

DESCRIPTION

Title of Invention: APPARATUS FOR WASTEWATER TREATMENT

5 **Technical Field**

[0001] The present invention relates to an apparatus for wastewater treatment (which will be referred to wastewater treatment apparatus hereinafter) which treats the wastewater with anaerobic microorganism.

10 **Background Art**

[0002] As a high speed wastewater treatment method with the aid of anaerobic microorganism, UASB (viz., Up-flow Anaerobic Sludge Bed) method has been known. This method is a so-called anaerobic microorganism used wastewater treatment method in which self-granulated microorganism granules, which are granules each being 1 to 5 mm in diameter made of mutually entangled anaerobic filamentous methanogen and exhibit excellent settling properties, are held in a treatment apparatus. The feature of the UASB method is that the microorganism is held as the microorganism granules in concentrated form thereby to increase the treatment efficiency.

[0003] In the up-flow type anaerobic microorganism used wastewater treatment method like the UASB method, self-granulated microorganism substances like the granules and substances produced by putting and fixing microorganism onto carriers are held, as microorganism granules, in a treatment apparatus thereby to increase efficiency of wastewater treatment. Most of the microorganism granules are held in a lower part of the treatment apparatus to form a sludge bed. In this method, growth and maintenance of microorganism, and separation between treated water and the microorganism are carried out in a single common apparatus.

[0004] By subjecting wastewater to anaerobic microorganism used wastewater treatment, organic substances and nitrogen oxides in the wastewater undergo biodegradation by the microorganism granules including anaerobic microorganism, thereby to produce various gases such as methane gas, carbon dioxide gas and nitrogen gas, etc.,. Because the sludge bed has a large amount of microorganism held therein, once the wastewater is led into the sludge bed, the biodegradation treatment is actively carried out, so that the gases in the form of bubbles rise from the sludge bed toward an upper portion of the treatment apparatus. Some of the bubbles are of a type that rises upward independently from the sludge bed, and some of the bubbles are of a type that adheres to the microorganism granules to provide the same with buoyancy and rises upward in the treatment apparatus together with the microorganism granules. In order to prevent the microorganism granules from discharging into outside of the treatment apparatus together with treated water after the wastewater has been treated by the treatment apparatus, the treatment apparatus has therein a gas/solid separating device (GSS) that separates the bubbles from the microorganism granules. The gas/solid separating device (GSS) is located below a gas/liquid interface in the treatment apparatus to capture the microorganism granules rising together with bubbles adherent thereto and separate the bubbles from the microorganism granules by practically using the upward flow of the bubbles and collision of the granules with the bubbles. The microorganism granules having the bubbles separated therefrom at the gas/solid separating device (GSS) settle (or sink) into the sludge bed again to contact with the wastewater to contribute to the biodegradation treatment.

[0005] In the up-flow type anaerobic microorganism used wastewater treatment method like the UASB method, the

function of the gas/solid separating device (GSS) is most important in view of treatment operation used for the method.

[0006] In view of need for higher load of the wastewater treatment, miniaturization of the apparatus and more increased water quality, a treatment apparatus as an apparatus having an improved gas/solid separating device (GSS) has been proposed in which partition walls that constitute the GSS in the treatment apparatus have characteristic combination (Patent Document-1).

[0007] For providing the microorganism granules with a certain strength to prevent the microorganism from being damaged by shocks attacked thereto in the GSS, a method has been proposed in which for carrying out biodegradation treatment holding in a treatment apparatus granules composed of anaerobic ammonia oxide microorganism, organic flocculant is added into the interior of the treatment apparatus to increase adhesion between microorganisms to produce strong and closely packed granules that exhibit excellent settlement characteristic (Patent Document-2).

Prior Art Documents

Patent Documents

[0008] Patent Document-1: Japanese Laid-open Patent Application (Tokkai) 2001-187394

Patent Document-2: Japanese Laid-open Patent Application (Tokkai) 2003-24988

Summary of Invention

Problems to be solved by Invention

[0009] In the following, conventional technique and problems possessed by the conventional technique will be briefly described.

[0010] UASB (viz., Up-flow Anaerobic Sludge Bed) method is a so-called anaerobic microorganism used wastewater treatment method in which self-granulated microorganism granules, which are granules each being 1 to 5 mm in diameter made of mutually

entangled anaerobic filamentous methanogen and exhibit excellent settling properties, are held in a treatment apparatus. The advantageous feature of the UASB method is that the microorganism can be held as the microorganism granules in concentrated form in a treatment apparatus thereby to increase the wastewater treatment efficiency.

[0011] With increase of load of the wastewater led into the treatment apparatus, biodegradation wastewater treatment using organic substances is actively carried out in the sludge bed where the microorganism granules are collected, so that the amount of various gases such as methane gas, carbon dioxide gas and nitrogen gas, etc., increases in accordance with microorganism metabolism. Some of the bubbles of the gases are of a type that rises upward independently from the sludge bed and some of the bubbles of the gases are of a type that adheres to the microorganism granules to provide the same with buoyancy and rises upward in the treatment apparatus together with the microorganism granules. In order to prevent the microorganism granules from discharging into outside of the treatment apparatus together with treated water after the wastewater has been treated by the treatment apparatus, the GSS is provided in the treatment apparatus at a position below a gas/liquid interface to capture the microorganism granules rising together with bubbles adherent thereto and separate the bubbles from the microorganism granules by practically using the upward flow of the bubbles and collision of granules with the bubbles. The microorganism granules having the bubbles separated therefrom at the GSS settle into the sludge bed again to contact with the wastewater to contribute the biodegradation treatment.

[0012] As the microorganism granules, various substances are known which are for example substances, like granules, produced by self-granulated microorganism, and/or substances produced by putting and fixing microorganism onto carriers. In

case of continuously carrying out a high load operation using the anaerobic microorganism used wastewater treatment method holding the microorganism granules in the treatment apparatus, the following problems tend to occur.

