FIELD OF INVENTION

The invention relates to a method for the purification of phosphorous, nitrogen and organic material from waste water in a continuous bio-film process with circulating carrier media. Further the invention relates to a reactor for use in carrying out the method.

BACKGROUND OF INVENTION

Municipal waste water and industrial waste water e.g. from food industry, comprise organic material and are also rich in nitrogen and phosphorous compounds, and thus purification of such waste water is necessary before the purified water is discharged to natural recipients like lakes, rivers and the sea.

Biological reactors are used for breakdown of organic and inorganic substrates in municipal and industrial waste water. Commercially there are two main types of biological reactors i) activated sludge reactors and ii) biofilm reactors. In activated sludge reactors the microorganisms are suspended in the waste water. In a biofilm reactor the microorganisms grow on carrier media. The carrier media can either be stationary e.g. surfaces of large drums or the reactor walls or free flowing smaller carrier elements.

Activated sludge reactors allow a continuous process; however such reactors are very area/volume consuming, and this is also the case for the final sludge separation by sedimentation. A portion of the sludge is re-cycled into the reactor or in-let stream of the reactor to maintain the microbiological culture.

Moving bed biofilm reactors are operated continuously or in batches. Enhanced biological phosphorous removal can only be applied in such a system if it is run in batches, i.e. the waste water is let into the reactor for treatment and the treated water is discharged before the reactor can be refilled with waste water. This implies that for each volume treated there is a time consuming filling and draining sequence. The method is thus laborious and will normally demand that series of reactors are operated in parallel.

Separation of sludge and water after the biological process is easier for a biofilm process than an activated sludge process. A biofilm process needs a smaller reactor volume than an activated sludge process, and also has no re-cycling of sludge demanding process control and energy. Since there is no recycling from the separation step in the biofilm process, the performance of the separation does not affect the biological process.

WO 2010/140898 A1 relates to a method and apparatus for biological purification of water in a reactor with one or more inlet and outlet zones where water and substrate come into contact with carrier elements for a biofilm.

US 2008/0053897 A1 disclose a liquid-solid fluidized bed waste water treatment system for simultaneous carbon, nitrogen and phosphorous removal. The system incorporates the fixed-film biological fluidized bed technology with the biological nutrient removal in a twin liquid-solid fluidized bed, which has achieved the simultaneous elimination of organic carbon, nitrogen and phosphorous.

CN 201999792 U is directed to a utility model related to a moving bed bioreactor, particularly an internal-circulation moving bed bioreactor. A disadvantage with this utility model is the leakage of water from the aerobic zone back to the anaerobic zone, thus inhibiting the anaerobic zone.

Other publications concerned with water purification/ treatment JPh 07163994 A, JP h 07163995 A, DE 19501260 C1 and Li, M., Nakhla, G., Zhu J.,"Simultaneous carbon and nitrogen removal with enhanced bioparticle circulation in a circulating fluidized bed biofilm reactor". Chem. Eng. Jour. 181-182 (2012) 35-44.

The problems connected with the prior art solutions are solved with the present invention.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 shows a schematic outline of an embodiment of the present invention.

Figure 2 shows inlet, anaerobic and aerobic PO_4 concentrations from the pilot experiments

Figure 3 shows PO_4 load and uptake and SCOD (soluble chemical oxygen demand) load and uptake.

SUMMARY OF THE INVENTION

The invention relates to a method for the purification of phosphorous, nitrogen and organic material from waste water in a continuous bio-film process with circulating carrier media and a reactor for use in carrying out the method. The invention is defined in the patent claims.

The present invention provides a Circulating Moving Bed Biofilm Reactor and method for treatment of different wastewaters. Biofilm carriers are circulated with the wastewater between different zones in the treatment plant, before the carriers are mechanically removed from the water and introduced at the beginning of the process.

DETAILED DESCRIPTION OF THE INVENTION

Enhanced biological removal of phosphorous involves subjecting the microorganism culture e.g. bacterial culture to alternating anaerobic and aerobic conditions. In an activated sludge installation this is simply done by leading the wastewater with the activated sludge from an anaerobic to an aerobic reactor and recycling sludge from the settling process to the anaerobic section. Phosphorous Accumulating Organisms, PAO, secrete phosphorous under anaerobic conditions, and are able to take up more phosphorous when subjected to aerobic conditions. Thus, in a bio-P (biological phosphorous) installation it is necessary to expose the sludge/bacteria to alternating anaerobic and aerobic conditions. Most bio-P installations today are activated sludge installations. A few bio-film installations with enhanced phosphorous removal exists, however, these are non-continuous batch installations, so-called Sequencing Batch reactor, (SBR). Here the carrier media with biofilm is in a reactor to which the waste water is added and is subjected to a period without air (anaerobic) and in a period with air (aerobic) before the purified water is drained off and the reactor re-filled with untreated waste water.

