

PATENT SPECIFICATION

(11) 1 524 765

1 524 765

- (21) Application No. 6310/77 (22) Filed 15 Feb. 1977
(31) Convention Application No. 5025/76
(32) Filed 27 Feb. 1976 in
(33) Australia (AU)
(44) Complete Specification published 13 Sept. 1978
(51) INT CL² C02C 1/06
(52) Index at acceptance
CIC 311 431 432 43Y 621 63X 640 647 666 66Y E
(72) Inventors MALCOLM CHAIKIN and
JOHN RAYMOND McKRAKEN



(54) PROCESS AND APPARATUS FOR THE AEROBIC BIOLOGICAL PURIFICATION OF LIQUID WASTES CONTAINING ORGANIC POLLUTANTS

(71) We, UNISEARCH LIMITED, a Company limited by guarantee and incorporated under the laws of the State of New South Wales, of 221—227 Anzac Parade, Kensington, New South Wales, Commonwealth of Australia, 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:—

This invention relates to a process and apparatus for the purification of liquid wastes containing organic pollutants.

According to the present invention, there is provided apparatus for the aerobic biological purification of liquid wastes containing organic pollutants, which comprises a tank containing a liquid having a high biomass concentration, means to introduce a liquid to be purified into the tank, a pump arranged to withdraw liquid from near the bottom of the tank, a fluid flow connection from the pump to eductor means arranged to aerate part of the liquid withdrawn, means to introduce the resulting aerated liquid into the tank so as to cause a rapid circulatory movement of liquid in the tank and to produce a vortex at the surface of the liquid, spray means connected to the output of the pump to spray liquid onto the vortex, liquid metering means arranged to feed a predetermined proportion of the withdrawn liquid to mechanical separating means arranged to separate sludge from the liquid and means for introducing a proportion of the separated sludge directly into the tank.

According to another aspect of the present invention, there is provided a process for the aerobic biological purification of liquid waste containing organic pollutants, which comprises: introducing the liquid waste into a tank containing a liquid having a high biomass

concentration, withdrawing liquid from the tank, aerating part of the liquid withdrawn and introducing the aerated liquid into the tank in such a manner as to cause liquid in the tank to circulate rapidly to produce a vortex at the surface of the liquid, spraying liquid withdrawn from the tank onto the surface of the vortex, separating sludge from liquid withdrawn from the tank using mechanical separating means and returning a proportion of the sludge directly to the tank.

Aeration may be effected by pumping the liquid through one or more eductors so as to entrain air into a tall column(s) or tank whereupon the air disperses as tiny bubbles throughout the liquid. The dispersion and pressure of pumping provides a means of efficient mixing and intimate contact and transfer of oxygen from air to liquid. The tiny bubbles of air gradually coalesce to form large bubbles but this can be controlled by the addition of a high foaming surfactant (if such a surfactant is not already present in the liquid waste) whereby the air and liquid are in the form of a foam. The amount of foaming is controlled by spraying liquid in the tank with some of the liquid withdrawn from the tank and by creating a vortex by tangential entry of the liquid from the eductors into the tank, whereby air is expelled from the liquid. The spray also contributes to efficient aeration of the liquid because of the large specific surface of the spray droplets. The large shear forces experienced by the biological floc in the eductors and in pumping permit a temporary disruption of the micro-organisms and other suspended matter from the floc thus increasing the oxygen and substrate concentration gradients between micro-organisms and liquid. The use of eductors and spray in this manner avoids the use of expensive air compressors

50

55

60

65

70

75

80

85

90

9

and the usual ancillary air filtration equipment. Furthermore, the heat generated in pumping the mixture through the eductors and the excess energy from the aerobic biological activity can be utilised to increase the temperature of the liquid and consequently to increase biological activity, which is particularly relevant in the colder climatic regions. In most aeration processes of biological treatment the efficiency of oxygen transfer is low and the amount of air required is many times the theoretical value and this excess air tends to cool the liquids by evaporation, thus decreasing biological activity, and to cause considerable wastage of energy in the air compression operation.