5 [0013] At the GSS, the microorganism granules to which bubbles have adhered are subjected to a bubble separation and then settle in the water in the treatment apparatus. As the load of the treatment rises, the biodegradation treatment becomes active and thus the amount of gases increases. Accordingly, the
10 amount of microorganism granules that remain in the GSS together with bubbles adherent thereto is larger than that of the microorganism granules that have the bubbles separated and are settling, and thus, a larger amount of microorganism granules remains in the GSS disturbing the GSS from making normal
15 operation. Thus, the microorganism granule holding capacity of sludge bed is reduced bringing about such a problem that the wastewater treatment efficiency is lowered. Furthermore, since the microorganism granules that have the bubbles separated and settle from the GSS are forced to collide against bubbles and
20 bubble streams that are being actively produced by the sludge bed, the microorganism granules are fragmented into smaller granules deteriorating settlement characteristic, so that fragments of the smaller granules rise to the surface of water inducing mixing of the same with the treated water causing
25 discharge of the fragments from the treatment apparatus while increasing the floating substance (SS) value resulting in that the quality of the treated water is lowered, which is a problem. Furthermore, during settling of the microorganism granules having the bubbles separated therefrom from the GSS, the
30 microorganism granules may contact rising bubbles and have the bubbles adherent thereto, so that the microorganism granules may rise again as bubble adhered microorganism granules

lowering the settling efficiency of the microorganism granules, which is another problem.

[0014] The present invention is provided by taking the above-mentioned conventional technique into consideration.

5 That is, by closely observing both the rising phenomenon of the bubbles from the sludge bed and the settling phenomenon of the microorganism granules from a GSS and carefully considering, examining and testing the GSS for the purpose of solving the problems, an ideal construction of the GSS has been invented. In
10 accordance with the present invention, there is provided in a wastewater treatment method practically using microorganism granules, a wastewater treatment apparatus which, by effectively separating bubbles from the microorganism granules having the bubbles adhered thereto and minimizing the contact between the
15 rising bubbles and settling microorganism granules, can suppress undesired outflow of the microorganism granules into treated water, which would be caused by fragmentation of the microorganism granules, and can operate under a high load while producing a stable quality of treated water without lowering the
20 wastewater treatment efficiency.

Means for solving problems

[0015] In the wastewater treatment apparatus according to a first aspect of the invention, a reactor vessel is provided in which microorganism granules are precipitated in a lower layer part,
25 wastewater led into the reactor vessel through an inlet opening provided in a lower part of the reactor vessel is subjected to biodegradation treatment under existence of the microorganism granules and treated water produced by the biodegradation treatment is discharged to the outside from a treated water outlet
30 portion, which is characterized in that a spiral plate is provided which extends from the side of the inlet opening to the side of the outlet portion.

[0016] In the wastewater treatment apparatus according to the first aspect of the invention, microorganism granules such as granules or the like are held in the lower layer part of the reactor vessel to serve as a sludge bed, and wastewater is led into the

5 sludge bed from the lower part with the aid of a pump to contact with the sludge bed thereby to subject organic substances and nitrogen compounds contained in the wastewater to the biodegradation treatment. Due to the biodegradation treatment for the wastewater, the sludge bed produces various gases such

10 as methane gas, carbon oxide gas, nitrogen gas and the like. When bubbles of the gases thus produced adhere to the microorganism granules, the bubbles provide the microorganism granules with buoyancy causing the microorganism granules to rise in the reactor vessel. The bubbles and the bubble adhered

15 microorganism granules produced in the sludge bed rise along a lower surface of the spiral plate. During this rising, the bubbles are separated from the bubble adhered microorganism granules due to contact impact, such as collision of the bubble adhered microorganism granules with the bubbles and the lower surface of

20 the spiral plate, the microorganism granules settle down onto an upper surface of the spiral plate that is located under that lower surface of the spiral plate. The microorganism granules thus put on the upper surface of the spiral plate slip down along the upper surface of the spiral plate and finally arrive at the sludge bed

25 located in the lower part of the reactor vessel to contact the wastewater to contribute biodegradation. During this slipping down, the microorganism granules avoid contacting with bubbles that are rising from the lower surface of the spiral plate and thus undesired fragmentation of the microorganism granules is

30 suppressed. Furthermore, it never occurs that the settling microorganism granules catch the rising bubbles and thus rise again together with the bubbles in the reactor vessel, which

improves the settlement characteristic of the microorganism granules.

[0017] In a continuous treatment of the wastewater, the above-mentioned movement of the microorganism granules is repeated. Accordingly, in the sludge bed, the microorganism granules are so conditioned as to float with freedom. Treated water is discharged to the outside from a treated water outlet portion that is arranged at an upper part of the reactor vessel. While, the bubbles that have been separated by the spiral plate are collected in a space provided at an upper part of the reactor vessel and then discharged to the outside.

[0018] If desired, the spiral plate may be of integral type or split type so long as it can be arranged with no clearance therearound.

[0019] In the wastewater treatment apparatus according to a second aspect of the invention, in addition to the characterized arrangement of the first aspect of the invention, a further characterized manner is provided in which the spiral plate has a pole disposed therethrough, the pole extending along an axis of the reactor vessel.

[0020] In the wastewater treatment apparatus according to the second aspect of the invention, in addition to the operation of the first aspect of the invention, the following operation is obtained. That is, due to provision of the pole disposed through the spiral plate, the bubbles and the bubble adhered microorganism granules don't rise rapidly but move upward in a spiral manner along the lower surface of the spiral plate, so that they stay in the vessel for a longer time increasing the chance of collision of them with the bubbles and the lower surface of the spiral plate, which brings about increase in the gas/solid separation efficiency.

[0021] In the wastewater treatment apparatus according to a third aspect of the invention, in addition to the characterized

arrangement of the first and second aspects of the invention, a further characterized matter is provided in which upper and lower surfaces of the spiral plate incline upward in a direction from an axial part of the spiral plate to a wall of the reactor vessel.

5 [0022] In the wastewater treatment apparatus according to the third aspect of the invention, in addition to the operation of the first and second aspects of the invention, the upward inclination of the upper and lower surfaces of the spiral plate in the direction from the axial part of the spiral plate to the wall of
10 the reactor vessel brings about the following advantageous operation. That is, it is possible to separate two flows in a radial direction, one being an upward flow of the bubbles and the bubble adhered microorganism granules and the other being a downward flow of the microorganism granules. With this flow
15 separation, undesired fragmentation of the downward flowing microorganism granules is suppressed or at least minimized. Furthermore, since the bubbles and the bubble adhered microorganism granules tend to collect at the side of the wall of the reactor vessel, collision of the rising bubbles with the bubble
20 adhered microorganism granules is closely carried out, which brings about not only increase in the gas/solid separation efficiency but also the following advantageous operation. That is, since the microorganism granules having the bubbles separated therefrom tend to collect in the vicinity of the axis part of the
25 spiral plate and tend to slip down, the moved distance of the microorganism granules is shortened as compared with a case wherein the microorganism granules slip down at random on an incline-free upper surface of a spiral plate that is caused by the same height possessed by both the axis part and the side of the
30 wall of the reactor vessel. Thus, in the invention, the microorganism granules can speedily return to the sludge bed located in the lower part of the reactor vessel and contact with

newly led wastewater to contribute to biodegradation establishing expectation of increase in the treatment efficiency.

