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lems with many of the biorotors, and if the biorotor breaks down, it is difficult to adapt the biorotor to another system. True enough, there are several examples of biorotor reactors having been rebuilt to biofilter reactors, but then with a system based on a fixed filter material.

The main disadvantage with the traditional biofilter system (trickling filter) where the water is trickled over the carrier material for the biofilm and where the oxygenation takes place through natural ventilation, is that the bioreactor volume becomes relatively large. It is also a considerable disadvantage that in this system the amount of oxygen fed to the process cannot be adjusted to the amount which is used in the bioprocess and which corresponds to the organic load. It is commonly known that these circumstances result in that traditional biofilters (trickling filters) give a poorer purification effect for a given organic load per area than the other biofilm methods.

Another type of biofilter is the so-called immersed biofilter. The principle thereof is that a stationary biofilter material is immersed in the reactor while the biomass is oxygenated by aeration. The growth surface of the immersed biofilter is stationary and most often consists of corrugated plastic flakes glued together to form cubes which are placed one upon the other as building bricks or of randomly located single elements or granulates, which are all however, stationary during the use of the biofilter. The main disadvantage with the fixed, immersed biofilter, is that access to the underside of the biofilter is made very difficult. If the biofilter gets clogged from the underside, or if the aerating means, which are placed under the biofilter, get clogged, the whole biofilter has to be taken out for cleaning. It has also been a problem that whole biofilter elements have floated up as a consequence of partial clogging and capture of great air pockets in the biofilter material.

Another system is the so-called "fluidized bed" bioreactor. This is based on the bioreactor being filled with sand, and the water being pumped from the bottom to the top of the bioreactor with sufficient speed for the sand to fluidize. The biofilm grows on the sand grains. With this system a very great biomass per volume unit of the reactor can be obtained, because the specific growing area for biofilm will be large.

The disadvantage of the system is a result of the very great organic load per volume caused by this. Consequently, aerobic systems cannot be supplied with sufficient oxygen per volume unit to replace the oxygen used by the biomass. In practice, another problem has been to separate the biofilm from the sand grains, since these are so small (typically 0.4-0.6 mm).

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In addition there are other systems which are in the borderland between the above discussed traditional systems. Most of these systems aim to increase the biomass per volume unit of the bioreactor by formation of a biofilm.

Most of these alternative systems are based on something in between a biofilm system and an active sludge system, the sludge from the post separation stage being returned from the post-separation basin, in order to establish a slurry culture in addition to the biofilm culture in the bioreactor. In this way an attempt is made to "ride both horses".

This system is unfavourable because:

a. The sludge concentration in the sludge separation basin becomes very high, which results in greater risks for the recipient because of loss of sludge.

b. The slurry particles will present an organic strain on the biofilm, a fact which has been demonstrated in several research projects.

A very important disadvantage with a system based on biomass growing on and in small foam rubber dices which are floating in the reactor, is that these dices float so well that they will be floating on the surface of the water of the bioreactor and thus give a poor contact between the biomass and the incoming substrate. Another essential disadvantage has proved to be that the biomass grows on the surface of the dice only, and not in the pore volume as intended. This is a consequence of the fact that the biofilm on the outer surface prevents access of the water and the substrate to the inner volume.

It has now been found that the essential disadvantages of the above discussed systems may be avoided, while at the same time the most important advantages of each of these can be maintained.

Thus, according to the invention there is provided a method for water purification in which waste water is fed into a reactor containing carriers on which biofilm will grow and which promotes a desired conversion of impurities, and this method is characterized in that the carriers with the biofilm are kept suspended and moving in the water in a reactor with inlet and outlet tubes and optionally mixing means. The carriers are particulate elements having a larger surface than smooth elements of the same dimension. The surface of the elements is at least 1.5 times, and preferably at least 2 times as large as the outer surface of a smooth element of the same dimensions. The density of the elements is 0.90-1.20, particularly 0.92-0.98 and most particularly 0.92-0.96 kg/dm³.

