

Moving bed bioreactor and water treatment process

Technical field

- 5 This invention relates to a moving bed bioreactor and water treatment process. The bioreactor and method are particularly suitable for improvement of water quality in land-locked water bodies such as ponds or lakes for the holding of shrimp, fish and other aquatic creatures to be produced under aquaculture conditions, but can also find application in other areas such as wastewater purification.

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Background

The accumulation of ammonia is the biggest problem in intensively stocked aquaculture systems such as tanks and ponds containing either salt or fresh water.

- 15 Ammonia builds up rapidly in these environments due to waste products of the reared individuals, the regular addition of food, which contains nitrogenous compounds, organic debris from dead and dying organisms, uneaten feed, and faeces.

- At high concentrations, ammonia becomes noxious to aquatic life and therefore the control of these nitrogenous compounds is particularly important in intensive aquaculture ponds and tanks.

- To address this problem, polluted water from ponds is frequently replaced with unpolluted water in order to maintain a healthy environment. Water replacement can be time consuming and also expensive, especially if the pond is not in close proximity to the ocean, or other sources of unpolluted water. Furthermore the use of natural coastal water bears the risk of introducing pathogens and planktonic organisms acting as carriers for various diseases that have the potential to destroy a complete harvest.

- 30 Reducing the exchange rate of pond water to avoid the above negative effects negatively affects water quality and tends to increase the concentration of toxic nitrogen components. In closed aquaculture systems, the solution to the accumulation of excreted compounds is the internal recirculation of the water using mechanical and biological filters (also called biofilters). For example, ammonia removal can be achieved using a biofilter for nitrification. This type of biological treatment process

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employs bacteria that grow either attached to a surface (fixed films) or suspended in the water column (biofloc) and that successively oxidize ammonia to nitrite and nitrite to nitrate. This process needs aerobic conditions; usually oxygen is supplied by intensive aeration. Other biological treatment processes may use other types of bacteria, which
5 may operate in aerobic or anaerobic conditions, to remove other types of pollutant.

Water treatment systems in which pond or tank water is removed, filtered and sent back to the pond or tank are called recirculating systems. Typically, recirculating systems use fixed-film bioreactors, in which the bacteria (e.g., nitrifying bacteria) grow
10 on either a wetted or submerged media surface. The pollutant removal capacity of biological filters is largely dependent on the total surface area that is available for the growth of a biofilm formed by the bacteria. As long as sufficient area is provided for the colonizing bacteria, the removal rates will be proportional to the volume of media providing the surface area. Efficient media are characterized by a high specific surface
15 area, expressed as surface per unit volume and an optimal ratio of open pore space to allow minimal resistance of water flow over the biofilm to enable self-cleaning driven by the shear forces of the passing water flow.

The most common biological filters in use in aquaculture applications, and other
20 wastewater treatment applications, for commercial scale systems are trickling filters, fluidized sand beds (FSBs), floating bead filters (FBFs), rotating biological contactors (RBCs), and moving bed bio reactors (MBBRs).

All the above biological filter types, except the trickling filter, are submerged biofilters.
25 (with most being fully submerged, but with RBCs having roughly half of the filter media submerged). Submerged biofilters include a volume of biofilter medium upon which nitrifying bacteria grow. The wastewater flows in either an up-flow or a down-flow direction or in a completely mixed fashion. The retention time can be controlled by adjusting the hydraulic flow rate through the reactor vessel.

30 The growing cell masses from nitrifying and heterotrophic bacteria can accumulate within the submerged filter, eventually blocking the void spaces of the media. For continuous and long-term operation, additional flow patterns need to be induced in the treatment volume in order to flush solids from the filter media. It is generally considered

in the art that the most challenging aspect of operating any submerged biofilter is to keep it relatively free of accumulated bio-solids (feed, faeces, and bacterial flocs).