[0023] In the wastewater treatment apparatus according to a fourth aspect of the invention, in addition to the characterized arrangement of the first, second and third aspects of the invention, a further characterized matter is provided in which the spiral plate comprises a plurality of spiral units and mutually neighboring ends of neighboring two spiral units are overlapped in a circumferential direction.

[0024] In the wastewater treatment apparatus according to the fourth aspect of the invention, in addition to the operation of the first, second and third aspects of the invention, the construction in which the spiral plate comprises a plurality of spiral units brings about the following advantageous operation.

That is, the bubble adhered microorganism granules rising at steps of the spiral plate violently collides against the lower surface of the spiral plate and thus, the bubbles adhered to the microorganism granules tend to be easily separated from the microorganism granules. Accordingly, the returning of the microorganism granules to the sludge bed provided at the lower part of the reactor vessel is speedily carried out causing the sludge bed to contain a sufficient amount of microorganism granules and thus the wastewater treatment efficiency is increased.

[0025] In the wastewater treatment apparatus according to a fifth aspect of the invention, in addition to the characterized arrangement of the first, second and third aspects of the invention, a further characterized matter is provided in which the spiral plate comprises a plurality of spiral units, at least paired neighboring two of the spiral units are so formed as to have opposed turning directions and mutually neighboring ends of the paired neighboring two spiral units are spaced apart from each other by a given angle in a circumferential direction.

[0026] In the wastewater treatment apparatus according to the fifth aspect of the invention, in addition to the operation of the first, second and third aspects of the invention, the following advantageous operation is further obtained. That is, the upward-moving stream composed of the bubbles and the bubble adhered microorganism granules is forced to change its turning direction at the end of the spiral unit where the spiral direction is changed, and thus, the upward-moving stream is turbulent at that end. As a result, as compared with a case wherein an upward-moving stream goes along spiral units whose spiral directions extend in a given common direction, the phenomenon of shaking the bubbles and microorganism granules from the bubble adhered microorganism granules is largely carried out by the turbulent flow of the upward-moving stream caused by the direction change of the stream, and thus, the bubbles are easily separated from the bubble adhered microorganism granules, which brings about improvement of the gas/solid separation. The settle point where the microorganism granules having the bubbles separated therefrom settle after the same have moved down from the end of the spiral unit toward the lower spiral unit is not a point that is near the upper side of the spiral unit located just below that end of the spiral unit, but a point that is on that same spiral unit at a down position of that end of that same spiral unit. The microorganism granules put on the settle point slip down along the upper surface of the spiral unit and repeat such slip down movement and finally return to the sludge bed. In case wherein the ends of the neighboring spiral units are placed at different positions in a circumferential direction, it never occurs that the microorganism granules slip down along the entire course of the upper surfaces of the spiral units, and thus, the moved distance of the granules is shortened. As a result, as compared with a case of using a spiral plate in which the ends of the neighboring spiral units are not placed at different positions in a

circumferential direction, the microorganism granules having the bubbles separated therefrom can return to the sludge bed much quickly. With this, the sludge bed located at the lower layer part of the reactor vessel can hold much more microorganism
5 granules for carrying out the biodegradation treatment and thus, the wastewater treatment efficiency is increased.

[0027] In the wastewater treatment apparatus according to a sixth aspect of the invention, in addition to the characterized arrangement of the first to fifth aspects of the invention, a further
10 characterized matter is provided in which baffle plates are provided to the lower surface of the spiral plate to baffle and obstruct upward flow of bubbles and bubble adhered microorganism granules.

[0028] In the wastewater treatment apparatus according to
15 the sixth aspect of the invention, in addition to the operation of the first to fifth aspects of the invention, the following advantageous operation is further obtained. Due to provision of the baffle plates provided on the lower surface of the spiral plate to baffle rising (viz., upward movement) of the bubbles and the
20 bubble adhered microorganism granules, once a given amount of bubbles and bubble adhered microorganism granules accumulates, they rush to rise from the baffle plates and run along the lower surface of the spiral plate thereby to produce a rapid upward flow. It is preferable that the lump of bubbles forming the upward flow
25 gradually catches a lump of bubbles placed at the upper side of the spiral plate, while rising along the lower surface of the spiral plate. If so, rising bubbles violently collide against the bubble adhered microorganism granules causing easy separation of the bubbles from the bubble adhered to the microorganism granules.
30 As a result, returning of the microorganism granules to the sludge bed located at the lower part of the reactor is speedily made and thus, the wastewater treatment efficiency is increased. The baffle plates are those that obstruct the bubble adhered

microorganism granules and bubbles from rising along the lower surface of the spiral plate. However, each baffle plate should have a height that does not extremely obstruct the upward flow, and a free end of each baffle plate may have a linear flat shape or a saw tooth shape.

[0029] In the wastewater treatment apparatus according to a seventh aspect of the invention, in addition to the characterized arrangement of the first to sixth aspect of the invention, a further characterized matter is provided in which the spiral plate has a portion embedded in the sludge bed which is composed of the microorganism granules deposited in the lower layer part of the reactor vessel.

[0030] In the wastewater treatment apparatus according to the seventh aspect of the invention, in addition to the operation of the first to sixth aspects of the invention, the following advantageous operation is further obtained. Because a portion of the spiral plate is embedded in the sludge bed, the wastewater led into the reactor vessel is forced to move in the sludge bed along the spiral plate. As a result, undesired phenomenon, viz., shorten flow, in which the wastewater in the sludge bed would get out the sludge bed instantly is suppressed, which is able to increase the time for which the wastewater and microorganism granules keep contact therebetween in the sludge bed and thus a contact/mixing effect is increased. Furthermore, because the wastewater is enforcedly guided by the spiral plate, the flow of high SS value wastewater is suppressed from having a stagnant portion and thus, undesired blockage of the reactor vessel which would be caused by such stagnant portion is suppressed and thus the contact/mixing effect in the sludge bed is increased.

Furthermore, undesired shortened flow of the wastewater is suppressed irrespective of the way in which the wastewater is led into the reactor vessel.

Advantages of Invention

[0031] As is described hereinabove, in accordance with the present invention, a spiral plate is arranged in a treatment apparatus to provide the spiral plate with a gas/solid separation function. With this, bubbles are effectively separated from
5 bubble adhered microorganism granules, and by minimizing the contact between bubbles and settling microorganism granules, undesired mixing of the microorganism granules with treated water, which would be caused by fragmentation of the microorganism granules, is suppressed or at least minimized.