The carrier elements have a linear dimension of from 0.2

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to 3 cm, particularly from 0.5 to 1.5 cm. The carriers have walls which allow easy passage of water, and are such that some of the surface thereof is protected against biofilm wear during use.

The carrier is prepared from soft plastic, so that it does not wear on the other carriers nor on the reactor itself with equipment. Since it is here a question of plastic which should primarily be a carrier for a film of bacteria, recycled plastic can advantageously be used for the preparation of the carrier.

The carrier has the above defined density, in order to be kept suspended. The carriers consist of pieces of a tube with internal separating walls. Both on the outer and the inner walls as well as on the separating walls there will be formed a biofilm layer of the desired bacterium culture. Generally, there should be as many separating walls as possible in order to make the surface extra large, but on the other hand care must be taken that the openings between the separating walls do not become so small that the openings get clogged. When the carrier is in the form of a piece of tube with internal separating walls, the tube walls may suitably comprise inward bends so that the outer wall is subjected to less friction against other carriers or against the reactor during operation. Thereby the biofilm on the outer wall of the carrier is kept more intact. A tube used for the preparation of the carrier, may for instance suitably have internal walls forming a cross. Also, the internal walls in the tube can be made to form a honeycomb pattern, but other patterns which provide a large surface and easy passage may just as well be used. It is also possible to use particles with a rough surface.

Most suitably, the carrier is a piece of an extruded tube having separating walls in the longitudinal direction of the tube with "fins" on the outer side. The reason why such a carrier is particularly advantageous, is that it will be very easy to prepare, contrary to a carrier prepared by other possible methods, for instance die-casting where each carrier has to be prepared individually. For extrusion, a tube is continually extruded and cut in suitable pieces. All the separating walls will then be in the longitudinal direction of the tube, so that irrespective of where the tube is cut, the cross-section will be the same.

In addition to the carrier containing internal separating walls, it has been found advantageous that it also contains "fins" on the outer side, thus to be in the form of a piece of an extruded tube

having separating walls in the longitudinal direction of the tube, both inside and outside the circumference of the tube. By such an arrangement a particularly large surface is obtained with relatively little material, for instance plastic, compared with the surface. Like the internal surfaces of the tube, also the outer surfaces close to where the "fins" protrude from the circumference of the tube, will be protected against wear on the biofilm during use.

A suitable type of carrier with "fins" is illustrated by the cross section on figure 1. Seen from the side, the carrier will look like a rectangle. This is almost the simplest conceivable shape. Another shape is illustrated on figure 2, where the tube has a square cross section and is supplied with several internal walls. A modification of this embodiment is illustrated on figure 3, where the inner walls as well as the outer walls extend beyond the circumference of the tube to give the above mentioned "fins". As illustrated on figure 1 such "fins" do not only have to be a continuation of inner walls or outer walls, but may also be independent "fins" between those which for instance have been illustrated on figure 3.

The carrier is used in reactors for water purification by feeding an adjusted amount of the carrier into the reactor, and the water to be purified is treated in the reactor by the biofilm which is established and will grow on the carriers, causing the desired conversion of the pollutants. Suitably there is used a reactor with water inlet at the bottom and outlet for the purified water at the top, but such a location is not necessary, particularly if suitable mixing and circulation devices are used. The reactor is conveniently equipped with sieve means in which the mesh width is less than the smallest diameter of the carrier. This will serve to prevent the carriers escaping from the reactor. The carriers may easily be pumped in and out of the reactor, and maintenance does not require a break in the operation.

The carriers, the use thereof, the reactor and the method according to the invention, constitute a system which, compared with the above described, previously known systems, has several advantages:

- The reactor volume is completely open and the growth surface for the biofilm, consisting of solid, non-porous particles, circulates around in the bioreactor, while the specific weight of the particles is very close to 1.0 kg/dm³.
- The bioreactor may be totally closed, and the carrier material immersed, which makes optimal contact between the impurities in the water and the microorganisms on the carriers possible, as well as complete control with possible smelling agents from the process.

