

APPARATUS AND METHOD FOR WASTEWATER TREATMENT

FIELD OF THE INVENTION

- 5 The present invention relates to an apparatus and method for wastewater treatment. In particular, the apparatus and method is suited for biological treatment of wastewater and will be described in such a context.

BACKGROUND ART

- 10 Throughout the specification, unless the context requires otherwise, the word “comprise” or variations such as “comprises” or “comprising”, will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

- Furthermore, throughout the specification, unless the context requires
15 otherwise, the word “include” or variations such as “includes” or “including”, will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

- There exist a variety of methods for wastewater treatment including chemical methods such as activated carbon absorption, chemical oxidation; or biological
20 methods utilizing aerobic or anaerobic microorganisms. Chemical methods are relatively costlier and may not be very effective due to the high concentration of organic contaminants in the wastewater. Biological treatment is typically preferred due to its cost effectiveness over chemical treatment or other physical methods.

- 25 Amongst biological treatment, anaerobic treatment systems like upflow anaerobic sludge blanket (UASB) or expanded granular sludge bed (EGSB) are much less costly than aerobic treatment for wastewater where the wastewater to be treated contains high concentration of organic contaminants (i.e. at chemical oxygen demand (COD) levels of more than 1,000 ppm). This is due to
30 the UASB/EGSB’s relatively high efficiency in treating high organic content

wastewater. However, such anaerobic treatment processes do not show much advantage over aerobic process for treating wastewater containing low concentration of organic contaminant because the efficiency declines at COD level below 1000ppm.

- 5 Aerobic biological treatment is preferred for treating wastewater having COD of less than 500ppm, such as municipal sewage. However aerobic biological treatment is still relatively expensive for treating wastewater with COD between 500ppm to 1000ppm, partially caused by high oxygen demand, high bio-sludge production and high chemical consumption. There exists a gap for biological
10 treatment systems for wastewater having a COD of between 500ppm to 1000ppm, in which both aerobic and anaerobic treatment methods are not optimal.

Various systems have been used to bridge the above-mentioned gap by “combining” or having hybrids of both aerobic and anaerobic treatment
15 methods. In these hybrid systems, equalization tanks having a large enough capacity is adopted to cater for high fluctuation of wastewater quality and quantity. The purpose of using equalization tank for wastewater treatment facilities is to dampen organic fluctuations to prevent shock loading of biological system, minimize or control fluctuations in wastewater flow rate. This is
20 especially relevant in industrial wastewater treatment. Such equalization tank is operable to equalize flow or concentration, or both. In terms of flow equalization, cumulative flow versus time is a factor to determine maximum volume with respect to constant discharge line. In terms of concentration equalization, an equalization basin/tank may be sized to restrict the discharge to
25 a maximum concentration. For industrial wastewater, the retention time can vary from hours to days. The great volume of equalization tank can cost as high as more than one third of total civil construction cost of wastewater plant. As such there is a need to reduce such cost associated with industrial wastewater treatment.

Conventional industrial wastewater treatment plants are described such as in US patent 6,312,599 B1 "Method of using wastewater flow equalization basins for multiple biological treatments", and PCT International publication WO02/059044 "wastewater treatment process", as well as Korean Patent
5 publication KR1020090055160, "Wastewater treatment system and a method utilizing an equalization tank and bioreactor, capable of substantially improving water treatment efficiency without adding a new reactor".

While the aforementioned patent disclosures sought to improve efficiency while not increasing cost, they generally describe methods that directly link an
10 equalization tank to an aeration reactor. However, in operation, as the anaerobic sludge in the equalization tank is in suspended solid form, the equalization has to be operated in batch form with very big hydraulic retention time or in a continuous mode with low efficiency. For the batch operation mode, after wastewater enters the equalization tank in which anaerobic
15 microorganisms are suspended, it has to be stopped for a certain period or duration for the anaerobic microorganisms to settle and properly separated from water. For the continuous operation mode, because of continuous washout of the anaerobic microorganisms, the amount of the anaerobic microorganisms is limited and the efficiency is low. For example, as mentioned by US patent
20 6,312,599, the flow equalization of 2-to-6 day wastewater inflows to produce substantially uniform 7-day outflows. As the equalization tank directly contacts to downstream aerobic reactor, when the equalization tank is upset and anaerobic sludge overflows to the downstream aerobic reactor, foaming at the aerobic reactor will become an issue.