10 Thus, in accordance with the present invention, there is provided a wastewater treatment apparatus which can operate under a high load while producing a stable quality of treated water without lowering the wastewater treatment efficiency.

[0032] Furthermore, undesired phenomenon in which rising
15 bubbles adhere to settling microorganism granules to form bubble adhered microorganism granules and the bubble adhered microorganism granules rise again is suppressed or at least minimized. As a result, fragmentation of the microorganism granules is suppressed and the settling efficiency of the
20 microorganism granules is increased.

BRIEF DESCRIPTION OF DRAWINGS

[0033] Fig. 1 is a schematic view (side view) showing a first embodiment of a wastewater treatment apparatus of the present invention;

25 Fig. 2 is an enlarged view of an interior of a reactor employed in the first embodiment of the wastewater treatment apparatus of the present invention;

Fig. 3 is a schematic view (side view) showing a second embodiment of the wastewater treatment apparatus of the
30 present invention;

Fig. 4 is an enlarged view of an interior of a reactor employed in the second embodiment of the wastewater treatment apparatus of the present invention;

Fig. 5 is a schematic view (side view) showing a third embodiment of the wastewater treatment apparatus of the present invention;

Fig. 6 is a schematic view (plan view) showing the third embodiment of the wastewater treatment apparatus of the present invention;

Fig. 7 is a schematic view (plan view) showing the third embodiment of the wastewater treatment apparatus of the present invention;

Fig. 8 is a schematic view (side view) showing a fourth embodiment of the wastewater treatment apparatus of the present invention;

Fig. 9 is a schematic view (side view) showing a fifth embodiment of the wastewater treatment apparatus of the present invention; and

Fig. 10 is a schematic view (side view) showing a sixth embodiment of the wastewater treatment apparatus of the present invention.

EMBODIMENTS OF INVENTION

[0034] In the following, embodiments of the present invention will be described with reference to the accompanying drawings.

[First Embodiment]

[0035] Figs. 1 and 2 are drawings showing a first embodiment of a wastewater treatment apparatus of the present invention.

[0036] As is shown in Fig. 1, the wastewater treatment apparatus 100 comprises a reactor vessel 1, a sludge bed 9 held in a lower part of the reactor vessel 1 and including microorganism granules, a pole 2 extending between lower and upper ends of the reactor vessel 1 along an axis of the reactor vessel 1, and a spiral plate 3 that is provided between a wall (or inner wall surface) of the reactor vessel 1 and the pole 2 and

extends in a so-called spiral manner between an upper face 9a of
 the sludge bed 9 in the reactor vessel 1 and a gas/liquid interface
 of the reactor vessel 1. Upper and lower surfaces of the spiral
 plate 3 spirally extend upward in the reactor vessel 1 defining an
 5 angle of, for example, 10 to 60 degrees relative to a bottom wall
 of the reactor vessel 1. The angle is so determined as to allow
 bubbles 10, bubble adhered microorganism granules 12 and
 microorganism granules 11 to move along the spiral plate 3
 without a hitch, and so determined as not to fragment the
 10 microorganism granules 11 into smaller granules which would be
 caused by a too sharp angle. That is, a suitable angle is set by a
 design. The upper and lower surfaces of the spiral plate 3 have
 the same height at both the side of the pole 2 (viz., axis) and the
 side of the wall of the reactor vessel 1. The distance between
 15 upper and lower vane parts of the spiral plate 3 is so determined
 that even when the bubble adhered microorganism granules 12
 and the microorganism granules 11 make a movement in
 opposed directions, they are prevented from contacting to and
 interfering from each other. Considering this, the distance is
 20 determined to 10 mm and above, as a minimum value, which is
 twice as long as the maximum value of 1 to 5 mm that shows the
 size of the microorganism granules 11. That is, such distance is
 determined with reference to the size of the microorganism
 granules 11 led into the reactor vessel 1 and determined so that
 25 movements of the bubbles 10 and microorganism granules 11 do
 not interfere with each other. If fixing of the spiral plate 3 is
 made by only the wall of the reactor vessel 1, the pole 2 may be
 omitted. In case of omitting the pole 2, it is preferable to
 determine the radius of the spiral plate 3 to a value larger than
 30 the radius of the reactor vessel 1 in order to prevent the bubbles
 10 and bubble adhered microorganism granules 12 from straying
 off the lower surface of the spiral plate 3 and straightly rising.

[0037] With the aid of a water pump 5, wastewater 6 is led into the reactor vessel 1 from a lower part of the vessel 1 and guided to the sludge bed 9. Water (treated water) 7 treated in the reactor vessel 1 is discharged to the outside from an upper part of the vessel. As an example of ways for discharging the treated water 7, there is a system in which a SS trap 4 is provided to the wall of the reactor vessel 1 at a position of the gas/liquid interface and treated water 7 overflowing the SS trap 4 is discharged to the outside.

10 [0038] Fig. 2 shows the spiral plate 3 arranged in the reactor vessel 1, which is a schematically illustrated enlarged view of the interior of the reactor vessel 1 showing movement (viz., moving direction) of the bubbles 10, the bubble adhered microorganism granules 12 and the microorganism granules 11 having the bubbles 10 separated therefrom.

[0039] In this drawing Fig. 2, numeral 10 indicates the bubbles, 11 indicates the microorganism granules, 12 indicates the bubble adhered microorganism granules, 13 indicates the moving direction of the bubbles 10 and the bubble adhered microorganism granules 12, 14 indicates the moving direction of the microorganism granules 11, and 16 indicates a settling direction of the microorganism granules 11 that have the bubbles separated therefrom.

25 [0040] In the following, operation of the first embodiment having the above-mentioned arrangement will be described with reference to Figs. 1 and 2.

[0041] With the aid of the water pump 5, the wastewater 6 is led into the sludge bed 9 in the reactor vessel 1 from the lower part of the reactor vessel 1. The wastewater led into the sludge bed 9 from the lower part of the reactor vessel 1 is forced to contact to and mix with the microorganism granules 11 to be subjected to a biodegradation treatment. Gases produced by the biodegradation treatment at the sludge bed 9 form gas bubbles

10 and adhere to the microorganism granules 11 provide the same with a certain buoyancy causing the same to rise in the reactor vessel 1. The bubbles 10 and bubble adhered microorganism granules 12 rising from the sludge bed 9 rise

5 upward along a lower surface of the spiral plate 3 following the indicated direction 13 which shows the moving direction of the bubbles 10 and the bubble adhered microorganism granules 12. During this rising, the bubbles 10 are separated from the microorganism granules 11 due to the flow and contacts caused

10 by the bubbles 10 and the impact of contacts with the spiral plate 3. As is indicated by the arrows 16 that show the settling direction of the microorganism granules that have the bubbles separated therefrom, the microorganism granules 11 settle or go down to an upper surface of the spiral plate 3 that is located

15 below that part of the spiral plate 3. Thereafter, the microorganism granules 11 slip down along the upper surface of the spiral plate 3 and finally return to the sludge bed 9 located in the lower part of the reactor vessel 1, and there, the granules 11 mix with the wastewater 6 to contribute to the biodegradation.