In order to address this problem, the moving bed bioreactor (MBBR) was developed. In
5 MBBR, polluted water is pumped to a tank containing floating biofilter media. The floating media are agitated by aeration or other mixing technologies such that they undergo intense turbulent motion. The shear forces induced by the mixing cause the polluted water to flow over the active surface area of the media, thereby cleaning the water. Compared to trickling filters and rotating biological contactors, the MBBR has a
10 small footprint and low maintenance requirements. However, MBBR still requires that the water to be treated be transported from the pond or tank to the treatment site.

Summary

15 The present invention provides, in a first aspect, a moving bed bioreactor, comprising:
a reactor vessel, comprising: a treatment section for holding a plurality of biofilm carrier elements; and
an agitator for imparting motion to the biofilm carrier elements;
wherein the reactor vessel is buoyant and comprises at least one sidewall and a
20 lower wall, the at least one sidewall and/or the lower wall having a plurality of apertures for allowing flow of water into and out of the chamber when the reactor vessel is immersed in a body of water, each of said apertures being sized to prevent flow of the biofilm carrier elements out of the reactor vessel.

25 Advantageously, by providing a buoyant reactor vessel which can be immersed directly in the body of water, for example a tank or pond, the water may be efficiently treated in situ and the treated water may then be directly recirculated to the tank or pond. Accordingly, the apparatus according to at least some embodiments of the invention has a smaller footprint than existing MBBR systems which provide one or more tanks
30 located remotely from the body of water to be treated, and associated piping. Direct immersion in the water to be treated also means that a separate pumping system for transporting the water to the treatment site is not required.

In certain embodiments, the reactor vessel further comprises an outlet section in fluid
35 communication with the treatment section and separated from the treatment section by

a screen which is configured to prevent egress of biofilm carrier elements while permitting flow of water. Advantageously, the outlet section provides a separate area of the vessel into which treated water can flow, for example for the purposes of active recirculation into the body of water. If the treated water is actively recirculated (for example, by pumping), it can be drawn from the outlet section without removing the biofilm carrier elements, which remain in the treatment section due to the presence of the screen.

Preferably, the moving bed bioreactor has a water transport means, such as a pumping system, for transporting treated water from the outlet section to the body of water. In this way, the treated water can be directly expelled to the body of water in which the reactor vessel is immersed. If the body of water is a pond, for example, this can create an additional flow which prevents stratification in the pond, thereby reducing odours caused by production of hydrogen sulphide formed in anaerobic sediments.

In embodiments in which apertures are provided in the lower wall of the reactor vessel, water can be admitted directly from the pond bottom to the reactor vessel.

The agitator may comprise at least one gas entrainment device comprising at least one pressure source and configured to inject a pressurized gas into the reactor vessel. The gas entrainment device may be an aeration device or an oxygenation device, for example.

The gas entrainment device may comprise at least one pipe having a plurality of apertures formed in at least a portion thereof, the at least a portion being disposed in the treatment section. In some embodiments, a plurality of pipes may be arranged concentrically with respect to each other. Advantageously, the concentric arrangement of the pipes provides for even and thorough mixing of the biofilm carrier elements, and even aeration throughout the treatment section.

The apertures of the pipe or pipes may be disposed in a portion of the treatment section adjacent the lower wall. This may provide superior aeration since air bubbles emitted from the apertures have a greater path length through the treatment section.

The moving bed bioreactor may comprise a pump system for pumping treated water from the outlet section. This allows the treated water to be efficiently recirculated directly to the pond (or other body of water) from the reactor vessel, and may allow a directed flow of treated water into the pond; such that further aeration may occur as the treated water breaks the pond surface. The pump system may be an airlift pump system, for example.

In embodiments including an airlift pump system, the at least one pressure source may act as a pressure source for the airlift pump system. Accordingly, therefore, the same pressure source may be used to drive both the agitator and the airlift pump system, providing for a more efficient configuration than if separate pressure sources were used.

The airlift pump system may comprise an airlift pipe disposed in the outlet section. If so, the screen separating the treatment section and the outlet section may be disposed around the airlift pipe.