25 It is an object of the invention to alleviate the abovementioned problem at least in part. In particular it is an object of the invention to reduce operation treatment cost in terms of power and sludge generation in the aerobic reactors.

SUMMARY OF THE INVENTION

The invention seeks to alleviate the abovementioned problem. In particular, by manipulation of the upstream anaerobic treatment, the invention reduces operation treatment cost in terms of power and sludge generation in the downstream aerobic reactors. An embodiment of the invention seeks to install a clarifier within an equalizer tank operable to function as an anaerobic hydrolysis reactor. The clarifier in the equalization tank can capture the anaerobic hydrolysis microorganisms as much as possible and washout the microorganisms which cannot survive in the water conditions in equalization tank

In accordance with an aspect of the invention there comprises an apparatus for wastewater treatment comprising an equalization tank arranged to receive wastewater for treatment and operable to function as an anaerobic hydrolysis reactor in addition to performing the equalization function; a first clarifier coupled with the equalization tank, the first clarifier operable to separate wastewater from anaerobic hydrolysis microorganisms within the equalization tank; an aerobic bioreactor coupled with the first clarifier to receive wastewater from the first clarifier; the aerobic bioreactor operable to further process the wastewater from the first clarifier; and a second clarifier operable to receive treated wastewater from the aerobic bioreactor, the second clarifier further operable to separate treated wastewater from aerobic biosludge; wherein a portion of aerobic biosludge separated by the second clarifier is recycled back to the equalization tank.

Preferably, the anaerobic hydrolysis reactor function of the equalization tank comprises chemical oxygen demand (COD) removal.

Preferably, the first clarifier is built into the equalization tank, and preferably, in this instance the first clarifier comprises a first portion to receive anaerobic sludge arising from the anaerobic hydrolysis and a second portion to receive separated wastewater.

Preferably, the second portion is in the form of a trough positioned upstream relative to the aerobic bioreactor.

Preferably, the first clarifier comprises a submersible pump for directing the separated anaerobic sludge back to the equalization tank or out of the system.

- 5 Preferably, there comprises a baffle to prevent the anaerobic sludge from flowing into the second portion.

Preferably, the equalization tank comprises at least one mechanical agitator operable to prevent suspended solid from settling in the equalization tank.

- 10 Preferably, the first clarifier is formed using concrete, carbon steel, stainless steel or fibre reinforced plastic (FRP).

Preferably, the equalization tank with hydrolysis (EQ-H tank) is operably maintained at an anaerobic condition with dissolved oxygen (DO) of less than 0.5ppm.

- 15 Preferably, the anaerobic hydraulic retention time (HRT) of EQ-H tank is from six hours to two days.

Preferably, the anaerobic hydraulic retention time of the first clarifier is from 1 hour to 4 hours.

Preferably, the mixed liquor suspended solids (MLSS) in the EQ-H tank range from 1000ppm to 10,000ppm.

- 20 Preferably, the EQ-H tank accepts industrial wastewater with pH range of 5 to 10.

Preferably, the equalization tank comprises an access cover.

- 25 In accordance with a second aspect of the invention there is a method for wastewater treatment comprising the following steps: (a.) hydrolysing wastewater anaerobically with anaerobic microorganisms; (b.) separating hydrolysed wastewater from the anaerobic microorganisms; (c.) processing the

hydrolysed wastewater aerobically, the processing forming aerobic biosludge; and (d.) recycling a portion of the aerobic biosludge for hydrolysis in step (a.)

Preferably, the step of hydrolysing wastewater is targeted to reduce the chemical oxygen demand (COD) within the wastewater.

- 5 Preferably, the step of separating hydrolysed wastewater from the anaerobic microorganisms includes the use of a clarifier.

Other aspects of the invention will become apparent to those of ordinary skill in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

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BRIEF DETAILS OF THE DRAWINGS

In order that this invention may be more readily understood and put into practical effect, reference will now be made to the accompanying drawings, which illustrate preferred embodiments of the invention, and wherein:

- 15 Fig. 1 illustrates a prior art process diagram of conventional industrial wastewater treatment plant without EQ-H process;

Fig. 2 is a system block diagram of industrial wastewater treatment plant with EQ-H process in accordance with an embodiment of the invention; and

- 20 Fig. 3 shows the results of the EQ-H process in comparison with the conventional industrial wastewater treatment plant.