20 During this, the microorganism granules 11 slipping down along the upper surface of the spiral plate 3 can avoid or at least minimize contact with the bubbles 10 that are rising, and thus, fragmentation of the microorganism granules 11 is suppressed or at least minimized. It never occurs that the microorganism

25 granules 11 rise again which would be caused by adhesion of the bubbles 10 to the granules 11, and thus, improved settlement is achieved. That is, as is indicated by the arrows 13 that show the moving direction of the bubble adhered microorganism granules 12 and the arrows 14 that show the moving direction of the

30 microorganism granules 11, the bubbles 10 and the microorganism granules 11 having the bubbles separated therefrom are forced to move in opposed directions keeping the

spiral plate 3 put therebetween, and thus, no contact occurs therebetween.

[0042] Bubbles 10 that have been separated from the microorganism granules 11 in the reactor vessel 1 are collected in a space 8a provided at the upper part of the reactor vessel 1, and discharged from an upper portion to the outside as a produced gas. The wastewater 6 is treated in the reactor vessel 1 to form a treated water 7 and after separating the microorganism granules 11 by the spiral plate 3, the treated water 7 is discharged from the reactor vessel 1. For example, this discharge is carried out through the SS trap 4.

[0043] By disposing the pole 2 in and along the axis of the spiral plate 3 or determining the radius of the spiral plate 3 to a value equal to or larger a radius of the reactor vessel 1, undesired phenomenon, viz., shorten flow, wherein the bubbles 10 and the bubble adhered microorganism granules 12 would get out the lower surface of the spiral plate 23 is suppressed.

[Second Embodiment]

[0044] Fig. 3 is a drawing showing a second embodiment of the wastewater treatment apparatus of the present invention.

[0045] Fig. 4 shows, in addition to the reactor vessel 1, the pole 2 and the spiral plate 31 which are shown in Fig. 3, the bubbles 10, the microorganism granules 11 having the bubbles separated therefrom and the bubble adhered microorganism granules 12. Furthermore, in order to explain movement of the bubbles and the microorganism granules, Fig. 4 shows a setting direction 16 of the microorganism granules that have the bubbles separated therefrom. With the aid of Fig. 3, the way for fixing the spiral plate 3 in the second embodiment will be described.

[0046] The construction of the wastewater treatment apparatus of the second embodiment is the same as that of the first embodiment except for the shape of a spiral plate 31. Upper and lower surfaces of the spiral plate 31 incline upward in a

direction from the pole 2 (viz., axis) of the spiral plate 31 to a wall of the reactor vessel 1. The inclination angle is for example 30 degrees. The angle is so determined as to allow the bubbles 10, the bubble adhered microorganism granules 12 and the microorganism granules 11 to move along the spiral plate 31 without a hitch, and so determined as not to fragment the microorganism granules 11 into smaller granules which would be caused by a too sharp angle.

[0047] In the following, operation of the second embodiment having the above-mentioned arrangement will be described with reference to Figs. 3 and 4.

[0048] Differences in operation from the first embodiment are as follows. In the second embodiment, the spiral plate 31 is arranged in the above-mentioned manner. With such arrangement, it is possible to separate two flows in a radial direction of the reactor vessel, one being an upward flow of the bubbles and the bubble adhered microorganism granules 12 and the other being a downward flow of the microorganism granules 11. Furthermore, since, before rising, both the bubbles 10 and bubble adhered microorganism granules 12 are collected near the wall of the reactor vessel 1, they receive much higher contact impact as compared with the case of the first embodiment, and thus, the gas/solid separation effect is increased. Furthermore, since the microorganism granules 12 having the bubbles 10 separated therefrom are collected near the pole 2 and then slip down along the upper surface of the spiral plate 31, they can quickly return to the sludge bed 9 located at the lower part of the reactor vessel 1 for contributing to the biodegradation, and thus, increase in the treatment efficiency is expected.

[Third Embodiment]

[0049] Figs. 5 and 6 are drawings shown a third embodiment of the wastewater treatment apparatus of the present invention.

[0050] As is shown in Fig. 5, the construction of the wastewater treatment apparatus 100 is the same as that of the first embodiment except for the shape of a spiral plate 32. The spiral plate 32 comprises a plurality of spiral units. For example,
 5 each spiral unit is a semicircular spiral plate that has an arc angle of 180 degrees with respect to an axis of the pole 2. Neighboring two of the spiral units have mutual ends that are overlapped in a circumferential direction.

[0051] Fig. 6 shows a plan view of the wastewater treatment apparatus 100. Numerals (1 to 12) shown around the illustration
 10 of the reactor vessel 1 are provided for explaining the positional relation between the ends of the spiral units. The numerals correspond to numerals provided on a clock face.

[0052] An imaginary one unit of the spiral plate 32 consists
 15 of three (viz., lower, middle and upper) spiral units which are spaced from one another in an axial direction and arranged equally around the pole 2 having ends of each spiral unit overlapped with ends of neighboring spiral unit at an angle of 30 degrees. If, in the spiral plate 32 having the above-mentioned
 20 construction, the lower spiral unit takes a position having a leading end (viz., starting point of arc) thereof placed at numeral 12, a trailing end (viz., end point of arc) of the lower spiral unit, which is spaced from the leading end in a counterclockwise
 25 direction, takes a position at numeral 6. In this case, a leading end (viz., starting point of arc) of the middle spiral unit takes a position at numeral 7 and overlaps the trailing end (viz., end point of arc) of the lower spiral unit by an angle of 30 degree. Like this, a trailing end (viz., end point of arc) of the middle spiral
 30 unit, which is spaced from the leading end of the middle spiral unit in a counterclockwise direction, takes a position at numeral 1 and overlaps a leading end (viz., starting point of arc) of the upper spiral unit, which takes a position at numeral 2, by an angle of 30 degrees. A trailing end (viz., end point of arc) of the

upper spiral unit, which is spaced from the leading end of the upper spiral unit in a counterclockwise direction takes a position at numeral 8. Since, as is described hereinabove, neighboring spiral units are so arranged as to cause respective ends to
 5 overlap one another in a circumferential direction, undesired phenomenon in which the bubbles 10 and the bubble adhered microorganism granules 12 rise shortly is suppressed or at least minimized.

