A PROCESS AND APPARATUS FOR TREATING WASTE WATER

1. OUTLINE OF THE INVENTION

This invention concerns a process for treating wastewater , and in a further aspect concerns an apparatus for the treatment of waste water. This invention also concerns a treatment plant for treating wastewater. The invention may find application in a range of waste water and industrial plants ranging from the domestic to the largest industrial plants and for treatment of even the most polluted waste water and also may find applications in the field of biotechnology and bioprocesses.

2. INTRODUCTION

Biological wastewater treatment like other biological processes represents, in limited time and space, what happens in Nature over a long period of time and over a large area. Since its application in the late 19th and early 20th century, the trend has been towards reducing the required time and space, producing better performance and economy in wastewater treatment plants and other bioreactors.

3. SUMMARY OF THE INVENTION

According to the present invention, as currently envisaged, there is provided a process for biological processes and treatment of waste water. The process compromises the steps of simultaneously filtering and aerating the waste water by means of two or more filtering/aerating elements. Each of the filtering/aerating elements is alternately either supplied with pressurised gas, or drained. The process has the advantage of treating waste water without a secondary, or even a primary, settling tanks and or other solids/liquid separation devices. The process also overcomes the process disruptions caused by filamentous organisms or sludge bulking. The process also increases the efficiency, by keeping the microorganism population and concentration high in the bioreactor and or aeration tank.

Another advantage of the process is that it is adaptable to use in the other aerobic biprocesses and also in some type of water treatment plant as an alternative to aeration and or ozonation plus filtration.

The pressurised gas may be air or oxygen that may contain ozone or other oxidants. The pressurised gas may be supplied in intermittent pulses or in a fluctuating stream or steady stream or any combination of the three flow regimes.

The ratio of time each filtering/aerating element is used for aeration or filtering may vary between 1 to 99% depending upon operational requirements. The frequency with which the filtering/aerating elements are changed from their aeration mode of operation to their filtering mode of operation is also dependant upon operational requirements. Filtering/aerating elements can be submerged in the process tank or located externally to the tank.

In a further aspect of the present invention, as currently envisaged, there is provided an apparatus for the treatment of waste water. The apparatus comprises of two or more filtering/aerating elements each of which has an associated pressurised gas supply and an associated effluent drain. The supplies and drains are valved and controlled such that, in use, each element is alternately supplied with pressurised gas or drained. At any given time, one or more selected elements are supplied with the pressurised gas while the reminder are drained. If filtering/aerating elements are submerged in the process tank, arrangement is made such that pressurised gas coming out of the aerated acrating/filtering elements has optimum cleansing action on the filtering surface of the acrating/filtering elements, and if the aerating/filtering elements are located externally to the process tank, arrangement is made in such a way to guide the liquid flow to the acrating element before passing through filtering elements.

The use of these elements allows for the construction of very compact waste water treatment plants or other biologically processing plants, and the size may be reduced by

up to 95% compared to the traditionally based plants such as an activated sludge plant, to obtain at least equivalent effluent quality.

The aerating/filtering elements, by virtue of their alternate aeration and filtering modes of operation, become self cleaning filters.

The aerator/filter elements may have different shapes and configurations and the configuration may vary from closed end aerator/filter elements to a flow through self–housing multi channel aerator/filter elements.

The aerator/filter elements can be constructed from various organic and inorganic materials, especially ceramic.

The pore size may vary between 0.0001 micrometers to 200 micrometers. A smaller pore size means less permeability and as a result greater surface area, more transmembrane pressure and more investment. However, it also results in better effluent quality and more stable process.

A number of different parameters have to be taken into account when designing a waste water treatment plant or other biological processing plants embodying the invention. These factors include the required economy and efficiency, the required product quality, the size of the plant, The hydraulic and organic load of the waste water and the capacity of the plant. Taking these factors into account enables a plant to be constructed from an array of the aerator/filter elements and open channels. The aerator/filter elements may be supplied with pressurised gas and drained by connecting incoming and outgoing pipes together in banks, in series or a combination of two in order to control the operation of a number of elements at a time while increasing cleaning action of the gas bubbles on the surfaces of the filtering aerator/filter elements and/or their channels. Taking into account the considerations mentioned above,the depth of the process tanks, the pressure of the gas supply and the gas and liquid flow characteristics of the porous media, allows the shape and configuration of the plant to be decided.