In some embodiments, the at least one pressure source is a compressor or blower system located remotely from the reactor vessel.

The moving bed bioreactor may comprise a spacer element for elevating the lower wall. This prevents inlet apertures in the lower wall from being blocked as might occur if the lower wall were to touch the pond bottom,

The moving bed bioreactor may further comprise a plurality of biofilm carrier elements disposed in the treatment section.

In some embodiments, the reactor vessel is generally cylindrical. It may have a diameter approximately 1.5 times its height.

In another aspect, the present invention provides a water treatment process, comprising:

disposing a plurality of biofilm carrier elements in a treatment section of a reactor vessel having a plurality of apertures, each of said apertures being sized to prevent flow of the biofilm carrier elements out of the reactor vessel;

immersing the reactor vessel in a body of water such that the reaction vessel floats and water enters the treatment section from the body of water through the plurality of apertures and mixes with the biofilm carrier elements; and

agitating the biofilm carrier elements.

The method may further comprise allowing treated water to flow to an outlet section of the reactor vessel while retaining the biofilm carrier elements in the treatment section;

5 and

expelling the treated water from the outlet section to the body of water.

In some embodiments, said agitating comprises injecting a pressurized gas into the reactor vessel. The gas may be air or oxygen. The gas may be injected at a plurality of
10 injection points arranged concentrically with respect to each other. The injection points may be located adjacent a lower wall of the reactor vessel.

In some embodiments, the treated water is expelled by pumping. The pumping may be airlift pumping, for example. In some embodiments, a common pressure source is used
15 for both the agitating and the pumping operations.

In some embodiments, the plurality of apertures of the reactor vessel are formed in at least one sidewall and/or a lower wall of the reactor vessel.

20 Brief Description of the Drawings

Embodiments of the invention will now be described, by way of non-limiting example only, with reference to the accompanying drawings in which:

25 Fig. 1 is a cross-sectional view through a moving bed bioreactor according to embodiments of the invention;

Fig. 2 is a plan view from above of the moving bed bioreactor of Fig. 1;

Fig. 3 shows the apparatus of Fig. 1 and Fig. 2 in use; and

Fig. 4 is a flow chart of a water treatment process according to embodiments of the
30 invention.

Detailed Description of Embodiments

It will be convenient to describe embodiments of the invention with reference to their
35 application to water treatment in aquaculture. However, the skilled reader will

appreciate that the described embodiments, or straightforward variants thereof, may find application in other types of water treatment, such as cleaning or renaturation of polluted lakes or reservoirs, or sewage water treatment.

- 5 The moving bed bioreactor of embodiments of the present invention, in use, is placed directly into a body of water, such as a pond, in which toxic nitrogen compounds are excreted by marine animals which are being farmed, such as shrimp, fish and other aquatic species. Air may be used to both agitate the biofilm carrier elements in the reactor vessel, and transport the water into and out of the reactor vessel, additionally
10 creating a flow in the pond and avoiding stratification in the pond and reducing odours caused by the production of hydrogen sulphide gas formed in anaerobic sediments.

The pond water may be directly transported into the floating reactor vessel through perforations in the reactor vessel, and expelled from an outlet at the top of the reactor
15 vessel, thereby allowing transport of water from the pond bottom to the pond surface, introducing additional oxygen in the process. Inside the reactor vessel the biofilm carrier elements may be randomly mixed through aeration at the reactor vessel bottom, avoiding clogging and creating hydrodynamic forces that circulate the biofilm-carrying surfaces of the carrier elements, positively influencing the thickness of the biofilm by
20 shear forces.