In addition to aeration as described above, a high concentration of micro-organisms can be maintained in the waste liquid, for example, by recycling a portion of the largely dewatered biological floc directly from a centrifugal decanter or other mechanical concentrator back into the aerated liquid in the tank. The micro-organism population should be kept as high as possible to maintain a high rate of biodegradation of the organic pollutants which results in smaller equipment and capital cost. The limitation on further concentrating the biological floc is the increase in viscosity which ultimately reduces the pumping and mixing characteristics of the liquid and thereby affecting, in particular, the oxygen transfer from air to liquid and then to each micro-organism. A particularly beneficial result of directly recycling the sludge from the centrifugal decanter or other mechanical concentrator is that the time involved is very small and so the micro-organisms are always in an oxygen-rich environment. (Where gravity clarifiers are used to settle the activated sludge the dissolved oxygen may be depleted in the floc and some of the more susceptible micro-organisms may die before the recycled sludge is returned to the aeration tanks; however gravity clarifiers can also be used in the present invention). The clear supernatant liquor from the centrifugal decanter or other mechanical concentrator may be the effluent from the purification process in which case the rate of feed of the waste liquid is dependent on the rate of effluent withdrawn from the concentrator. If a flotator or gravity clarifier is used after aeration of the mixture the supernatant liquor from the machine is mixed with the feed to the flotator or clarifier (if the machine is a centrifugal decanter then the supernatant liquor will be very well aerated and mixing this with the feed to the flotator or clarifier would be an advantage). The rate of recycle of sludge from the machine

is best controlled by proportioning the quantity produced over a given time interval into recycled sludge and waste sludge. The proportion is set by allowing the maximum workable concentration of sludge to build up in the process commensurate with the highest concentration of pollutants that would be expected in the waste liquid. For lesser concentrations of pollutants the micro-organisms populations are therefore also less and so a reasonably constant treatment effect is realised for a given aeration time (the aeration time is fixed by the liquid volume in the apparatus and the rate of feed of waste liquid). Two more advantages of using a machine to concentrate the micro-organisms in the aeration zone are (i) the problem of sludge bulking is reduced or eliminated permitting a much higher ratio of substrate to micro-organism concentrations to be tolerated, and (ii) the shear forces encountered by the biological floc in the machine lead to increased oxygen and substrate concentration gradients as with pumping the liquid through air eductors (with a centrifugal decanter considerable aeration of the liquor is also provided). The use of a flocculation aid such as a polyorganoelectrolyte may be necessary or desirable when a mechanical concentrator is employed.

In order that the present invention may be more fully understood, one preferred embodiment thereof is hereinafter described, by way of example, with reference to the accompanying diagrammatic drawing in which sectional views of aeration and sludge concentration units are shown. In the apparatus shown in the drawing, waste liquid (P) enters the tank (T) via a constant level header tank (H) and mixes with the aerated liquid (M) in the tank, which contains a high concentration of micro-organisms. The liquid (M) is circulated by pump (C) from the bottom central zone of the tank (T) where all, or most, of the air has separated, through one or more eductors (E) which entrains air (A), into a spiral trajectory inside the tank (T). The partially deoxygenated air and other gases from biological degradation separate from liquid (M) owing to buoyancy and centrifugal forces on the bubbles towards and upwards of the central vortex, where they escape to the atmosphere. Foam (F) produced by aeration is dissipated with a spray (S) of liquid (M). A metered portion of the liquid (M) is passed to a centrifugal decanter (D) where a sludge (W) is separated from a supernatant liquor (L) which is the effluent from the process. The sludge (W) has a very high content of micro-organisms and for a greater part of the time is recycled back into the tank (T)