Other arrangements of the invention are possible and, consequently, the accompanying drawings are not to be understood as superseding the generality of the description of the invention.

25 DESCRIPTION OF EMBODIMENTS OF THE INVENTION

In accordance with an embodiment of the invention there is an apparatus for wastewater treatment 10 comprising an equalization tank 20 arranged to

receive wastewater for treatment, first clarifier 30, an aerobic bioreactor 40, and a second clarifier 50. In addition to the typical equalization function, equalization tank 20 is operable to also function as an anaerobic hydrolysis reactor, and in particular an anaerobic hydrolysis reactor for the removal of
5 COD levels. The level of COD is taken as an indirect measure of the amount of organic compounds in water as a measure of water quality. Hydrolysis comprises metabolic activity of anaerobic bacteria that result in the transformation of particulate organic substrate into liquefied monomers and/or polymers. The equalization with hydrolysis function (hereinafter EQ-H) tank 20
10 has equalization function of smoothing the variation of water quality and quantity. In addition, the equalization tank also has the function of reducing COD concentration of the incoming industrial wastewater. This combination of equalization and COD removal function of the equalization tank 20 is termed as equalization-hydrolysis or EQ-H and the resultant tank is termed the EQ-H tank
15 20.

EQ-H tank 20 has a first inflow 22 to accept untreated industrial wastewater and outflow 24 to discharge the effluent treated industrial water from the first clarifier 30 after separating water and anaerobic sludge. The EQ-H tank 20 has a second inflow 26 to accept wasted activated aerobic biosludge from the down-
20 stream aerobic bioreactor and second clarifier 50.

EQ-H tank 20 further comprises at least one agitator 28 installed to prevent anaerobic sludge from setting at the bottom of the EQ-H tank 20. Preferably there comprise a plurality of agitators 28 installed to prevent the sludge settling at the bottom of the EQ-H tank 20. The agitators 28 are also installed in the
25 EQ-H tank 20 to equalize the fluctuation of water quality and quantity. The agitators may be mechanical agitators.

The EQ-H tank 20 is operable to be maintained at an anaerobic condition with dissolved oxygen (DO) of less than 0.5 part per million (ppm). Any anaerobic hydrolysis microorganisms known in the art would be suitable provided they are
30 able to hydrolyse the wastewater.

The first clarifier 30 is coupled with the equalization tank 20 and is operable to separate wastewater from anaerobic hydrolysis microorganisms within the EQ-H tank 20. In one embodiment, the first clarifier 30 is built into the equalization tank 20 in order to save space. The first clarifier 30 comprises a first portion 32 (S8) to receive anaerobic sludge arising from the anaerobic hydrolysis and a second portion 24 to receive separated wastewater. The second portion 24 is preferably in the form of a trough positioned upstream relative to the aerobic bioreactor 40. The first clarifier 30 comprises a submersible pump 36 for directing the separated anaerobic sludge back to the equalization tank or out of the system. In between the first clarifier 30 and second portion 24, there comprises a baffle to prevent the anaerobic sludge from flowing into the second portion 24. The baffle allows water to pass through but not larger particles and sludge that float on the surface of the first clarifier 30. The first clarifier 30 may be formed using concrete, carbon steel, stainless steel or fibre reinforced plastic (FRP).

In various embodiments the EQ-H tank 20 may comprise an access cover (not shown). Such an access cover is removable to allow a man access to the EQ-H tank 20 for maintenance of the first clarifier 30 and/or the agitators 28. Preferably, the access cover is located at the upper most roof of the EQ-H tank 20 to ensure that when it is opened there is no loss of liquid from the EQ-H tank 20. In various embodiments the access cover is an inverted U type cover placed in a water seal around its periphery to seal the access through hole cut from the upper most roof of the EQ-H tank 20. Any cover that will minimise air entering the tank would also be suitable. In various embodiments the EQ-H tank 20 may be formed of concrete. In various other embodiments the EQ-H tank 20 may be formed using carbon steel, stainless steel or fibre reinforced plastic (FRP) or any other material that will not be corroded by the hydrolysis by-products.