Turning to Figs. 1 to 3, there is shown a moving bed bioreactor (MBBR) 100 suitable for immersion in a body of water, such as a pond, in order to treat water in the pond. The MBBR 100 comprises a reactor vessel 1 which is substantially cylindrical in shape
25 and which has a treatment section 30 for receiving a plurality of biofilm carrier elements 6 (Fig. 3). Although a cylindrical shape is particularly advantageous, other cross-sectional shapes, such as octagonal, are also possible. If a polygonal cross-section is chosen then the angles between the edges of the polygon should be chosen to be large enough to allow efficient mixing of fluid throughout the treatment section 30 when
30 the apparatus 100 is in operation.

The biofilm carrier elements 6 (also called filter media units herein) provide growth surfaces for the bacteria-containing biofilm. While media having any practical size and shape may be used, media having a high surface area of $> 500\text{m}^2/\text{m}^3$ (typically up to
35 about $750\text{m}^2/\text{m}^3$) is preferred. One preferred form of support media is small plastic

spheres or tubes, although any shape known in the art may be used. Suitable biofilm carriers are disclosed for example in European patent publication no. EP0750591B2, the contents of which are hereby incorporated by reference in their entirety. Typically, about 50% to 70% of the reactor volume is filled with such media.

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The plastic media is lightweight and may float in the water with a specific weight of the particles being close to 1.0 kg/dm^3 , typically having a density in the range 0.92 to 1.08 kg/dm^3 . Because the carrier elements 6 are immersed in the vessel, they make optimal contact between the impurities in the water and the microorganisms on the carriers 6 possible.

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The reactor vessel 1 may be formed from a buoyant material such as high density polyethylene (HDPE). In some embodiments, a float chamber 2 may be provided in an upper portion of the reactor vessel 1 (preferably at its top) to provide buoyancy. The float chamber 2 may, for example, be a section of the vessel body which is formed from the same material as that of the vessel body, sealed and air-filled. The dimensions of the reactor vessel 1 and/or float chamber 2 may be chosen to provide a desired degree of buoyancy, for example such that the reactor vessel 1 can freely float at a desired operational water level in the pond. In one embodiment, the diameter of the reactor vessel 1 is approximately 1.5 times its height. The level of the reactor vessel 1 in the pond may be adjusted by the use of stabilisation weights 14, if desired. In one arrangement, the stabilisation weights 14 may be arranged concentrically, preferably symmetrically, about a central axis of the vessel 1. Typically, two or more stabilisation weights 14 may be used.

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The reactor vessel 1 has a lower portion 20 having a plurality of apertures 3, 23. In one embodiment, the lower portion 20 extends along approximately one third of the height of the vessel 1. A first plurality of apertures 3 is formed in a sidewall 22 of the reactor vessel 1, while a second plurality of apertures 23 is formed in a lower wall 4 of the vessel 1. The apertures 3, 23 enable water exchange into and out of the treatment section 30 of the reactor 1 when the lower portion 20 is immersed in the pond (or other body of water). In one operational mode, treated water is pumped out of the reactor vessel 1 and the pond water flows into the vessel 1 through the apertures 3, 23 in the shell. To retain the biofilm carrier elements 6 inside the treatment section 30 of the

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reactor 1, the size of the apertures 3, 23 is chosen to be smaller than the smallest cross sectional area of the biofilm carrier elements 6.

Advantageously, in addition to allowing flow of pond water into and out of the vessel 1, the apertures 23 in the lower wall 4 allow efficient draining of water from the reactor vessel 1 in the event that the pond is drained.

Provided on the lower wall 4 of the reactor vessel 1, and projecting outwardly therefrom, is a spacer element 5. The spacer element 5 ensures that the lower wall 4 of the vessel 1 will remain elevated above the pond bottom, thus preventing the apertures 23 from being blocked by sediment.

The treatment section 30 of the reactor 1 is in fluid communication with an outlet section 40 and separated from the outlet section 40 by a screen 13. The screen 13 is configured to allow flow of water therethrough, but to prevent the biofilm carrier elements 6 from escaping the treatment section 30 and flowing into the outlet section 40. In particular, apertures in the screen 13 may have a width which is less than a smallest dimension of the biofilm carrier elements 6 (or of a smallest one of the biofilm carrier elements 6) so that the biofilm carrier elements 6 cannot fit through the apertures.