In a waste water treatment plant there will advantageously be two tanks connected together and incorporating arrays of aerator/filter elements as described above, internally or externally, to provide a circulation of sludge and waste water between the two tanks, one aerobic for carbonaceous oxidation and nitrification and the other multi–zone for denitrification and anaerobic digestion. Both tanks or bioreactors can be packed with high specific surface area media to maintain a long biomass retention time in the bioreactors and increase the volatile solids content of the tanks by means of attached biomass growth on the media surface.

The treatment plant has the advantage of being very compact, having low sludge production due to its anaerobic zone, being able to remove nitrogen alongside other organic matters, having a high organic loading capability and being easy to run and operate. The treatment plant is also capable of treating waste waters with different strength from municipal waste water to the very strong industrial waste waters. aerator/filter array will ensure an efficient aeration, a good quality effluent and high solid retention in the system.

Benefits of using such a combination of two tanks or bioreactors in the present invention are many. The aerobic bioreactor not only can perform the nitrification but also can perform a secondary task that is usually done after denitrification to strip the produced nitrogen gas from the effluent. This arrangement also facilitates the pH adjustment between the two bioreactors by the circulation flow. Oxygen consumed for nitrification also will be recovered in the denitrification step.

The aerobic and multi–zone bioreactors can be suspended growth, attached growth or mixed growth bioreactors utilising a combination of attached and suspended growth.

Both bioreactors can be sealed but with the anaerobic zone in unaerated bioreactor, this should be a sealed reactor with biogas collection and discharge facility on top and an

air–trap in circulation flow pass to avoid explosion hazard by preventing the air from entering aerobic tank.

When aerator/filter array or unit is located externally to the bioreactor, a suitable settling device may be located on top of the aerated bioreactor or adjacent to it to decrease the suspended solids content of the liquid before entering the aerator/filter elements array.

BRIEF DESCRIPTION OF THE DRAWINGS

Example of the invention will now be described with reference to the accompanying drawings, in which:

figure 1 is a schematic diagram showing two acrating/filtering elements embodying the present invention;

figure 2 is a schematic diagram showing a cross section of a self–housing multi channel aerating/filtering element embodying the present invention;

figure 3 is a schematic diagram showing some possible shapes of the channels of the self–housing aerating/filtering elements embodying the present invention;

figure 4 is a schematic diagram showing some possible shapes of the self–housing aerating/filtering elements embodying the present invention;

figure 5 is a schematic diagram of an array of aerator/filter elements embodying the present invention;

figure 6 is a schematic diagram of an array of self–housing multi channel aerator/filter elements embodying the present invention;

figure 7 is a schematic diagram of a treatment plant embodying the present invention.

BEST MODES FOR CARRYING OUT THE INVENTION

Referring now to figure 1 two aerating/filtering elements 1 and 2 are made of porous materials with specific pore size. There are two pipes connected to each element, one to supply pressurised gas and the other to carry away effluent. Pressurised gas is

supplied to element 1 through pipe 3 via gas valve 4, and to element 2 through pipe 5 via gas valve 6. Effluent, permeated liquid, is removed from element 1 through pipe 7 via drain valve 8, and from element 2 through pipe 9 via drain valve 10. In use the elements are immersed in a tank or located externally to the process tank.

While one of the elements is operating as an aerator the other will be operating as a filter. For example when element 1 is operating as an aerator, gas valve 4 will be open while drain valve 8 will be closed. Gas will be pumped into the interior of the element and forced through its pores in order to aerate the surrounding liquid.

At the same time element 2 will be operating as a filter so drain valve 10 will be open and gas valve 6 closed. Filtered liquid will be permeating into the interior of element 2 through its pores and escaping through the drain pipe 9.

After a designated period of time the gas and drain valve positions will be reversed and element 1 will then act as a filter while element 2 acts as an aerator.

Switching the mode of operation from filtering to aeration will result in cleaning off the cake which is formed over the pores of the element while it acts as a filter. In addition the pressurised gas can often unblock the pores.

In practice the aerator/filter elements may have different shapes and configurations. Further aspect of present invention is one of such configurations. It is especially preferable when the aerator/filter array is located externally to the process tank to use the self–housing multi channel aerator/filter elements in the aerator/filter array.