[0053] It is to be noted that a turning direction in which the
 10 spiral units are arranged is not limited to the above-mentioned turning direction. That is, it is not necessary that all of the spiral units are constructed to have the same turning direction. If desired, one of paired neighboring spiral units may be constructed to a turning direction that is opposed to that of the
 15 partner's spiral unit. That is, if the lower spiral unit is so arranged that when the spiral vane thereof turns in a clockwise direction, it looks as if the spiral vane moves upward from a lower position to an upper position, the upper spiral unit may be so arranged that when the spiral vane thereof turns in a
 20 counterclockwise direction, it looks as if the spiral vane moves upward from a lower position to an upper position.

[0054] Fig. 7 is a plan view of the wastewater treatment apparatus that comprises spiral units of which turning direction changes for each spiral unit. In Fig. 7, an imaginary one unit of
 25 the spiral plate consists of three (lower, middle and upper) spiral units each being a semicircular spiral plate that has an arc angle of 180 degrees with respect to an axis of the pole 2. That is, opposed ends of each semicircular spiral plate define therebetween an angle of 180 degrees. The three spiral units are
 30 arranged about the pole having respective ends spaced from one another by an angle of 30 degrees in a circumferential direction.

[0055] In the spiral plate 32 having the above-mentioned construction, if the lower spiral unit takes a position having a

leading end (viz., starting point of arc) thereof placed at numeral 12, a trailing end (viz., end point of arc) of the lower spiral unit, which is spaced from the leading end in a counterclockwise direction, takes a position at numeral 6. In this case, a leading end (viz., starting point of arc) of the middle spiral unit takes a position at numeral 5 and is spaced from the trailing end (viz., end point of arc) of the lower spiral unit by an angle of 30 degrees. Like this, a trailing end (viz., end point of arc) of the middle spiral unit, which is spaced from the leading end of the middle spiral unit in a clockwise direction, takes a position at numeral 11 and is spaced from a leading end (viz., starting point of arc) of the upper spiral unit, which takes a position at numeral 12, by an angle of 30 degrees. A trailing end (viz., end point of arc) of the upper spiral unit, which is spaced from the leading end of the upper spiral unit in a counterclockwise direction takes a position at numeral 6.

[0056] As is described hereinabove, neighboring spiral units are so arranged as to cause respective ends to be angularly spaced from one another in a circumferential direction, and thus, undesired phenomenon in which the bubbles 10 and the bubble adhered microorganism granules 12 rise shortly is suppressed or at least minimized. In the above-mentioned example, the angular distance between the neighboring ends is determined to 30 degrees. When rising from a low-positioned spiral unit to an upper-positioned spiral unit, the bubbles 10 and the bubble adhered microorganism granules 12 are violently stirred together with the upward flow of the gas/liquid mixture. In order to assuredly suppress the free and quick rising of the bubbles 10 and the bubble adhered microorganism granules 12 in the reactor vessel, the angular distance defined between the adjust ends of the neighboring spiral units should be equal to or larger than 30 degrees, and preferably, the angular distance should be around 90 degrees.

[0057] In the examples of Figs. 6 and 7, the spiral plate 32 having a specialized construction is described. However, the number of the spiral units, the angle defined between the leading and trailing ends of each spiral unit, the circumferentially
5 overlapping angle between the ends of the neighboring spiral units, the turning direction of the spiral units, and the angular distance between the ends of the neighboring spiral units are suitably determined in accordance with the size of the reactor vessel 1, etc.,. The size of gap possessed by the end of each
10 spiral unit should be equal to or larger than the size of the microorganism granules 11, that is, to such a size as not to fragment the microorganism granules 11.

[0058] In the following, operation of the first embodiment having the above-mentioned arrangement will be described.

15 [0059] Differences in operation from the first embodiment are as follows. In the third embodiment, the spiral plate 32 is arranged in the above-mentioned manner. With such arrangement, the bubble adhered microorganism granules 12 that rise at the gap of the end of each spring unit can easily
20 separate the bubbles 10 therefrom due to impact caused by collision of the granules against the spiral plate 32. Thus, the microorganism granules 11 can quickly return to the sludge bed 9 located at the lower part of the reactor vessel 1 to contribute to the biodegradation thereby to increase the wastewater treatment
25 efficiency.

[0060] When, in the above-mentioned spiral plate 32, at least paired neighboring two of the spiral units are so arranged as to have opposed turning directions, the upward flow including the bubbles 10 and the bubble adhered microorganism granules 12 is
30 forced to change its travelling direction and is violently stirred at the end where the turning direction changes. As a result, as compared with a case of uniformed upward flow caused by paired spiral units that have the same turning directions, the

phenomenon of throwing the bubbles 10 and microorganism granules 11 off the bubble adhered microorganism granules 12 is remarkable due to the violent stirring of the upward flow caused by the opposed turning directions, and thus, the bubbles 10 are easily separated from the bubble adhered microorganism granules 12 thereby to much increase the gas/solid separation efficiency.

[0061] When, as is described hereinabove, the spiral plates 32 is so arranged that the neighboring spiral units are arranged with their ends spaced apart from each other in a circumferential direction by a given angle, the settle point where the microorganism granules 12 having the bubbles 10 separated therefrom settle after the same have moved down from the end of the spiral unit toward the lower spiral unit is not a point that is near the upper side of the spiral unit located just below that end of the spiral unit, but a point that is on that same spiral unit at a down position of that end of that spiral unit. (The position of the settle point varies in accordance with both the angle defined by leading and trailing ends of the spiral unit (viz., spiral vane) and the angle defined by the trailing end of the spiral unit and the leading end of the neighboring spiral unit that is spaced from that spiral unit in the circumferential direction. For example, in case wherein the angle defined between the leading and trailing ends of one (or upper) spiral unit is 360 degrees and the angle defined between the trailing end of the spiral unit and the leading end of a neighboring (or lower) spiral unit is 30 degrees, the settle point is a point located at a lower side of the neighboring spiral unit. While, in case wherein the angle defined between the leading end trailing ends of one spiral unit is 270 degrees and the angle defined between the trailing end of the spiral unit and the leading end of a neighboring spiral unit is 90 degrees, the settle point is a point that is not provided on the neighboring spiral unit but provided on another spiral unit located below the neighboring

spiral unit.) The microorganism granules 12 that have come to the settle point slip down along the upper surfaces of the spiral units and continue the slipping movement and finally return to the sludge bed 9.