In the illustrated embodiment, the treatment section 30 is substantially annular, and is arranged around the outlet section 40 which is substantially cylindrical by virtue of the cylindrical shape of the screen 13. Other arrangements are of course possible. For example, the treatment section 30 and the outlet section 40 could be arranged side-by-side, and separated by a substantially planar screen. It is particularly advantageous for the treatment section 30 to be concentric with the outlet section 40 as this allows for better flow characteristics within the treatment section 30 than a side-by-side arrangement.

The MBBR 100 has an agitator, comprising aeration pipes 7A and 7B, for imparting motion to the biofilm carrier elements 6 and in particular to maintain the reactor volume in constant motion, thoroughly mixing the media 6 inside the reactor volume and thereby maintaining good contact between the biofilm growing on the carriers 6 and the

substrate in the pond water. Agitation maintains the media 6 in constant motion creating a scrubbing effect that prevents clogging and sloughs off excess biomass.

5 In the MBBR 100, clogging of the biofilter medium will generally not be a problem since the biofilter carrier elements 6 are not stationary, but rather move with the flow in the bioreactor which is induced by the air jets from aeration pipes 7A and 7B. In the event that the aeration devices 6 in the reactor 1 become clogged, it is very easy to remove them by pumping them out, and replacing with fresh media.

10 Air is injected under pressure through apertures in the pipes 7A and 7B, which each have a ring-shaped outlet portion as best shown in Fig. 2, the ring-shaped outlet portions being arranged concentrically with respect to each other and also with respect to the outlet section 40. Two ring-shaped pipes 7A and 7B are shown in the Figures, but it will be appreciated that a single pipe may be used, or more than two pipes may
15 be used. Air supply to each pipe 7A, 7B is separately regulated by a respective valve 8A, 8B. The valves 8A, 8B may be ball valves, for example. In some embodiments a single valve may regulate supply to both pipes 7A, 7B but individual regulation is preferred as it allows more control over the air jets produced by the respective pipes 7A, 7B and thus the flow pattern within the treatment section 30.

20 The outlet portions may be at the same depth within the treatment section 30 or, as shown in Fig. 1 and Fig. 3, may be at different heights. In the depicted embodiment both outlet portions are located near the lower wall 4 of the reactor vessel 1. Advantageously, placement of the outlet portions near the lower wall 4 provides for
25 better mixing and oxygenation due to the longer path length of air bubbles traversing the vessel 1 from near the vessel bottom 4.

The air jets injected by the outlet portions of the aeration pipes 7A and 7B cause agitation of the water in the treatment section 30. The first ring 7A has a diameter
30 slightly larger than the diameter of the cylindrical screen 13 so that air jets from the first ring 7A influence water near the centre of the treatment section 30, while the second ring 7B has a diameter slightly smaller than the diameter of the reactor vessel 1 such that air jets from the second ring 7B influence water near the perimeter of the treatment section 30. This arrangement of rings 7A and 7B has been found to be optimal as
35 allows for thorough mixing of the biofilter carrier elements 6 throughout the treatment

section 30. However, other arrangements could also be used, for example a single ring arranged concentrically about the screen 13 and having a diameter approximately half the vessel diameter.

5 In addition to agitating the biofilm carrier elements 6, the air jets carry oxygen, which supports the aerobic biological process of nitrification in the bioreactor 100. The aeration process makes correct adjustment between consumption and supply of oxygen possible. Advantageously therefore, the aeration pipes 7A and 7B simultaneously provide agitation and aeration. It will be appreciated that in some
10 embodiments, the agitation and aeration functions could be provided by separate components. For example, aeration could be provided by air supplied at lower pressure through one or more pipes (which need not have ring-shaped outlet portions) while agitation could be performed by one or more separate agitation devices such as impellers and the like.