One of their biggest advantage of these elements/modules are their lower cost because they do not need any separate housing for collection of permeate. These aerator/filter elements can be made from different materials especially from inorganic materials like ceramic.

Figure 2 shows a schematic cross section of a self–housing aerator/filter element. Support layer 11 has a much larger pores than the skin layer 12. Support layer 11 also

occupies most of the element's bulk while skin layer 12 is very thin. Skin layer is laid on the surface of the element/module channels. Most of the channels like channel 13 are channels having the skin layer with the small pores. The liquid to be filtered is passing through these channels. Some channels like channel 14 do not have skin layer and have larger pores the same as support layer. Thus the filtrate that is passing through pores of the skin layer of channel 13 into the support layer's larger pores, flows into the channel 14 and subsequently is removed from the element through channel 14. The pores on the outer–side surface of the element 15 is blocked by a proper mean and filtrate can not escape through it. When aerating, the gas is forced into the channel 14 and it finds its way through the support layer and skin layer into the liquid flow that is flowing inside channel 13. At the entrance and end of channels, all the channels which have skin layer on their surface join together and form one channel. The remaining channels also join together and form one channel at one or both end of the element/module 15. Each self–housing aerator/filter element may have 2 or as many as hundreds of channels of which the majority are with the skin layer laid on their surface. The channels of self–housing aerator/filter elements may have different shapes depending on the usage and other operational parameters.

Figure 3 shows some possible shapes of the channels. A thin transition layer also may be placed between support layer and skin layer. The transition layer has a pore size larger than the skin layer and smaller than that of support layer. In reality 2 or more aerator/filter element may form a bigger aeration/filtration array or module to provide more aeration/filtration area in each unit. Self–housing elements may have different shapes depending on the usage and operational parameters as shown in figure 4.

For achieving the alternate functions of aeration and filtration when using self–housing aerator/filter elements or other flow through aerator/filter elements, two or more elements is required. The liquid flow always is guided to the aerating element first to increase the cross–flow velocity in the filtering elements channels by injecting a

substantial volume of gas bubbles into the liquid flow through aerating elements while reducing the viscosity of the flow and increasing the transverse mixing effect by lateral air bubble movements in the filtering elements channels. The porous elements may placed horizontally or vertically to improve cleaning action of gas–bubble–flow inside filtering elements channels. A set of valves which are connected to a time controller provides the necessary means for shifting the aeration task from one element to another while guiding the liquid flow to the aerating element first.

In practice there may be a large number of aerating/filtering elements having different shapes and configured to assist in self–cleaning while producing more surface area. Figure 5 shows elements 1 and 2 included in an array of further elements separated from each other by open channels indicated generally by 16. Liquid is able to flow through the open channels which allows it to mix effectively with the gas being injected into the liquid by aerating elements. If the array submerged inside the process tank, the mixed liquid and gas bubbles flows from open channel 16 directly into the bulk liquid inside the tank. When the array in figure 6 is located externally to the process tank, then the aerated liquid from channel 16 is collected and guided to the bottom of the process tank by a pipe. Another pipe carries the liquid from the tank to the other open end of channel 16 and other open channels in the array.

Exchanging the aerating and filtering operation between two neighbouring rows of elements assists in cleaning the surfaces and the pores of the elements, and carries flocs up to prevent cake formation.

It is not necessary to have valves for individual element, but the array may be set up with banks of elements with each bank controlled by one or more pressurised gas and one or more drain valves. The proportion of elements in the array acting as aerators at any time may vary say between 5 and 90%, depending upon the design parameters.

