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DRAWINGS ATTACHED

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(54) TREATMENT OF WATER CONTAINING ORGANIC WASTE MATTER

(71) We, KURITA WATER INDUSTRIES LIMITED, a Japanese body corporate of No. 1, Koraibashi 3-chome, Higashi-ku, Osaka-shi, Japan, do hereby declare the invention,

for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to methods for treating organic-waste water, (by which is meant water contaminated with waste products of organic origin, e.g. sewage) for reducing its biological oxygen demand, (B.O.D.).

As a method for treating organic-waste water, e.g. sewage, supernatant liquor effluent from night-soil digesters, and organic-waste water produced in industrial plants, the conventional 'activated sludge process' which comprises aeration subsequent to mixing the organic-waste water with activated sludge has been popular. This method, however, requires an air-distributing process to introduce air for aeration and regulation of the quantity of air distributed constitutes one of the most important requirements. Moreover, fluctuations in the load of the organic-waste water or changes in the kinds of organic matters contained therein may affect the micro-organisms in the activated sludge and cause a condition known as 'bulking'. This may result in the treatment becoming ineffective or in fluctuations of quality in the post-treatment water. Hence, it has been difficult to stabilise the conditions for treatment.

The present invention provides a method of treating organic-waste water which comprises bringing activated sludge containing denitrifying bacteria into contact with the organic-waste water in the presence of nitrate ions and/or nitrite ions and keeping the resultant mixture in an anaerobic state to decompose the organic matter contained in the organic-waste water. Herein, the wording 'in the presence of nitrate ions and/or nitrite ions' includes such cases where, for example: the nitrate and/or nitrite is added to and mixed with the organic-waste water to form a solution before the contact with the activated sludge; the organic-waste water originally contains the nitrate ions and/or nitrite ions; or the organic-waste water is mixed with further waste water containing nitrate and/or nitrite before contact with the activated sludge. Thus, a state is produced wherein nitrate ions and/or nitrite ions exist in a liquid mixture comprising the waste water and the denitrifying sludge.

As to the means for bringing the organic waste water into contact with the denitrifying activated sludge, an alternative to mixing both together within a tank is first to form a denitrifying activated sludge layer within a cylindrical vessel and then to cause the organic-waste water containing nitrate ions and/or nitrite ions to infiltrate into the denitrifying sludge layer from the bottom to the surface thereof. Denitrifying bacteria are so-called facultative anaerobic bacteria which solely utilize dissolved oxygen for respiration if there exists a sufficient quantity of dissolved oxygen available, whereas when there is no dissolved oxygen available, they act to reduce nitrate or nitrite ions and utilize the resultant chemical oxygen, thereby decomposing organic matters through oxidation. These denitrifying bacteria, which exist plentifully in soil, waste water, and activated sludge, are heterotrophic bacteria and capable of not only decomposing organic compounds through oxidation into inorganic matters but also forming sludge and proliferating.

Denitrifying activated sludge to be employed in the present invention may be acclimated by such means as, for example, employing returned sludge produced in a disposal plant as a result of the activated sludge process for treatment of supernatant liquor effluent from an anaerobic digester treating night-soil, sewage and other industrial waste waters or a soil

of high organic nitrogen content and mixing therewith the organic matter of the kind to be decomposed in the organic-waste water and further adding thereto nitrate and/or nitrite ions, and keeping this sludge in an anaerobic state. The kinds of bacteria contained in the denitrifying sludge include such denitrifying bacteria as *Bacillus denitrificans, Bacterium denitrificans, Pseudomonas denitrificans, Pseudomonas stutzeri, Spirillum,* and the like.

As for the nitrate to be employed, sodium nitrate, potassium nitrate, ammonium nitrate, and the like are suitable.

Examples of the method of the invention will now be given together with a description of suitable apparatus for performing the method with reference to the accompanying diagrammatic drawings in which:—

Fig. 1 shows a vertical sectional view of one apparatus and

Fig. 2 shows a vertical sectional view of another apparatus.

Fig. 1 shows an apparatus for treating waste water by mixing the organic waste water with denitrifying activated sludge within a tank to bring them into contact with each other. In order to treat an organic-waste water, denitrifying activated sludge is preliminary acclimated by means of this apparatus and the process of treating the waste water follows thereon.

Activated sludge produced from sewage treatment or produced from night-soil treatment and the organic-waste water are supplied to the reaction tank 1 and mixed therein. The mixed liquor suspended solid (M L S S) within this reaction tank on this occasion is 1,000—4,000 ppm and $B.O.D._5$ added thereto is several times the amount of M L S S. It is necessary to add to this mixture nitrate and/or nitrite ions, as a source of oxygen supply, to the extent that the quantity of nitrate and/or nitrite ions added will provide more than 0.5 Kg of oxygen per 1 kg of $B.O.D._5$ of the organic-waste water. Subsequently, the processed mixture is stirred with stirrer 2 and acclimated for about one week to cause denitrifying bacteria to proliferate. The speed of stirring is slow, e.g. 2—5 rpm so that it suffices to prevent sludge from precipitating on the bottom of the reaction tank while augmenting the contact between the waste water and the denitrifying activated sludge. Intensive stirring is undesirable as it causes air to dissolve in the mixture which hampers nitrate-respiration therein.