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In some embodiments, oxygen supply can be provided by use of technical oxygen gases, although use of air is preferred as it is cheaper and safer.

The MBBR 100 comprises a pumping system, in particular an airlift pumping system 9,
20 comprising an airlift pipe 10 having one end disposed in the outlet section 40, near the lower wall 4 and just above the ring-shaped outlets of the aeration pipes 7A, 7B. The airlift pipe 10 has a vertical section 10A disposed in the outlet section 40, the vertical section 10A being coupled to a horizontal section 10B having an outlet 12 disposed above a top of the reactor vessel 1 and positioned to expel treated water back into the
25 pond as shown in Fig. 3. An air inlet pipe 11 extends from a pressure source into the airlift pipe 10, via a standard connection, near a bend junction between the vertical section 10A and the horizontal section 10B. Supply of air from the pressure source into the airlift pipe 10 is regulated by a valve 8C, such as a ball valve, of the air inlet pipe 11. Pressurised air can be injected into the airlift pipe 10 to force treated water in the
30 outlet section 40 to rise up the vertical section 10A of the airlift pipe 10 and be expelled through the outlet 12 back into the pond such that the treated water is recirculated to the pond in a directed manner. Accordingly, a directed water flow into the pond is created, and pond water flows into the reactor through the apertures 3, 23 in the reactor body ensuring good contact between the biofilm growing on the carriers and the
35 substrate in the pond water.

Advantageously, by using an airlift system to pump the treated water to the outlet 12, it is possible to use the same pressure source to simultaneously agitate/aerate and recirculate water. It will be appreciated, though, that in some embodiments separate pressure sources can supply the aeration pipes 7A, 7B on the one hand, and the airlift system 9 on the other hand. In other embodiments, an airlift system need not be used, and an alternative pumping system could be used to pump treated water from the outlet section 40 to the pond.

The flow capacity of the airlift system 9 essentially depends on the width of the vertical pipe 10A, the depth of the air inlet pipe 11 into the vertical section of the pipe 10A, and the pressure of the air flow. In practice, it is believed that the flow capacity of the airlift system 9 should be sufficient to achieve a retention time (in the reactor vessel 1) of 5 to 10 minutes. The flow rate of the air-lift system 9 can be adjusted by the volume of air introduced into the vertical pipe 10A of the airlift 9 by ball valve 8C in the aeration piping 11.

The pressure source used to supply the MBBR 100 for airlift and aeration operations may be provided by a blower, compressor or other similar air pressurisation device mounted on top of the reactor vessel 1, for example. In other embodiments the air can be transported through an air hose from any aeration device that is located remotely from the reactor vessel 1, for example a land-based aeration device next to the pond. Advantageously in such embodiments, no electrical equipment is used at the reactor 100 in the pond.

An exemplary water treatment process, which may use the MBBR 100, is illustrated in Fig. 4.

At step 402, the reactor vessel 1 is immersed in a body of water, such as a pond, for example a pond in which shrimp are being bred, such that the treatment section 30 is in fluid communication with the pond water via apertures 3, 23. The reactor vessel 1, being buoyant, will float in the pond such that the outlet 12 is above water level. If necessary, the floating position of the bioreactor 100 can be stabilised, and the immersion depth chosen to achieve optimal reactor volume, by adding stabilising

weights 14 to, or removing them from, the reactor vessel 1 after placing the reactor 1 in floating position in the pond – step 404.

At step 406, once water from the pond has entered the vessel 1, biofilm carriers 6 are added to the treatment section 30. In some embodiments, the biofilm carriers 6 may already be present in the treatment section 30 prior to the vessel 1 being immersed in the pond.

Next, at step 408, the pressure source (compressor, blower, etc.) is activated and the aeration piping valves 8A, 8B and airlift system valve 8C are opened (steps 410, 412). This leads to agitation 414 of the biofilm carriers 6, and flow 416 of treated water from the treatment section 30 to the outlet section 40, as described above. The treated water can be pumped 418 from the outlet section 40 back to the pond. Typically, steps 414 to 418 are carried out continuously.