Figure 6 shows a schematic of a arrangement of self-housing multi channel aerator/filter elements in an array. Aerator/filter elements 17, 18, 19 and 20 are made of porous materials with specific pore size and surface area. There are two pipes connected to each element, one to supply pressurised gas and the other to carry away effluent. Pressurised gas is supplied to element 19 through pipe 38 via gas valve 37, and to element 20 through pipe 47 via gas valve 46. Effluent, permeated water or filtered product, is removed from element 19 through pipe 36 via drain valve 35, and from element 20 through pipe 45 via drain valve 44. While one of the elements is operating as an aerator the other will be operating as a filter. For example when element 19 is operating as an aerator, gas valve 37 is open while drain valve 35 is closed. Gas is pumped into the channels of element 19 through its porous structure and is forced through its pores in order to aerate the waste water or broth which is flowing in the channels inside element 19. Pipe 34 is carrying waste water/broth into the element 19 and pipe 39 is carrying away the aerated waste water/broth from the element 19. While element 19 is acting as an aerator valves 37, 41, 44, 22, 25, 27, 30, 31 and 33 are open and valves 35, 40, 42, 46, 21, 23, 24, 26, 28, 29, and 32 are closed. As a result waste water/broth 50 is passing through pipe 53 via valve 33 and pipe 34 and flowing through element 19 while is aerated by the gas that is supplied through pipe 38 and valve 37. Aerated liquid/broth which is containing gas bubbles leaves element 19 through pipe 39. Pipe 43 is guiding the aerated water/broth to element 20. The filtered liquid that has found its way through element 20 pores, will be carried away through valve 44 and pipe 45. Gas bubbles in the aerated water that is passing through the channels of element 20, can eliminate or decrease the chance of cake formation over the channels walls. Elements 17 and 18 also filtering the aerated water/broth along with element/module 20. After aerated water/broth is passed through elements 20,17 and 18 via valves 22 and 27, will be passing through pipe 52 via valve 31 and will leave the aerator/filter array towards the process tank through pipe 51.

After a designated period of time, aerating task will be shifted to element 20 and while elements 17, 18 and 19 are acting as filters. Switching the mode of operation from filtering to aeration will result in cleaning off the cake that is formed over the surface of the channels of element 20 while it acts as a filter. In addition the pressurised gas can often unblock the pores. for stronger effect it is more effective to change the gas supply volume for short times and in specific intervals. Supply gas can also oxidise and sterilise the structure of the aerating element.

When element 20 is acting as an aerator, the arrangement will be in such a way that by opening certain valves and closing some other valves, water/broth flow 50 passes through valve 42 and enters element 20 through pipe 43 where aeration is occurring. The aerated water/broth leaves element 20 through pipe 48 and is passing through elements 17, 18 and 19 via valves 22, 27 and 32. Filtered water permeates through pores of filtering elements while aerated water/broth is passing through their channels. Aerated water/broth finally leaves the aerator/filter array towards bioreactor through pipe 51 via pipe 39 and valve 40. This sequence can be continued for as many elements. In figure 6 configuration, aeration mode after a designated time shifts to element 17, then element/module 18 and cycle continues by shifting the aeration mode to element/module 19 again.

In an array like the one that is shown in figure 6, each element may consist of several elements that are connected together in a parallel way and then each of this multi elements acts as one element in the array.

Referring now to figure 7, a plant for treating waste water is described. Influent 56 enters a conditioning tank 57 and nutrients 58 may be added to the tank if needed. Pump 59 pumps the waste water to the upper portion of bioreactor 54 through pipe 60. Bioreactor 54 is packed with a high specific surface area media with a high void percentage. Waste water is getting mixed with the circulation flow 61 which is also

entering bioreactor 54 at its upper portion. The mixed flow moving downward inside bioreactor 54. The dissolved oxygen and some of the organic substrate in the flow will be consumed by the microorganisms that has grown on the media surface inside bioreactor 54 in the aerobic zone. As the flow moves further down, the dissolved oxygen content of the flow decreases until it reaches to a low level and microorganisms begin to utilise nitrate as the electron donor thus an anoxic zone forms. Finally when little oxygen or nitrate is left in the downward flow inside bioreactor 54, anaerobic microorganisms dominate the population of the biomass and the anaerobic zone forms. As a result of anaerobic activity, biogas will be produced in this zone. Biogas bubbles move up ward due to its lower density than water. Biogas will leave the bioreactor 54 via pipe 62 to the processing and consumption point. Some of the detached biomass will settle in the hopper 63 located right in the bottom of the bioreactor 54. pipe 64 is for anaerobic sludge wastage that may be done at specific intervals or continuously. The down ward flow inside bioreactor 54 leaves bioreactor 54 through pipe 65. The pH adjustment takes place in pipe 65 by pH sensor 66 and alkalinity addition pipe 67. Pipe 65 guides the circulation flow to the lower part of bioreactor 55. Air or oxygen that may contain specific dose of ozone enters bioreactor 55 in the form of two phase flow through pipe 68. Oxygen transfer from gas bubbles into the liquid inside pipe 78 and bioreactor 55 provides oxygen that is vital for carbonaceous oxidation and nitrification in the bioreactor 55. To increase the oxygen transfer and ozone transfer and consumption efficiency, the tubing between the aerator/filter array 81 and the bottom of the bioreactor 55 can be long enough to let the liquid flow inside pipe 78 reaches to or near its oxygen saturation point when entering the bioreactor 55. This tubing may have larger cross-section area to lower the superficial flow velocity to maximise the gas transfer in the tube. Circulation flow 61 leaves bioreactor 55 in its upper portion. Circulation flow 61 passes through air trap 69, valve 70 and pump 71 before entering bioreactor 54. A settling device 72 that may be located in the upper portion of the bioreactor 55 may separate solids from effluent 73. A portion or all the settled sludge in the settling device