The aerobic bioreactor 40 is coupled with the first clarifier 30 to receive treated wastewater from the first clarifier 30, and operable to further process or treat the wastewater from the first clarifier 30. In combination with the aerobic bioreactor

40 is a second clarifier 50 operable to receive treated wastewater from the aerobic bioreactor 40, the second clarifier 50 further operable to separate treated wastewater from aerobic biosludge resultant from the wastewater treatment of the aerobic bioreactor.

- 5 A portion of aerobic biosludge separated by the second clarifier 50 is recycled back to the EQ-H tank 20 via the second inflow 26. The process is continuous until the treated wastewater is at a suitable level to be discharged. Advantageously this means that the high biosludge production of the aerobic process is reduced as it is partially feed into the anaerobic EQ-H tank 20
- 10 reducing the cost of sludge dewatering as the volume discharged from the system is reduced. Further the aerobic biosludge entering the EQ-H tank 20 helps to maintain an organic substrate and minimise dilution of the anaerobic microorganisms in the EQ-H tank 20 that may help maintain hydrolytic activity of the anaerobic microorganisms and reduce the hydraulic retention time (HRT).
- 15 The apparatus 10 will next be described in the context of the processing of wastewater, and in particular in the context of a method of utilizing industrial wastewater equalization (EQ) tank as an anaerobic hydrolysis reactor for COD removal and sludge reduction to improve downstream aerobic process performance and reduce power consumption as well as sludge production.
- 20 In operation, the following parameters of the EQ-H tank 20 and clarifier 30 apply.
- The EQ-H tank 20 is maintained at anaerobic condition with dissolved oxygen (DO) at less than 0.5ppm.
 - The anaerobic hydraulic retention time (HRT) of EQ-H tank can be 6 hours
 - 25 to several days.
 - The HRT of the first clarifier 30 can be 1 hour to 4 hours.
 - The Mixed liquor suspended solids (MLSS) in the EQ-H tank 20 can be in the range of 1000ppm to 10,000ppm.

- The EQ-H tank 20 has a COD removal efficiency in the range of 10% ~60%.
- The EQ-H tank 20 can accept industrial wastewater with pH range of 5 to 10.

5 The operation of the apparatus 10 is described with reference to both Fig. 1 and Fig. 2, wherein Fig. 1 refers to the conventional industrial wastewater treatment plant without the EQ-H process; while Fig. 2 refers to the use of apparatus 10 for industrial wastewater treatment. It is to be appreciated and understood that the volumes and operation parameters described are for illustrative purpose
10 only.

Referring to Fig. 1, the conventional industrial wastewater treatment comprises an equalization tank T1 having a volume of $10,000\text{m}^3$ coupled to an aerobic reactor T2 having a volume of $10,000\text{m}^3$. T2 is coupled to a clarifier T3 having a volume of $2,000\text{m}^3$. Mechanical agitator M1 is similar in function to the
15 agitator 28 described. An air blower M2 is used to provide the oxygen necessary for aerobic reactor T2.

In operation, wastewater (S1) discharged from chemical industrial facilities has an average concentration of COD of $1,000\text{mg/l}$ and average flow rate of $10,000\text{m}^3/\text{d}$. It is pumped to an equalization tank (T1). Mechanical agitators
20 (M1) are installed in T1 to prevent suspended solid from settling in the T1 and to equalize the fluctuation of water quality and quantity. Average quality and quantity of effluent (S2) from T1 does not change, maintaining COD of $1,000\text{mg/l}$ and flow of $10,000\text{m}^3/\text{d}$. S2 enters to an aerobic reactor (T2) and mixes with bio-sludge (microorganisms). Air blower (M2) supplies
25 air to T2. Under aeration conditions, microorganisms digest organics in S2 and convert organics as CO_2 and bio-sludge. COD concentration of wastewater in T2 decreases. The mixture (S3) of wastewater and bio-sludge enters a clarifier (T3), where water is separated from biosludge. The supernatant from T3 is treated water effluent containing COD of

100mg/L. The settled biosludge at the bottom of T3 with concentration of around 8000mg/L is partially (S5) pumped to T2 to maintain the aerobic biosludge concentration in T2, and the excess aerobic biosludge (S6) is discharged out of biological treatment system and goes to sludge dewatering equipment to reduce water content in the sludge for further disposal.