10

- using a moving conveyor (B). For the remaining part of the time (of a predetermined period) the conveyor (B) direction is reversed towards a container (V) used for carting the waste sludge for disposal by digestion (aerobic or anaerobic), composting, dumping, incinerating or by other means. A further dewatering stage for the waste sludge may be necessary depending on the economics of disposal. It may be advantageous to add a small amount of a high foaming surface active agent to the aeration tank to enhance oxygen transfer from air to liquid of the surface tension of the polluting stream is not already low. Also the addition of a polyelectrolyte to the liquid fed to the decanter may be necessary continuously during operation or only when discharging waste sludge to improve the dewatering and/or flocculating of the sludge. Where the rate of flow of the waste liquid is high it may well be an advantage to have a flotator or gravity clarifier before the centrifugal decanter with the supernatant liquor from the decanter mixed with the feed to the flotator or clarifier (this enables a high flow through the centrifuge otherwise a much larger machine would be required if the supernatant liquor was to be as good as the effluent from the flotator or clarifier).
- The apparatus and the process according to the invention have a number of advantages, which are summarised below:
1. It is possible to purify a waste liquid having a high biomass concentration, for example, from 10,000 mg/l to 100,000 mg/l, whereby the volume of the apparatus can be kept small or alternatively (a) the organic removal rate per unit of reactor volume can be increased, (b) the sludge age and sludge stability can be increased, or (c) the excess sludge for disposal can be reduced.
 2. The high biomass concentration is obtained by mechanical concentration, specifically by centrifugation or by other means such as filtration or ultrafiltration where the sludge is recycled to the tank or to disposal and the supernatant liquor is the effluent. The mechanical means of concentration may be used in conjunction with a gravity clarifier or flotator such that the thickened biomass from the clarifier or flotator is passed to the mechanical concentrator from which a sludge is produced for recycling to the tank and to disposal, and the supernatant liquor being recycled to the clarifier or flotator permitting a smaller or less efficiency mechanical concentrator to be used.
 3. Bulking sludge by mechanical concentration may be prevented thus (a) allowing treatment over a wide range of feed to micro-organism ratios, (b) producing high quality effluent, (c) allowing higher micro-organism concentration in the aeration reactor due to the very low recycle flow rate of concentrated micro-organisms in the sludge from the mechanical concentrator, which in addition enables a smaller gravity clarifier or flotator to be used.
 4. The production of a dewatered sludge for disposal as excess sludge according to the invention avoids the necessity of further mechanical concentration equipment to dewater the excess sludge.
 5. The maintenance of a healthy sludge recycled to the tank, since the biomass need only be removed from the aeration zones in its passage through the mechanical concentrator for a short time. The dissolved oxygen may be kept at a sufficient level in the biomass during the rapid concentration stage to sustain life forms present in the biomass.
 6. Aeration maintains sufficient dissolved oxygen in the mixture at high biomass concentration, this being effected preferably by the suction of air through venturi eductors with the mixture pumped from the aeration reactor so as to provide intimate contact of air with liquid under pressure to force the mass transfer of oxygen from air to liquid.
 7. The reduction of the surface tension of the liquid when a surfactant is used causes foaming and smaller bubbles, permitting an increased mass transfer rate of oxygen from air to liquid as a result of the increased exposure of the interfacial surface between air and liquid.
 8. The tangential delivery of the educted air and liquid to a vortex formed in the tank permits the separation of bubbles of air from the liquid by centrifugal and gravitational forces into a layer of foam, and also provides efficient mixing and prevention of solids settling in the tank.
 9. The use of a spray of aerated liquid breaks and controls the foam formed in the tank and provides further means of oxygen transfer from air to liquid due to the large surface exposed to the air by the spray droplets.
 10. High oxygen and substrate concentration gradients are experienced by the individual micro-organisms as a result of the high rate of shear of the mixture by (a) pumping, (b) by passage through air eductors (c) vortex mixing, (d) by passage through a spray nozzle and (e) by passage through a mechanical concentrator. Where high shear forces exist the biological floc can be disrupted or it disintegrates exposing individual or at least small groups of micro-organisms to the oxygen and substrate rich environment surrounding the floc.
 11. The rate of treatment may be

(11)

4

1,524,765

4

5 increased by the utilisation of the energy expended as heat in the pump, eduction, vortex mixing, spraying and other frictional losses to the liquid and from the excess energy of biological activity particularly when the waste liquid is of high biomass concentration. Because of efficient mass transfer of oxygen from the air little heat is lost through evaporation. Insulation of the system is preferably provided.

10 12. It is possible to filter or ultrafilter the effluent from the system, which improves the quality of the effluent and enables the concentrate to be recycled to the tank so as to further increase the biomass concentration particularly of free-swimming micro-organisms.

WHAT WE CLAIM IS:—

20 1. Apparatus for the aerobic biological purification of liquid wastes containing organic pollutants, which comprises a tank containing a liquid having a biomass concentration, means to introduce a liquid to be purified into the tank, a pump arranged to withdraw liquid from near the bottom of said tank, a fluid flow connection from the pump to eductor means arranged to aerate part of the liquid withdrawn, means to introduce the resulting aerated liquid into the tank so as to cause a rapid circulator movement of liquid in the tank and to produce a vortex at the surface of the liquid, spray means connected to the output of the pump to spray liquid onto the vortex, liquid metering means arranged to feed a predetermined proportion of the withdrawn liquid to mechanical separating means arranged to separate sludge from the liquid and means for introducing a proportion of the separated sludge directly into the tank.