72 will be returned to the bioreactor 54 and the remaining portion will be wasted through pipe 74. Pump 75 delivers the over flow 76 of settling device to the aerator/filter elements array 81 through pipe 77. If no settling device is used, liquid from top of the bioreactor 55 is pumped to the aerator/filter elements unit 81 via pipe77. Effluent 79 or treated water, is drawn from the aeration filtration unit 81.
Pipe 68 is carrying flow 70 That contains air plus ozone to the bottom of bioreactor 55. Ozone generator 73 and air supply pipe 82, suppling gas to the aerating elements in aerator/filter array 81.

Aerator/filter elements array 81 can be of different configurations but it is preferable to use configurations in figure 5 and or configuration shown in figure 6.

The other option is to place the aerator/filter elements array inside bioreactor 55 by omitting pipes 76, 77 and 78 and pump 75. In this case it is preferable to use configuration of the aerator/filter array shown in figure 5.

Although the invention has been described with reference to particular embodiments it should be appreciated that many embodiment are possible taking into account the design parameters and different applications identified.

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CLAIMS

1. A process for treating waste water comprising the steps of:

simultaneously filtering and aerating the waste water by means of two or more filtering/aerating elements; each of which is alternately supplied with pressurised gas, and drained.

2. A process according to claim 1, wherein the pressurised gas is air.

3. A process according to claim 1 or 2, wherein the pressurised gas is oxygen.

4. A process according to claims 1 to 3, wherein the pressurised gas is containing ozone.

5. A process according to any preceding claim wherein the ratio of time each aerator/filter element is used for aeration or filtering varies between 1 to 99%.

6. A process according to any preceding claim wherein the pressurised gas is supplied in variable and/or a steady stream.

7. A process according to any preceding claim wherein the filtering/aerating elements may be located inside and/or outside the tank containing the fluid.

8. An apparatus for the treatment of waste water, comprising two or more aerator/filter elements each of which has an associated pressurised gas supply and an associated effluent drain; wherein the supplies and drains are valved and controlled such that, in use, each element is alternately supplied with pressurised gas or drained, and at any given time, one or more selected elements are supplied with the pressurised gas while the remainder are drained.

9. An apparatus according to claim 7, wherein the aerator/filter elements are constructed from porous materials.

10. An apparatus according to claim 9, wherein the filtering/aerating elements are constructed from porous organic, inorganic or composite materials.

11. An apparatus according to claim 9, wherein the filtering/aerating elements are constructed from ceramics.

12. An apparatus according to any one of claims 8 to 11, wherein the pore size of the elements are between 0.0001 micrometers to 200 micrometers.

13. An apparatus according to claims 8 to 12, wherein the aerator/filter elements are self-housing.

14. An apparatus according to any one of claims 8 to 13, wherein the aerator/filter elements has two or more channels.

15. An apparatus according to claims 13 and 14, wherein the aerator/filter elements have a thick support layer with large pores.

16. An aerator/filter element/module that according to claims 13 and 14, wherein the aerator/filter elements have a thin skin layer with small pores.

17. An apparatus according to claims 13 and 14, wherein the most of the channels of the aerator/filter elements have a skin layer with small pores on their surfaces.

18. An apparatus according to claims 13 to 17, wherein one or more channels of the aerator/filter elements do not have a skin layer on their surfaces.

19. An apparatus according to claims 13 to 18, wherein liquid to be aerated or filtered is flowing inside the channels with the skin layer on their surfaces.

20. An apparatus according to claims 13 to 18, wherein permeate is drained through the channels that do not have skin layer on their surfaces.