5 [0062] Accordingly, in case wherein a trailing end of one spiral unit is spaced from a leading end of a neighboring spiral unit in a circumferential direction by a given angle, the microorganism granules 12 do not slide on the upper surfaces of all of the spiral units, which shortens the travelling way of the
10 microorganism granules 12 to the sludge bed 9. Thus, as compared with a case of the spiral plate 32 in which the trailing end of the upper spiral unit and the leading end of the lower spiral unit are not spaced from each other in the circumferential direction, it is possible to speedily return the microorganism
15 granules 12 having the bubbles 10 separated therefrom to the sludge bed 9. With this, the sludge bed 9 located at the lower part of the reactor vessel 1 can hold a larger amount of microorganism granules 12 for the biodegradation treatment and thus the wastewater treatment efficiency is much increased.

20 [Fourth Embodiment]

[0063] Fig. 8 is a drawing showing a fourth embodiment of the wastewater treatment apparatus of the present invention.

[0064] The construction of the wastewater treatment apparatus 100 is the same as that of the first embodiment except
25 in that in the fourth embodiment, baffle plates 15 are fixed to the lower surface of the spiral plate 3 for the purpose of baffling or obstructing the upward flow of the bubbles 10 and the bubble adhered microorganism granules 12. The spiral plate 3 is arranged about the pole 2 in a spiral manner, and the baffle
30 plates 15 are fixed to the lower surface of the spiral plate 3 to baffle or obstruct the upward flow of the bubbles 10 and the bubble adhered microorganism granules 12. The span between the baffle plates 15 is determined suitably in accordance with the

size of the reactor vessel 1 and that of the microorganism granules 11, and for example, they are arranged at intervals of 60 degrees about the pole 2 using the leading end of the spiral plate 3 as a start point. However, the span between the baffle plates 15 may be suitably determined based on a design, that is, the span may gradually increase or decrease in accordance with the position thereof.

[0065] When, after the amount of the bubbles 10 and bubble adhered microorganism granules 12 held by the baffle plates 15 becomes beyond a predetermined limit, the bubbles 10 and the bubble adhered microorganism granules 12 are forced to rise in a lower side of the spiral plate 3. In this case, holding the bubbles 10 and the bubble adhered microorganism granules 12 by the baffle plates 15 is so made as to cause the gas/solid separation of the bubble adhered microorganism granules 12 to induce an expected rising speed. For this, the height of each baffle plate 15 is determined suitably in accordance with characteristics of the wastewater, gas (bubbles) and an interfacial tension.

Furthermore, the height of each baffle plate 15 is so determined as not fragment the bubble adhered microorganism granules 12 at the time when the bubbles 10 and the bubble adhered microorganism granules 12 rush to rise after overflowing the bubble plates 15.

[0066] The width of each baffle plate 15 is the same as that of the spiral plate 3 and the baffle plate 15 extends between the pole 3 and the wall of the reactor vessel 1 without clearance. An outward end of each baffle plate 15 may have a saw tooth shape. In this case, the bubbles 10 and the bubble adhered microorganism granules 12 held by the baffle plate 15 can flow over the baffle plate 15 little by little, which suppresses or at least minimize undesired fragmentation of the microorganism granules 11. It is preferable that the above-mentioned phenomenon wherein the bubbles 10 and the bubble adhered

microorganism granules 12 overflow the baffle plate 15 is continuously made. Such continuous overflow is obtained by adjusting the volume of the bubbles 10 and the granules 12 kept by the bubble plate 15.

5 [0067] In the following, operation of the fourth embodiment having the above-mentioned arrangement will be described.

[0068] Differences in operation from the first embodiment are as follows. In the fourth embodiment, by providing the spiral plates 3 with the baffle plates 15, the upward flow of the bubbles 10 and the bubble adhered microorganism granules 12 is obstructed and thus the bubbles 10 and the granules 12 are temporarily kept by the baffle plates 15. Once the amount of the bubbles 10 and the bubble adhered microorganism granules 12 exceeds the holding limit determined by the baffle plates 15, the bubbles 10 and the bubble adhered microorganism granules 12 overflow the baffle plates 15 and instantly rise along the lower surface of the spiral plate 3. When the bubbles 10 and the bubble adhered microorganism granules 12 overflow the baffle plates 15, rapid upward flow is produced which promotes separation of the bubbles 10 from the bubble adhered microorganism granules 12.

[0069] That is, since the bubbles 10 are temporarily held by the baffle plates 15 together with the bubble adhered microorganism granules 12 and formed into larger bubbles, the bubbles 10 can speedily rise causing increase in contact impact with the microorganism granules 11, which increases the gas/solid separation effect.

[0070] When the bubbles 10 and bubble adhered microorganism granules 12 overflow a lower baffle plate 15, the bubbles 10 rise upward along the lower surface of the spiral plate 3 and arrives at an upper baffle plate 15 with a powerful upward flow. It is preferable that due to impact caused by the powerful upward flow, the bubbles 10 and the bubble adhered

microorganism granules 12 held by the upper baffle plate 15 rush to overflow the upper baffle plate 15. If this phenomenon is continuously carried out at upper baffle plates 15, separation of the bubbles 10 from the bubble adhered microorganism granules 12 is much effectively made, which brings about improvement in the gas/solid separation effect.

[Fifth Embodiment]

[0071] Fig. 9 is a drawing showing a fifth embodiment of the wastewater treatment apparatus of the present invention.

10 [0072] In the fifth embodiment of the wastewater treatment apparatus 100, the spiral plate 3 extends into the sludge bed 9.

[0073] In the following, operation of the fifth embodiment having the above-mentioned arrangement will be described.