The materials for constructing the components of the MBBR 100 described above, including the body of the reactor vessel 1 and the piping 7A, 7B, 10A, 10B, 11, are preferably chosen to be safe and non-toxic to aquatic organisms and are preferably corrosion resistant. Examples of such materials include plastics, such as polyethylene, polypropylene, acrylic plastic or fiberglass reinforced plastic (FRP), or stainless steel.

EXAMPLE

We have demonstrated that the use of a floating MBBR 100 can effectively control ammonia level in a pond. The ammonia range recorded was between 0.25 – 1 mg / L, as shown in Table 1 below. Despite the gradual increase in the daily amount of feed to be added into the pond, the amount of ammonia level rose steadily in parallel and the maximum level stays at 1 mg / L from day 10 – 25. On day 26, the ammonia level dropped to 0.5 mg / L and the ammonia level stays constant at 0.25 mg / L from day 33- 60. The lethal range of ammonia as cited in literature is 2 mg / L. In this regard, we are able to maintain the optimal range of ammonia level in the pond which is necessary for the growth and development of shrimp.

Table 1.

Record of ammonia level in a shrimp culture pond for a duration of 60 days.						
Days	Feeding QTY (kg)	Ammonia (mg/L)		Days	Feeding QTY (kg)	Ammonia (mg/L)
1	14.3	0		32	148.5	0
2	17.6	0		33	148.5	0.25
3	20.9	0.25		34	148.5	0.25
4	27.5	0.25		35	157.5	0.25
5	35.2	0.25		36	157.5	0.25
6	48.4	0.25		37	157.5	0.25
7	55	0.25		38	157.5	0.25
8	71.5	0.5		39	166.5	0.25
9	82.5	0.5		40	166.5	0.25
10	82.5	1		41	203.5	0.25
11	82.5	1		42	225.5	0.25
12	82.5	1		43	225.5	0.25
13	82.5	1		44	225.5	0.25
14	93.5	1		45	225.5	0.25
15	93.5	1		46	236.5	0.25
16	82.5	1		47	236.5	0.25
17	93.5	1		48	236.5	0.25
18	103.4	1		49	247.5	0.25
19	114.4	1		50	253	0.25
20	126.5	1		51	242	0.25
21	138.6	1		52	200	0.25
22	138.6	1		53	230	0.25
23	138.6	1		54	242	0.25
24	138.6	1		55	242	0.25
25	138.6	1		56	242	0.25
26	100.8	0.5		57	220	0.25
27	110.7	0.25		58	220	0.25
28	112	0.25		59	200	0.25
29	109.6	0.25		60	200	0.25
30	135	0				
31	148.5	0				

5 The moving bed bioreactor of embodiments of the present invention is relatively compact relative to the pond or similar closed environments of water, is easy to use, needs very little maintenance and is unlikely to clog or overflow.

As described generally above, embodiments of the floating biofilter placed directly in a pond or water body with intensive aquaculture production can be used not only for

nitrification, but may also be used for any purification technique based on biological degradation of a substance which is desired to be removed from the body of water.

In particular, embodiments of the invention can be used for the following:

- 5 - Removal of organic substances in aquaculture pond water through aerobic reaction.
 - Removal of ammonium by oxidation to nitrite and nitrate through aerobic reaction (nitrification).

Embodiments of the invention have one or more of the following advantages:

- 10 - Efficient ammonia removal directly where the ammonia is excreted
 - No water pressure (pump) required to move the pond water to a separate treatment facility
 - Use of inexpensive, inert media
 - No collection of solids – no backwashing
15 - Almost maintenance-free operation
 - Small footprint in pond

- Whilst the foregoing description has described exemplary embodiments, it will be understood by those skilled in the technology concerned that many variations in details
20 of design, construction and/or operation may be made without departing from the present invention.