In biological removal of nitrogen/ammonium, there are different bacterial cultures responsible for different parts of the break down of ammonium in the waste water. The first step is nitrification which takes place under aerobe conditions; the second step is de-nitrification taking place under anoxic (without air) conditions. This can be carried out in two different biofilm reactors each having its carrier media where only the waste water flows from one reactor to the other.

The present invention enables the possibility to combine the biofilm process' advantages with enhanced biological phosphorous removal in a continuous process. Thus the present invention provides new embodiments for biological waste water purification processes.

The process according to the invention involves that the carrier media for the biofilm is moved or flows with the waste water between anaerobic and aerobic and optionally anoxic reactor zones. From the last step in the process the carrier media is moved without water to the start of the process.

Before the waste water stream is allowed into the biological reactor the raw waste water stream is subjected to pre-treatment. The pre-treatment is usually mechanical screening to remove large objects such as plastic, fabrics and the like, followed by sand and grease removal. Depending on the quality and origin of the wastewater, sedimentation or fine screening can also be introduced as pre-treatment steps.

In the following an embodiment of the invention, reactor and method, is described with reference to figure 1.

The biological reactor comprises an anaerobic (A), optionally an anoxic (B), and an aerobic (C) zone, all including carrier media for bio film. The waste water to be purified flows into the first zone of the reactor through an inlet (1). The separation of the different zones are made in such a way that waste water and carrier media can flow together from one zone to the next, or they can be mechanically (3,4,) moved for instance by an impeller or channel transport device. At the end of the last zone (C) of the reactor the carrier media, without water, is mechanically moved (5) to the inlet end of the first process zone (A). Moving of the carrier media is carried out by use of one or more mechanical devices such as e.g. elevators, transport screws, belt conveyers or the like. Each zone (anaerobic (A), anoxic (B), aerobic (C)) may be separated in several consecutive chambers, or designed as long channels to achieve as much plug flow as possible. The treated waste water, without the biofilm carriers, leaves the aerobe zone (C) through one or more outlets (2). Optionally a part of the outlet stream (6) is re-introduced into the anoxic zone (B) for additional nitrogen removal. The stream (6) can be moved by e.g. use of a pump.
In this way the bacteria culture is subjected to alternating anaerobic and aerobic conditions to obtain enhanced biological phosphorus removal combined with the biofilm’s efficiency, simplicity and good separation properties with respect to sludge separation.

The process will effectively provide removal of phosphorous and organic material, and if the process is extended with an anoxic zone and a return of water from the aerobic to the anoxic zone also removal of nitrogen/ammonium.

It is also possible to achieve complete/partly nitrogen removal by simultaneous nitrification/de-nitrification in the aerobic zone.
Since there is no waste water transported from the aerobic to the anaerobic zone, inhibition of the anaerobic zone by NO_3 is avoided.
The biofilm carriers are mechanically moved (5) from the aerobic zone (C) to the anaerobic zone (A) without the water, and in this way the present invention prevent nitrate being carried back to the anaerobic zone (A). Nitrates are dissolved in the water and as water is drained off as the biofilm carriers are moved (5) to the anaerobic zone (A) the nitrates are not carried over to the anaerobic zone (A).

Biofilm carriers varying in size, density, material and shape/design are known in the art, and any biofilm carrier may be suitable in the present invention.

For the separation of biofilm sludge following the biological process several methods are available e.g. flotation, sedimentation or fine screening. Any such methods known in the art can be used. In contrast to activated sludge from an active sludge process, the sludge removed from water treated according to the present invention comprises phosphorous in a plant available form and the sludge is thus a valuable resource as plant nutrient/fertilizer.

The present invention provides a continuous process which is area efficient compared with a batch run process. A batch process has to be run in several parallels to treat the same amounts of waste water as in a continuous process.

In one aspect of the invention a method for biological purification of waste water in a continuous process is provided where the method comprises the steps of
a) receiving a pretreated waste water in-let stream (1) in an anaerobic zone (A) of a reactor wherein micro-organism culture exist on freely moving biofilm carriers,
b) letting the waste water stream with the biofilm carriers into an aerobic zone (C) aerating the waste water stream and carriers received from the anaerobic zone (A),
c) at the end of the aerobic zone (C) moving the biofilm carriers mechanically to the anaerobic zone without transfer of water, and
d) discharge the water through an out-let (2) to a sludge separation process

In an embodiment of the method an anoxic zone (B) is included between the anaerobic (A) and the aerobic (C) zones.