- The bioreactor may be oxygenated through aeration, which makes correct adjustment between consumption and supply of oxygen possible. Thus, the organic load may be adjusted in accordance with that consumed by the biomass.

The system according to the invention has the same advantage as the active sludge systems in that the reactor is open and therefore cannot become clogged. Further, the reactor may have practically any form.

A great advantage of the present system, compared with the other biofilm systems, is that existing active sludge systems may very easily be rebuilt in such a manner that the system according to the invention may be adapted to the existing installations based on the active sludge principle. Such a rebuilding is very complicated with the other biofilm systems.

The difference between the present system and the immersed biofilter discussed above, is primarily that the growth surface for biofilm in the present system is circulated around in the bioreactor as a consequence of the turbulence made by the aeration or by hydrodynamic forces, while the growth surface in the immersed biofilter, as stated above, is stationary, and normally consists of corrugated plastic flakes glued together as cubes which are placed one upon the other as building bricks, or single elements or granules randomly placed in the bioreactor, but which are still stationary during the operation of the biofilter.

In the present system clogging of the biofilter medium will not be possible, since the biofilter medium is not stationary, but moves with the streams in the bioreactor. If the aeration devices in the reactor become clogged, it is very easy to remove the biofilter medium by simply pumping it out. Similarly, it may be pumped into the bioreactor when the process is started up.

When the bioreactor is used for anaerobic processes, where there is no aeration, the bioreactor medium is subjected to continuous or sporadic stirring, for instance by means of a propeller stirrer or by circulation pumping. Accordingly, the chance of clogging is very small, contrary to when a stationary biofilter is used, where the risk of clogging in an anaerobic system is rather great. The reactor content may here be heated to increase the reaction rates in the anaerobic processes.

In the present system the surface per volume unit desired for the operation may be decided, and because of this the oxygen supply can be adjusted in exact conformity with the oxygen consumption that takes place. The oxygen supply can also be adjusted so that air instead of pure oxygen may be used for the oxygenation. The particles on which the biofilm grows, are comparatively large, and

they do not sink, but circulate, or are kept circulating, so that the particle density may be chosen independent of the amount of water desired through the reactor.

In the method according to the invention, the sludge is not returned to the bioreactor.

A particular object of the invention is to obtain a greater disintegration rate of the substrate per volume unit of the reactor than that which is obtained by competing systems, and thereby to obtain lower costs per disintegrated weight unity of substrate.

The object is obtained by allowing the biofilm to grow on the carrier according to the invention, placed in a reactor through which the water to be purified is flowing.

When an aerobic biological process should take place in the bioreactor, the content of the reactor is aerated. Through the aeration the carriers get thoroughly mixed in the reactor volume, and good contact between the biofilm growing on the carriers and the substrate in the waste water is thereby ensured.

When an anaerobic process should take place in the bioreactor, the content of the reactor is not aerated. Thorough mixing of the content of the reactor is then ensured e.g. by mechanical stirring (propeller stirrer) or by circulation pumping of the content of the reactor.

Normally the carriers will be retained in the reactor when the water flows out of the reactor through a sieve means with light orifice less than the cross section of the carriers. For special uses, for instance in biologic removal of phosphorus, it will be possible to let the carriers follow the water out of the reactor, later to be separated off and returned to the reactor. This is in case done to let the biofilm growing on the carriers flow through both an aerobic and an anaerobic reactor.

The reactors may in pre-fabricated form be totally closed both for aerobic and anaerobic processes. This makes it possible completely to control the smell that may be produced in the reactor. Both when the reactor is used in aerobic and in anaerobic processes, the exhaust gases from the process are captured and led away. In aerobic processes the exhaust gases consist primarily of carbon dioxide and smaller amounts of other gases which are let out in the air, optionally after separate deodorizing. In anaerobic processes, the waste gases consist primarily of methane and carbon dioxide with smaller amounts of other gases. This biogas has a high heat value and accordingly may optionally be used for energy production.