Upon completing the activated denitrifying sludge acclimation, decomposition of organic matter contained in the organic-waste water is effected by utilising nitrate-respiration of denitrifying bacteria, by continuously feeding the organic-waste water through the raw feed pipe 4 and solution of nitrate and/or nitrite ions through the chemical agents feed pipe 5, respectively, to the treated sludge and mixing it therewith, maintaining the anaerobic state of the liquid mixture within the reaction tank throughout the operation as when acclimating the activated denitrifying sludge. The liquid mixture within the reaction tank 1 is separated into sludge and supernatant liquid in the precipitation chamber 3, and the supernatant liquid is discharged through the drain-pipe 6, while the precipitated sludge is returned to the reaction tank 1. It is noted, however, than when the precipitation chamber 3 is to be installed apart from the reaction tank 1, it is necessary to provide a return pipe for sending the precipitated sludge back to the reaction tank 1.

The supply of waste water to the reaction tank is so regulated as to stabilize the B.O.D. loading in the range of 3—4Kg and the quantity of nitrate and/or nitrite to be employed is more than 0.5 Kg in terms of oxygen per lkg of B.O.D. of the waste water to be treated. The reaction tank is so designed that denitrifying bactria may decompose organic compounds into inorganic material by utilizing the oxygen in the nitrate and/or nitrite and, at the same time, nitrate nitrogen or nitrite nitrogen may be gasified and discharged from the system as nitrogen gas.

As for the temperature and pH value of the liquid mixture within the reaction tank, it is desirable to keep the former in the range of 20—30°C and the latter in the range of 7—9 but there is no necessity for regulating them particularly.

Inasmuch as the treating method according to the present invention does not require any air distribution whatever, there is no necessity for providing any blower or air-distribution pipe, and simple mixing of the nitrate and/or nitrite with the sludge and subsequent stirring will suffice. Drawbacks of conventional activated sludge process such as the diffusion of bad-smelling gas owing to air-distribution and the noise made by the blower have been reduced by the present invention. Moreover, denitrifying activated sludge in the present invention being anaerobic sludge, does not give rise to 'bulking', and moreover, it is capable of maintaining normal conditions suitable for treatment and accordingly no particular operation is required. Also, as compared with conventional activated sludge processes, the B.O.D. loading per capacity of the reaction tank can be augmented (in the conventional processes it has been in the range of 1—2kg B.O.D.), and it is possible to perform high-rate treatment with a reaction tank of relatively small capacity.

When waste water containing nitrate ions and/or nitrite ions is employed in lieu of nitrate and/or nitrite solution in the foregoing treatment, it becomes possible to perform simultaneous treatment of organic waste water and waste water containing nitrate or nitrite ions. Furthermore, in certain plants

where the waste water contains both the organic matter and the nitrate and/or nitrite ions, there may be cases where waste water treatment is feasible without employing any additional nitrate.

Next, the process of forming a denitrifying activated sludge layer preliminarily within a vessel and subsequently causing organic waste water containing nitrate ions and/or nitrite ions to infiltrate into the denitrifying sludge layer from the bottom toward the upper part thereof will be described.

The vessel to be employed for the method in the present invention is preferably a cylindrical tower-type one.

The cylindrical tower-type vessel is first packed with packing materials, such as broken stone or gravel, and then denitrifying activated sludge is caused to adhere onto the surface of the packing material to form a sludge layer. Subsequently, organic-waste water containing nitrate ions and/or nitrite ions is blown upward from the bottom of said vessel by means of a pump or a headtank and brings the waste water into contact with denitrifying activated sludge adherent to the packing material and causes the nitrate ions and/or nitrite ions to decompose. Organic compounds within the waste water are simultaneously decomposed, while newly formed sludge is caught by the packing material and the denitrifying activated sludge adherent to the packing material. The treated water flowing out from the upper part of the vessel does not contain any denitrifying activated sludge and can be discharged as it is. Furthermore, in order to discharge any excessive sludge adhered to the packing material, an outlet may be provided at the middle or the bottom of the vessel so as to allow excessive sludge to be automatically discharged by virtue of water pressure whenever feeding of waste water is suspended and the outlet is opened.