In another embodiment of the method a recycling (6) stream is e.g. pumped from the outlet (2) stream into the optional anoxic zone (B).

In a further embodiment of the method the carrier media with biofilm are mechanically (3,4) moved from one zone/chamber to the next.

In yet an embodiment of the invention the filling ratio of carrier media is between 1% and 100%, preferably between 30 % to 70 %, of the wet volume of the reactor.

In another aspect of the invention a reactor for continuous biological purification of waste water is provided, where the reactor comprises an in-let (1) to an anaerobic zone (A), followed by an aerobic zone (C), one or more mechanical device (5) for transfer of biofilm carriers from the aerobic zone (C) to the anaerobic zone (A), and an out-let (2) characterized in that the one or more mechanical transport devices (5) for transfer of biofilm carriers allow water to drain off.

In one particular embodiment the reactor further comprises an anoxic zone (B) between the anaerobic (A) and the aerobic zone (C).

In another embodiment of the invention (the reactor) the mechanical transport devices for transfer of biofilm carriers allow water to drain off during transfer. The mechanical transport devices for transfer of biofilm carriers may be selected from elevators, transport screws, belt conveyers or the like.

EXPERIMENTAL

The pilot plant used in the experiments has a total volume of 6.6 m3 for the biological treatment step. At the end of the aerobic zone the biofilm carriers were lifted up from the water by a transport screw, and delivered to the first anaerobic zone. The inlet wastewater was introduced to the first anaerobic zone, and withdrawn from the last aerobic zone. The biofilm carriers were flowing through the anaerobic zones and the aerobic zones following the wastewater stream. Both the anaerobic and the aerobic zones were divided into several compartments separated by a wall with a small opening where wastewater and carriers flew through. Separation of biofilm sludge was carried out in a flotation unit.

Pilot scale experiments were carried out in order to verify the process. Inlet wastewater to the pilot plant has been wastewater from Hias wastewater treatment plant in Norway, receiving wastewater from 4 municipalities in Hedmark County. In Figure 2, the orthophosphate concentrations in the inlet, anaerobic and the aerobic zones are shown for some weeks of the experimental period.

In Figure 3 the PO4 load and uptake, and the SCOD load and uptake are shown for some pilot experiments.

CLAIMS

1. Method for biological purification of waste water in a continuous process comprising
   a) receiving a pretreated waste water in-let stream (1) in an anaerobic zone (A) of a reactor wherein micro-organism culture exist on free flowing biofilm carriers,
   b) letting the waste water stream with the biofilm carriers into an aerobic zone (C) aerating the waste water stream and carriers received from the anaerobic zone,
   c) at the end of the aerobic zone (C) moving the biofilm carriers mechanically to the anaerobic zone (A) without transfer of water (5), and
   d) discharge the water through an outlet (2) to a sludge separation process

2. Method according to claim 1 comprising an anoxic zone (B) between the anaerobic and aerobic zone.

3. Method according to any one of claims 1 to 2 comprising mechanical transfer (3, 4) of the biofilm carriers between zones/chambers.

4. Method according to any one of claims 2 to 3 wherein a part of the out-let stream (6) is re-introduced into the anoxic zone.

5. Method according to any one of claims 1 to 4 wherein the filling ratio of carrier media is between 1% and 100%, preferably between 30 % to 75 %, of the wet volume of the reactor.

6. Method according to any one of the preceding claims wherein the out-let stream (2) proceed to a separation step for collection of sludge for further treatment and discharge of purified water to recipient.

7. Reactor for continuous biological purification of waste water, comprising an in-let (1) to an anaerobic zone (A), followed by an aerobic zone (C), one or more mechanical device (5) for transfer of biofilm carriers from the aerobic zone (A) to the anaerobic zone (C), and an out-let (2) characterized in that the one or more mechanical transport devices (5) for transfer of biofilm carriers allow water to drain off.

8. Reactor according to claim 7, wherein the reactor further comprises an anoxic zone (B) between the anaerobic (A) and the aerobic zone (C).

9. Reactor according to claims 7 or 8, wherein the one or more mechanical transport devices (5) are elevators, transport screws, belt conveyers or the like.

ABSTRACT