It is to be appreciated that the power consumption for air blower and volume of wasted aerobic sludge are determined by the COD load (kgCOD/day) to the aerobic tank. Higher COD load needs more power consumption and generates more wasted sludge.

In comparison, referring to Fig. 2 with the apparatus 10 and the EQ-H anaerobic hydrolysis process, wastewater (S1') discharged from chemical industrial facilities has an average COD concentration of 1,000mg/L and an average flow rate of 10,000m³/d. It is pumped to the EQ-H tank 20. However, as a significant amount of anaerobic hydrolysis microorganisms (more than 30,000kg for a volume of 10,000m³) is present in the EQ-H tank 20, these anaerobic hydrolysis microorganisms will digest the bio-organic waste in the wastewater. In various embodiments the volume of anaerobic microorganisms is preferable more than 2kg/L, or more than 3kg/L, or more than 4kg/L any volume of anaerobic microorganisms would be suitable that keeps the microorganisms close to the S-phase of growth and maximizes hydrolytic activity. Average COD concentration of effluent (S2') exiting from the EQ-H tank 20 will hence be decreased. Further, due to anaerobic hydrolysis reaction, the difficult biodegradable organic components in wastewater will breakdown and become smaller and more easily biodegradable organic compounds. The first clarifier 30 separates wastewater and anaerobic hydrolysis microorganisms. The supernatant (S2') from the first clarifier 30 overflows to downstream aerobic bioreactor 40, while the settled anaerobic hydrolysis microorganisms (S8) at the bottom of the first clarifier 30 recycles back to the EQ-H tank 20. The effluent treated wastewater S2 that enters to the aerobic reactor 40 mixes with aerobic

bio-sludge or microorganisms. An air blower 60 supplies air to aerobic reactor 40. Under aeration conditions, microorganisms digest organic compounds in S2 and convert organic compounds to carbon dioxide (CO₂) and bio-sludge. COD concentration of wastewater in the bio aerobic reactor 40 will thus further decrease. The mixture (S3) of wastewater and bio-sludge enters the second clarifier 50, where wastewater undergoing treatment is separated from biosludge. The supernatant from the second clarifier 50 is treated water effluent containing COD of 80mg/L. The settled biosludge at the bottom of the second clarifier 50 comprises concentration of around 8000mg/L is partially (S5) pumped back into the aerobic bioreactor 40 to maintain aerobic biosludge concentration in the aerobic bioreactor 40, and any excess aerobic biosludge is partially (S7) recycled back into the EQ-H tank 20 for digestion, while the remaining is discharged from biological treatment system (S6) and goes to sludge dewatering equipment to reduce water content in the sludge for further disposal.

It is to be appreciated that comparing between the conventional industrial treatment with the apparatus 10, the power consumption for air blower 60 and volume of aerobic biosludge waste are significantly decreased as the COD load (kgCOD/day) to the aerobic tank is decreased due to the pre-treatment from the EQ-H tank 20 with first clarifier 30 combination. Lesser amount of COD load will require less power consumption and generates less sludge waste.

The bench study result comparing between the conventional industrial treatment and the apparatus 10 is summarized in Fig. 3.

The COD in apparatus 10 was about 50% lower than in the conventional system. The power consumption in apparatus 10 was about three quarters of the power consumption in the conventional system. The cost of disposing of the biosludge waste was reduced by almost 50%. The consumption of chemicals in apparatus 10 was about 50% less than in the conventional system. The overall saving of all these advantages resulted in a reduction of about 30% in apparatus 10 compared to the conventional system.