21. An apparatus according to claims 13 to 20, wherein the gas is forced into the pores through channels that do not have skin layer on their surfaces.

22. An apparatus according to claims 13 to 21, wherein the pores on the outer surfaces of the aerator/filter elements are blocked.

23. An apparatus according to claims 13 to 22, wherein the channels in the aerator/filter elements have different shapes.

24. An apparatus according to claims 13 to 23, wherein the aerator/filter elements have different shapes.

25. A treatment plant constructed from apparatus according to any one of the claims 8 to 24 and comprising an array of the aerator/filter elements and open channels.

26. A treatment plant constructed from apparatus according to any one of the claims 8 to 25 and comprising an array of the self–housing aerator/filter elements.

27. A treatment plant constructed from apparatus according to claim 26, wherein the liquid is passing through an aerating element first.

28. A treatment plant constructed from apparatus according to claims 26 and 27, wherein the aerated liquid is passing through filtering elements.

29. A treatment plant constructed from apparatus according to claim 26, wherein the acrator/filter elements in the array can be placed vertically or horizontally.

30. A treatment plant constructed from apparatus according to claims 26 and 27, wherein the array of the aerator/filter elements may be placed inside of a process tank.

31. A treatment plant constructed from apparatus according to claims 26 and 27, wherein the array of the aerator/filter elements may be placed externally to the process tank.

32. An apparatus for aerating/filtering of liquids substantially as described in figures 2, 5 and 6.

33. A treatment plant for treating waste water comprising the steps of; aerobic carbonaceous oxidation, nitrification, denitrification and anaerobic digestion of organic matters in the waste water by means of two bioreactors and an aerator/filter elements array.

34. A treatment plant according to claim 33, wherein one bioreactor is aerobic.

35. A treatment plant according to claim 33 or claim 34, the other bioreactor is multi–zone with aerobic, anoxic and anaerobic zones.

36. A treatment plant according to claim 33 to claim 35, there is a circulation flow between the two reactors.

37. A treatment plant according to claim 33 or claim 36, air bubble flow in the aerobic reactor or a pump action causes the circulation flow between the two bioreactors.

38. A treatment plant according to claim 33 and 35, the influent waste water is introduced to the upper portion of multi zone bioreactor.

39. A treatment plant according to any preceding claim wherein the ratio of circulation flow to the influent flow rate varies between 0.1 to 50.

40. A treatment plant according to claim 35 or claim 36, bioreactors have suspended biomass growth.

41. A treatment plant according to claim 35 or claim 36, bioreactors are packed with a high specific surface area media and have attached biomass growth.

42. A treatment plant according to claim 35 or claim 36, bioreactors have mixed attached and suspended biomass growth.

43. A treatment plant according to claims 33, 36, 37 and 39, The circulation flow prevents clogging and channelling in the packed bioreactors.

44. A treatment plant according to claim 34 or claim 35, the ratio of multi zone bioreactor volume to the aerobic bioreactor volume varies between 0.2 to 20.

45. A treatment plant according to claim 33 to claim 35, the excess sludge is drawn from the bottom of the muti zone bioreactor.

46. A treatment plant according to claim 21 or claim 22, may have a settling facility on top of the aerobic bioreactor or adjacent to the aerobic bioreactor.

47. A treatment plant according to claim 34, settling facility is a shallow depth settler.

48. A treatment plant according to claim 34, settling facility is a settling tank.

49. A treatment plant according to claim 36, settling tank is incorporated to the top portion of the aerobic reactor.

50. A treatment plant according to claim 33, 34, and 46, sludge wastage is done from the settling facility.

51. A treatment plant according to claim 33, 34, 35, and 50, phosphorous removal takes place through aerobic sludge wastage from the settling facility.

52. A treatment plant according to claim 33 to 42, a gas trap is located in the circulation pass to prevent the gas bubbles enter the multi–zone bioreactor.

53. A treatment plant according to claim 1, claim 2, claim 33 and claim 34, a gas is supplied to the bottom of the aerobic reactor and through aerator/filter unit and or

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apparatuses.

54. A process for treating waste water substantially as herein described with reference to the accompanying drawings.

55. An apparatus for treatment of waste water substantially as herein described with reference to figures 1 to 6 of the accompanying drawings.

56. A treatment plant substantially as herein described with reference to figure 7 of the accompanying drawings.