[0074] Differences in operation from the first embodiment are as follows. In this fifth embodiment, due to the arrangement wherein the spiral plate 3 extends into the sludge bed 9, the wastewater 6 led into the reactor vessel 1 can be guided to the sludge bed 9 along the spiral plate 3. As compared with the case of the first embodiment, the time for which the wastewater 6 contacts the microorganism granules 11 in the sludge bed 9 is increased, and thus, undesired short flow wherein the wastewater 6 is forced to flow directly upward from the sludge bed 9 and thus discharged from the sludge bed 9 in a short time is suppressed. That is, in this embodiment, a contact/mixing effect of the microorganism granules 12 relative to the wastewater 6 is increased. For leading the wastewater 6 to the sludge bed 9, there are various methods, one being a method in which a plurality of openings are formed in the lower part of the reactor vessel 1 through which the wastewater 6 is led into the vessel 1 and guided upward, and the other being a method in which an opening is formed in the lower part of the reactor vessel 1 through which the wastewater 6 is horizontally led into the sludge bed 9. However, irrespective of the leading method of the

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wastewater 6, the enforced guiding of the wastewater 6 to the sludge bed 9 using the spiral plate 3 causes the flow of the high SS wastewater to have no stagnant portion and thus, undesired blockage of the reactor vessel which would be caused by such stagnant portion is suppressed and thus the contact/mixing effect in the sludge bed is increased. In the above-mentioned example, the spiral plate 3 extends into the sludge bed 9. However, if desired, a spiral part embedded in the sludge bed 9 may of a separate type.

10 [Sixth Embodiment]

[0075] Fig. 10 is a drawing showing a sixth embodiment of the wastewater treatment apparatus of the present invention.

In the sixth embodiment of the wastewater treatment apparatus 100, semicircular spiral plates 32 are set in the sludge bed 9. Each spiral plate 32 is the same as the spiral plate 32 used in the above-mentioned third embodiment.

15 [0076] Differences in operation from the first embodiment are as follows. In the sixth embodiment, the spiral plates 32 are set in the sludge bed 9. Due to provision of the spiral plates 32 in the sludge bed 9, the wastewater 6 led into the reactor bed 1 can be guided to the sludge bed 9 along the spiral plate 32. That is, as compared with operation of the first embodiment, the contact time for which the wastewater 6 contacts with the microorganism granules 12 in the sludge bed 9 is increased and thus, undesired shorten flow of the wastewater 6 in the sludge bed 9 is suppressed, and thus, the contact/mixing effect of the microorganism granules 11 to the wastewater 6 is increased. Furthermore, since the spiral plate 32 is constructed of a plurality of spiral units, the wastewater 6 can be enforcedly guided by the spiral plate 32 causing the flow of the high SS wastewater to have no stagnant portion and thus, undesired blockage of the reactor vessel 1 which would be caused by such stagnant portion is suppressed and thus the contact/mixing effect in the sludge

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bed is increased. Furthermore, by practically using the gaps provided between ends of the spiral units, separation of the bubbles 10 from the bubble adhered microorganism granules 12 is easily carried out and thus, undesired reduction of microorganism granules 11 in the sludge bed 9, which would be caused by escape or rising of the granules 11 from the sludge bed 9, is suppressed, and thus the biodegradation treatment effect is increased.

[0077] In the above, detailed description has been directed to only the embodiments described. However, various modifications to the embodiments are possible to those skilled in the art within the technical scope defined by the present invention. That is, it is a matter of course that such modifications belong to the scope of claims.

[0078] In the above description, the reactor vessel 1 is of a cylindrical and sealed construction. However, the vessel is not limited to such cylindrical one. That is, the vessel 1 may be prismatic in shape having a polygon shape in cross section. Furthermore, if there is no need of collecting gas, the vessel may be of an open type.

[0079] Materials of the reactor vessel 1, the pole 2 and the spiral plates 3, 31 and 32 are those that are resistant to corrosion, which are for example, concrete, metals, plastics and so on.

[0080] In the above-mentioned third embodiment, a spiral plate 32 of which leading and trailing ends define therebetween an angle of 180 degrees is described. However, the angle between the leading and trailing ends may be suitably determined by design.

[0081] In the first to sixth embodiments, only a single type spiral plate is described in detail. However, if desired, that is, in accordance with the size of the reactor vessel 1 and/or the load of the wastewater treatment apparatus, a double or more type spiral plate may be used for producing a multi-spiral construction.

That is, by displacing the leading ends of the spiral plates, it is possible to mount in the vessel double type, triple type or more type spiral plates. In this case, the interior of the reactor vessel 1 can be divided into two or more spaces. As a result, the gas/solid separation effect is increased and the function of the wastewater treatment apparatus is increased.

DESCRIPTION OF REFERENCE NUMERALS

[0082] 1....reactor vessel

2....pole

10 3, 31, 32....spiral plate

44...SS trap

5....water pump

6....wastewater

7....treated water

15 8....generated gas

8a...space provided at upper part of reactor vessel

9....sludge bed

9a....upper surface of sludge bed

10....bubbles

20 11....microorganism granules

12....bubble adhered microorganism granules

13....moving direction of bubbles and bubble adhered microorganism granules

14....moving direction of microorganism granules

25 15....baffle plate

16....settling direction of microorganism granules having bubbles separated therefrom

CLAIMS

1. A wastewater treatment apparatus that includes a reactor vessel that has microorganism granules deposited in a lower stratified part thereof to cause the microorganism granules to make a biodegradation treatment to wastewater that has been led to the microorganism granules through an inlet opening formed in a lower part of the reactor vessel, treated water produced as a result of the biodegradation treatment being discharged from a treated water outlet part,
which is characterized in that a spiral plate is provided which extends from the side of the inlet opening toward the side of the treated water outlet part.
2. A wastewater treatment apparatus as claimed in Claim 1, which is further characterized in that the spiral plate has a pole disposed therethrough, the pole extending along an axis of the reactor vessel.
3. A wastewater treatment apparatus as claimed in Claim 1 or 2, which is characterized in that upper and lower surfaces of the spiral plate incline upward in a direction from an axial part of the spiral plate to a wall of the reactor vessel.
4. A wastewater treatment apparatus as claimed in Claim 1, 2 or 3, which is further characterized in that the spiral plate comprises a plurality of spiral units and mutually neighboring ends of neighboring two spiral units are overlapped by a given angle in a circumferential direction.
5. A wastewater treatment apparatus as claimed in Claim 1, 2 or 3, which is further characterized in that the spiral plate comprise a plurality of spiral units, at least paired neighboring

two of the spiral units are so formed as to have opposed turning directions and mutually neighboring ends of the paired neighboring two spiral units are spaced apart from each other by a given angle in a circumferential direction.

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6. A wastewater treatment apparatus as claimed in one of Claims 1 to 5, which is further characterized in that baffle plates are provided to the lower surface of the spiral plate to baffle and obstruct upward flow of bubbles and bubble adhered microorganism granules.

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7. A wastewater treatment apparatus as claimed in one of Claims 1 to 6, which is further characterized in that the spiral plate has a portion embedded in a sludge bed that is composed by the microorganism granules deposited in the lower stratified part of the reactor vessel.

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