As an alternative to the foregoing method, the so-called sludge blanket type treating process may be adopted. According to this process, the cylindrical vessel is packed with denitrifying activated sludge as without using any packing material, so as to form a layer, and the resultant sludge layer is stable since the denitrifying sludge is relatively heavy. Organic waste water containing nitrate ions and/or nitrite ions is fed from the bottom of the vessel by means of a pump or a headtank to bring said water into contact with the sludge and cause nitrate ions and/or nitrite ions contained therein to be reduced to N_2 gas. In this case, upward flow of waste water at a fixed speed will bring about formation of a layer of activated denitrifying sludge within the vessel on account of the large specific gravity of that sludge. Inasmuch as any great change in the speed of waste water flow may put the sludge layer into disorder, it is necessary to maintain an appropriate speed of the waste water feed.

In general, activated sludge the main constituent of which is denitrifying sludge is relatively heavy, so that when waste water is caused to flow upwards, sludge suspended within the water is prone to adhere to the packing material and, as a result, a stable layer of sludge may be formed. On the contrary, when waste water is caused to flow downwards, sludge is apt to become detached from the packing material and it is difficult to obtain a stable layer of sludge, and therefore this process is undesirable. In a sludge blanket type treating process, too, a downward flow of waste water may cause sludge to settle with a high density in the lower part of the vessel and make it necessary to apply a high water pressure to expedite the flow of waste water. In this process also a downward flow is unsuitable.

When packing material is employed, even if the specific gravity of the denitrifying activated sludge is relatively small, a sludge layer can be kept in a stable condition because of the adhesion of the sludge to the packing material. Thus the sludge will not be washed away even when the speed of waste water flowing into the vessel is increased, this ensures uniform quality of treated water. When packing material is not employed, the effective area where denitrifying activated sludge and waste water come in contact with each other increases to the extent corresponding to the volume of packing material when it is employed, so that the vessel as a whole can be effectively utilized and the efficiency of waste water treatment be enhanced.

By the present invention, nitrate and/or nitrite ions contained in waste water cause denitrifying bacteria within the denitrifying activated sludge to undergo nitrate-respiration, whereby organic matters within said waste water are decomposed and gas such as nitrogen and nitric oxide is evolved. In other words, nitrous or nitric nitrogen contained in the waste water is gasified and removed so that the waste water is made harmless and at the same time organic matter is removed from the water.

In addition, organic-waste water treatment is performed without aeration within a tank or vessel, so that it can be put into practice without regard to such restriction as the location of a settling tank and by means of very simple processes with no requirement for any special apparatus; therefore it is extremely economical.

The present invention will be further described in connection with preferred Examples.

EXAMPLE 1

Raw organic-waste water containing 7,100 ppm of $B.O.D._5$ separated from solid matters

was fed to the reaction tank shown in Fig. 1, and by adding thereto sodium nitrate solution and activated sludge produced by sewage treatment, acclimation of denitrifying activated sludge was performed. Treatment was conducted by successively feeding the sewage and sodium nitrate solution. After treatment comprising a retention period of 24 hours, an added quantity of sodium nitrate of 13,000 ppm, M L S S of 3,700 ppm, and a $B.O.D._5$ loading of 3.6 $kg/m^2.day$, the B.O.D. of treated water became 520 ppm. Most of the B.O.D. of the treated water consisted of suspended solid, and could be separated by a centrifugal separation process, the residual B.O.D. was 50 ppm. Furthermore, when treatment was conducted by employing 20,000 ppm of sodium nitrite in lieu of sodium nitrate without changing other conditions, the resultant B.O.D. was 530 ppm.

Example 2

In this example the apparatus as shown in Fig. 2 was used and employed packing material. The apparatus comprised a tower 1, having an inlet 2 for waste water and an outlet 3 for treated water, a gas separation device 4, packing material 5 packed inside the tower, and pump 6 for use in feeding waste water. The tower of the apparatus was 15 cm in diameter and 170 cm high. It was packed with 3—7 cm broken stones from the bottom up to the top and had an effective capacity of 19.5 litres (with space ratio 61.7%).

To serve as waste water to be treated, a solution was prepared by dissolving 1g of skimmed milk in 1 litre of tap-water and adding to the resultant mixture 2g of sodium nitrate.

At the beginning, activated sludge (returned sludge produced in the disposal plant as a result of an activated sludge process for treatment of supernatant liquor effluent from an anaerobic digester treating night-soil) was fed to the tower 1 from its upper part by means of a pump (not shown in the drawing) thereby causing sludge to adhere to the surface of packing material 5, and subsequently waste water was continuously fed into the tower from pipe 2 through the heat exchanger 7 by employing the pump 6 at the rate of 57 litres per day. Sodium nitrate contained in the waste water was utilized as a source of oxygen for denitrifying bacteria, and the sodium nitrate utilized was reduced to gas and moved upwards through the gaps of packing material together with waste water to go into the gas liquor separation tank 4 through pipe 3 to be separated into gas and treated water.