It is to be understood that the above embodiments have been provided only by way of exemplification of this invention, and that further modifications and improvements thereto, as would be apparent to persons skilled in the relevant art, are deemed to fall within the broad scope and ambit of the present invention described herein. In particular:-

- The EQ-H tank 20 may comprise a plurality of compartments
- The aerobic bioreactor 40 may comprise a plurality of compartments
- The first and or second clarifiers may comprise sedimentation tanks as the first portion 32 to receive anaerobic sludge.
- pH controller or other form of controllers may be positioned at suitable locations to control the pH levels within the EQ-H tank 20.
- Valves may be positioned at suitable locations between the equalization tank, first and second clarifiers and aerobic bioreactor to facilitate and control flow of wastewater within the system. The valves may suitably be one way valves.
- It is to be appreciated that the first and second clarifiers 30, 50 may be replaced by their functional equivalents.

It would be further appreciated that although the invention covers individual embodiments, it also includes combinations of the embodiments discussed. Therefore, features described in one embodiment not being mutually exclusive to a feature described in another embodiment may be combined to form yet further embodiments of the invention.

CLAIMS

1. An apparatus for wastewater treatment comprising

an equalization tank arranged to receive wastewater for treatment and operable to function as an anaerobic hydrolysis reactor in addition to performing
5 the equalization function;

at least one mechanical agitator operable to prevent suspended solids from settling in the equalization tank;

a first clarifier built into the equalization tank, the first clarifier operable to separate wastewater from anaerobic hydrolysis microorganisms within the
10 equalization tank the first clarifier comprises a first portion to receive anaerobic sludge arising from the anaerobic hydrolysis and a second portion to receive separated wastewater wherein there comprises a baffle between the first clarifier and the second portion to prevent the anaerobic sludge from flowing into the second portion;

15 a pump for directing the separated anaerobic sludge back to the equalization tank suitable to keep anaerobic hydrolysis microorganisms close to an S phase of growth;

an aerobic bioreactor coupled with the first clarifier to receive wastewater from the first clarifier; the aerobic bioreactor operable to further process the
20 wastewater from the first clarifier; and

a second clarifier operable to receive treated wastewater from the aerobic bioreactor, the second clarifier further operable to separate treated wastewater from aerobic biosludge;

wherein a portion of aerobic biosludge separated by the second clarifier is
25 recycled back to the equalization tank.

2. An apparatus according to claim 1, wherein the anaerobic hydrolysis reactor function of the equalization tank comprises chemical oxygen demand (COD) removal.
3. An apparatus according to claim 1 or 2, wherein the second portion is in
5 the form of a trough positioned upstream relative to the aerobic bioreactor.
4. An apparatus according to any one of the claims 1 to 3, wherein the pump comprises a submersible pump.
5. An apparatus according to any one of the preceding claims, wherein the first clarifier is formed using concrete, carbon steel, stainless steel or fibre
10 reinforced plastic (FRP).
6. An apparatus according to any one of the preceding claims, wherein the equalization tank is operably maintained at an anaerobic condition with dissolved oxygen (DO) of less than 0.5ppm.
7. An apparatus according to any one of the preceding claims, wherein the
15 anaerobic hydraulic retention time (HRT) of equalization tank is from six hours to two days.
8. An apparatus according to any one of the preceding claims, wherein the anaerobic hydraulic retention time of the first clarifier is from 1 hour to 4 hours.
9. An apparatus according to any one of the preceding claims, wherein the
20 mixed liquor suspended solids (MLSS) in the equalization tank range from 1000ppm to 10,000ppm.
10. An apparatus according to any one of the preceding claims, wherein the equalization tank accepts industrial wastewater with a pH range of 5 to 10.
11. An apparatus according to any one of the preceding claims, wherein the
25 equalization tank comprises an access cover.
12. A method for wastewater treatment comprising the following steps:

(a.) equalizing the fluctuation of water quality and quantity in an equalization tank;

(b.) hydrolysing wastewater anaerobically with more than 2 kg/L of anaerobic hydrolysis microorganisms within the equalization tank;

5 (c.) separating hydrolysed wastewater from the anaerobic hydrolysis microorganisms within the equalization tank;

(d.) processing the hydrolysed wastewater aerobically, the processing forming aerobic biosludge; and

(e.) recycling a portion of the aerobic biosludge for hydrolysis in step (b.)

10 13. A method according to claim 12, wherein the step of hydrolysing wastewater is targeted to reduce the chemical oxygen demand (COD) within the wastewater.

14. A method according to claims 12 or 13, wherein the step of separating hydrolysed wastewater from the anaerobic microorganisms includes the use of
15 a clarifier.