load is calculated from

a calculated value of a concentration converted from a measured value of a concentration of the substance to be removed or a measured value of an absorbance,

a measured value of a raw water flow rate, and
a measured value or a calculated value of a packing volume or a surface area of the carrier.

[Claim 3]

The aerobic biofilm treatment method according to claim 1 or 2, wherein the aeration intensity is controlled by controlling an aeration air volume, an aeration stop time, or an aeration suppression time.

[Claim 4]

The aerobic biofilm treatment method according to any one of claims 1 to 3, wherein the relationship is set using any of an experimental result, an operation result of an actual machine, and a mechanism model considering diffusivity of oxygen in the biofilm.

[Claim 5]

An aerobic biofilm treatment device comprising an aeration tank to which raw water is supplied, an aeration device that aerates the aeration tank, a biofilm-attached carrier in the aeration tank, and a controller that controls the aeration device,

wherein the device further comprises:

a setting unit that sets in advance a relationship between a raw water biofilm load, which is a raw water load per carrier, and a corresponding DO target value and/or a corresponding aeration intensity set value; and

an adjusting unit that adjusts the DO target value and/or the aeration intensity set value based on the relationship according to a fluctuation of a measured value of the raw water biofilm load, and

wherein the controller controls the aeration apparatus such that the DO becomes the target value or the aeration intensity becomes the set value, and

wherein the raw water biofilm load is any of the load of a substance to be removed per packing volume of the carrier, and the load of a substance to be removed per total surface area of a carrier group.