In this example, the C.O.D. of waste water employed averaged 1,200 ppm, and that of sodium nitrate averaged 1,500 ppm. The result was analyzed as shown in Table 1, C.O.D. of treated water and nitrate nitrogen was 210 ppm and 40 ppm, respectively, and the rate of C.O.D. removal was about 83%.

The treated water obtained contained 75 ppm of suspended solids and was comparatively clear.

Table 1

Item of Analysis	pH	C.O.D. ppm	S.S. ppm	NO_3—N ppm	B.O.D. ppm
Untreated Waste Water	7.2	1,200	0	250	1,020
Treated Waste Water	7.9	210	75	40	100

Example 3

In this example, the treatment used the sludge blanket type process. The same tower as in Example 2 was employed, but, no packing material was used and 13 litres of activated sludge were packed intact within the tower. The quality and quantity of waste water employed were the same as in Example 2. Feeding of waste water by upward flow caused sludge to swell by about 20% of its volume in a stationary state, but the resultant sludge blanket was stable. Gas generated by reduction of nitrate ions ascended linearly infiltrating the sludge to escape away from the sludge blanket. The upper half of the tower is so devised as to permit suspended solids to make a natural precipitation there after coming up through the sludge blanket, but throughout the treatment period in this Example there was seen no such sizable sludge as to make a natural settling therein.

The analytical result of the treatment is shown in Table 2. It is to be noted that the C.O.D. of the resultant treated water was 96.4 ppm and B.O.D. was 17.0 ppm, and accordingly, the water was clear. Suspended solids (S.S.) was 60.0 $\pm$ 8.3 ppm and showed a stable value.

TABLE 2

Item of Analysis	pH	C.O.D. ppm	S.S. ppm	NO_3—N ppm	B.O.D. ppm
Untreated Waste Water	7.2	1,200	0	250	1,020
Treated Waste Water	7.9	96.4	60	14	17.0

WHAT WE CLAIM IS:—

1. A method of treating organic-waste water (as hereinbefore defined) which comprises bringing activated sludge containing denitrifying bacteria into contact with the organic-waste water in the presence of nitrate ions and/or nitrite ions and keeping the resulting mixture in an anaerobic state to decompose organic matter contained in the organic-waste water.

2. A method as claimed in claim 1, wherein the nitrate and/or nitrite ions are added to the organic-waste water and mixed therewith to form a solution before the contact with the activated sludge.

3. A method as claimed in claim 1, wherein the organic-waste water is mixed with further organic-waste water already containing nitrate ions and/or nitrite ions before the contact with activated sludge.

4. A method as claimed in claim 1, wherein the organic-waste water to be treated already contains the nitrate and/or nitrite ions.

5. A method as claimed in any preceding claim, wherein the pH of the system is maintained from 7 to 9 during the treatment.

6. A method as claimed in any preceding claim, wherein the contact between the activated sludge and the organic-waste water is effected by mixing them together in a tank.

7. A method as claimed in any of claims 1 to 5, wherein the contact between the activated sludge and the organic-waste water is effected by causing the organic-waste water to pass upwardly through an activated sludge layer within a vessel in which said layer has been formed.

8. A method as claimed in claim 7, wherein the activated sludge layer comprises a covering of the activated sludge adherent to the surface of packing material.

9. A method as claimed in claim 7, wherein the activated sludge layer consists of a sludge blanket.

10. A method of treating organic-waste water as claimed in claim 1 substantially as described in any of the foregoing Examples.

11. Organic-waste water after treatment by the method of any preceding claim.

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2. A method as claimed in claim 1, wherein the nitrate and/or nitrite ions are added to the organic-waste water and mixed therewith to form a solution before the contact with the activated sludge.

3. A method as claimed in claim 1, wherein the organic-waste water is mixed with further organic-waste water already containing nitrate ions and/or nitrite ions before the contact with activated sludge.

4. A method as claimed in claim 1, wherein the organic-waste water to be treated already contains the nitrate and/or nitrite ions.

5. A method as claimed in any preceding claim, wherein the pH of the system is maintained from 7 to 9 during the treatment.

6. A method as claimed in any preceding claim, wherein the contact between the activated sludge and the organic-waste water is effected by mixing them together in a tank.

7. A method as claimed in any of claims 1 to 5, wherein the contact between the activated sludge and the organic-waste water is effected by causing the organic-waste water to pass upwardly through an activated sludge layer within a vessel in which said layer has been formed.

8. A method as claimed in claim 7, wherein the activated sludge layer comprises a covering of the activated sludge adherent to the surface of packing material.

9. A method as claimed in claim 7, wherein the activated sludge layer consists of a sludge blanket.

10. A method of treating organic-waste water as claimed in claim 1 substantially as described in any of the foregoing Examples.

11. Organic-waste water after treatment by the method of any preceding claim.

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