Claims

1. A moving bed bioreactor, comprising:

a reactor vessel, comprising: a treatment section for holding a plurality of biofilm
5 carrier elements and an outlet section in fluid communication with the treatment section;
an agitator for imparting motion to the biofilm carrier elements, the agitator
comprising at least one gas entrainment device comprising at least one pressure source
and configured to inject a pressurized gas into the reactor vessel; and

an airlift pump system for pumping treated water from the outlet section,

10 wherein the reactor vessel is buoyant and comprises at least one sidewall and a
lower wall, the at least one sidewall and/or the lower wall having a plurality of apertures
for allowing flow of water into and out of the chamber when the reactor vessel is
immersed in a body of water, each of said apertures being sized to prevent flow of the
biofilm carrier elements out of the reactor vessel, and

15 wherein the at least one pressure source acts as a pressure source for the airlift
pump system.

2. A moving bed bioreactor according to claim 1, wherein the outlet section is separated
from the treatment section by a screen which is configured to prevent egress of biofilm
20 carrier elements while permitting flow of water.

3. A moving bed bioreactor according to claim 1 or claim 2, wherein the gas entrainment
device is an aeration device or an oxygenation device.

25 4. A moving bed bioreactor according to any one of claims 1 to 3, wherein the gas
entrainment device comprises at least one pipe having a plurality of apertures formed in
at least a portion thereof, the at least a portion being disposed in the treatment section.

5. A moving bed bioreactor according to claim 4, comprising a plurality of pipes arranged
30 concentrically with respect to each other.

6. A moving bed bioreactor according to claim 4 or claim 5, wherein the apertures of said
pipe or pipes are disposed in a portion of the treatment section adjacent the lower wall.

35 7. A moving bed bioreactor according to any one of the preceding claims, wherein the airlift
pump system comprises an airlift pipe disposed in the outlet section.

8. A moving bed bioreactor according to claim 7, wherein the screen is disposed around the airlift pipe.
- 5 9. A moving bed bioreactor according to any one of the preceding claims, wherein the at least one pressure source is a compressor or blower system located remotely from the reactor vessel.
- 10 10. A moving bed bioreactor according to any one of the preceding claims, comprising a spacer element for elevating the lower wall.
11. A moving bed bioreactor according to any one of the preceding claims, further comprising a plurality of biofilm carrier elements disposed in the treatment section.
- 15 12. A moving bed bioreactor according to any one of the preceding claims, wherein the reactor vessel is generally cylindrical.
13. A moving bed bioreactor according to claim 12, wherein the reactor vessel has a diameter approximately 1.5 times its height.
- 20 14. A water treatment process, comprising:
 - disposing a plurality of biofilm carrier elements in a treatment section of a reactor vessel having a plurality of apertures, each of said apertures being sized to prevent flow of the biofilm carrier elements out of the reactor vessel;
 - 25 immersing the reactor vessel in a body of water such that the reaction vessel floats and water enters the treatment section from the body of water through the plurality of apertures and mixes with the biofilm carrier elements; agitating the biofilm carrier elements;
 - allowing treated water to flow to an outlet section of the reactor vessel while retaining
 - 30 the biofilm carrier elements in the treatment section; and
 - airlift pumping the treated water from the outlet section to the body of water, wherein said agitating comprises injecting a pressurized gas into the reactor vessel and a common pressure source is used for said agitating and said airlift pumping.
- 35 15. A water treatment process according to claim 14, wherein said agitating comprises injecting a pressurized gas into the reactor vessel.
16. A water treatment process according to claim 15, wherein the gas is air or oxygen.

17. A water treatment process according to claim 15 or claim 16, wherein the gas is injected at a plurality of injection points arranged concentrically with respect to each other.
- 5 18. A water treatment process according to claim 17, wherein the injection points are located adjacent a lower wall of the reactor vessel.
19. A water treatment process according to any one of claims 14 to 18, wherein the treated water is expelled by pumping.