40 2. Apparatus as claimed in Claim 1, in which the mechanical separating means is a centrifugal decanter.

3. Apparatus as claimed in Claim 1 or Claim 2, which includes a flotator or gravity clarifier arranged to receive the predetermined proportion of the withdrawn liquid downstream of the mechanical separating means.

50 4. A process for the aerobic biological purification of liquid waste containing organic pollutants, which comprises: introducing the liquid waste into a tank containing a liquid having a high biomass concentration, withdrawn liquid from the tank, aerating part of the liquid withdrawn and introducing the aerated liquid into the tank in such a manner as to cause liquid in the tank to circulate rapidly to produce a vortex at the surface of the liquid, spraying liquid withdrawn from the tank into the surface of the vortex, separating sludge from liquid withdrawn from the tank using mechanical separating means and returning a proportion of the sludge directly to the tank.

5. A process as claimed in Claim 4, in which the biomass concentration is maintained at between about 10,000 mg/l and 100,000 mg/l.

6. A process as claimed in Claim 4 or Claim 5, in which a small quantity of a high foaming surface active agent is added to the contents of the tank.

7. Apparatus for the aerobic biological purification of wastes substantially as described with reference to and as illustrated in the accompanying drawing.

8. A process for the aerobic biological purification of wastes substantially as described with reference to and as illustrated in the accompanying drawing.

A. A. THORNTON & CO.,
Chartered Patent Agents,
Northumberland House,
303/306 High Holborn,
London, WC1V 7LE.

(11)



1,524,765

4
increased by the utilisation of the energy expended as heat in the pump, eduction, vortex mixing, spraying and other frictional losses to the liquid and from the excess
5 energy of biological activity particularly when the waste liquid is of high biomass concentration. Because of efficient mass transfer of oxygen from the air little heat is lost through evaporation. Insulation of the
10 system is preferably provided.

12. It is possible to filter or ultrafilter the effluent from the system, which improves the quality of the effluent and enables the concentrate to be recycled to the tank so as
15 to further increase the biomass concentration particularly of free-swimming micro-organisms.

WHAT WE CLAIM IS:—

20 1. Apparatus for the aerobic biological purification of liquid wastes containing organic pollutants, which comprises a tank containing a liquid having a biomass concentration, means to introduce a liquid
25 to be purified into the tank, a pump arranged to withdraw liquid from near the bottom of said tank, a fluid flow connection from the pump to eductor means arranged to aerate part of the liquid withdrawn, means to introduce the resulting aerated
30 liquid into the tank so as to cause a rapid circulator movement of liquid in the tank and to produce a vortex at the surface of the liquid, spray means connected to the output of the pump to spray liquid onto the
35 vortex, liquid metering means arranged to feed a predetermined proportion of the withdrawn liquid to mechanical separating means arranged to separate sludge from the liquid and means for introducing a
40 proportion of the separated sludge directly into the tank.

2. Apparatus as claimed in Claim 1, in which the mechanical separating means is a centrifugal decanter.

3. Apparatus as claimed in Claim 1 or Claim 2, which includes a flotator or gravity clarifier arranged to receive the
45 predetermined proportion of the withdrawn liquid downstream of the mechanical separating means.

4. A process for the aerobic biological purification of liquid waste containing organic pollutants, which comprises:
50 introducing the liquid waste into a tank containing a liquid having a high biomass concentration, withdrawn liquid from the tank, aerating part of the liquid withdrawn and introducing the aerated liquid into the
55 tank in such a manner as to cause liquid in the tank to circulate rapidly to produce a vortex at the surface of the liquid, spraying liquid withdrawn from the tank into the surface of the vortex, separating sludge from liquid withdrawn from the tank using
60 mechanical separating means and returning a proportion of the sludge directly to the tank.

5. A process as claimed in Claim 4, in which the biomass concentration is maintained at between about 10,000 mg/l
70 and 100,000 mg/l.

6. A process as claimed in Claim 4 or Claim 5, in which a small quantity of a high foaming surface active agent is added to the contents of the tank.
75

7. Apparatus for the aerobic biological purification of wastes substantially as described with reference to and as illustrated in the accompanying drawing.

8. A process for the aerobic biological purification of wastes substantially as described with reference to and as illustrated in the accompanying drawing.
80

A. A. THORNTON & CO.,
Chartered Patent Agents,
Northumberland House,
303/306 High Holborn,
London, WC1V 7LE.