When the invention is used to upgrade existing purification plants, the reactor will normally be open, since the basins already available can then be used (for instance aeration tanks in active sludge installations).

The amount of carriers in the reactor will vary according to the field of use and the reactor volume available. Normally, the amount will be such that the carriers in an empty tank take up 30-70% of the reactor volume. However, the amount may be adjusted to the substrate load the reactor is intended to work with. Thus, the amount may be decided by the oxygenation capacity of the reactor.

The three most important values to be decided when dimensioning the bioreactor, are the volume of the reactor, the number of carriers per volume unit and the amount of oxygen to be supplied (in the case of an aerobic reactor). The reactor of the invention for aerobic, anoxic or anaerobic water purification comprises inlet and outlet means and a large number of carriers as described above, the volume of the carriers is an empty reactor representing 30-70% of the reactor volume, and means for suspending and moving the carriers within the reactor.

The reactor itself may be built with any relevant materials, but the pre-fabricated, closed-reactors will normally be built from steel or GAP, while the open reactors will normally be built from concrete or steel.

The biofilm sludge may be separated downstream the bioreactor by any of the relevant particle separation techniques, as for instance sedimentation, flotation, filtration and membrane technique.

As described generally above, the bioreactor may be used for all purification techniques based on biological degradation of a substance which should be removed.

However, the most common fields of use can be:

- * Removal of organic substance in waste water through aerobic reaction.
- * Removal of organic substance in concentrated organic sewage through anaerobic reaction.
- * Removal of ammonium by oxidation to nitrite and nitrate through aerobic reaction (nitrification).
- * Removal of nitrogen by reduction of nitrite and nitrate to nitrogen gas through anaerobic (anoxic) reaction (denitrification).
- * Removal of phosphorus through aerobic/anaerobic reaction.

The invention provides the following advantages in purification of waste water:

- * The bioreactor according to the invention requires a smaller reactor volume to remove a given weight unity of pollutant (organic substance, ammonium, etc.) than the existing traditional arrangements, since the biomass per volume unit is higher.
- * In pre-fabricated form the present bioreactor normally is closed, in order to obtain better control with possible smelling gases than in

the traditional solutions.

- * In the aerobic embodiment there is a better possibility to adjust the oxygen supply in accordance with the oxygen need than in the traditional systems.
- * Due to the large contact surface between the biomass and the air supplied, it is reason to believe that the oxygen is better utilized in the present reactor than in the traditional active sludge installations. This entails reduced need of air and consequently lower energy costs for running the present reactor compared with the active sludge systems.
- * The reactor will have approximately the same design both for aerobic and anaerobic systems. As a result, an aerobic system may easily be rebuilt to an anaerobic system and vice versa. This is a particular advantage for those systems that require both an aerobic and an anaerobic step, for instance systems for biological removal of nitrogen and phosphorus.
- * Compared with immersed biofilters with a stationary growth surface for biofilm, the growth surface for biofilm anticipated here, is much more easy to remove from the reactor container, which simplifies cleaning, inspection and maintenance both of the reactor container and the aeration system, and which reduces the risks for clogging of the growth surface medium.
- * Existing biological purification plants based on active sludge can very easily increase their capacity when existing reactors are used in the system of the invention.

A simple reactor has been illustrated on figure 4, where the reactor 1 is a cylinder containing carriers 2 for biofilm. At the outlet for purified water 5 the reactor is equipped with a sieve means 3. Water is fed in through a tube at the bottom of the container 4, and the exhaust gas is let out through a tube in the top 6. Foam formation may be prevented by means of a sprinkler system 7 which may spray water on the surface.

Figure 5 illustrates the reactor equipped with means for the admixture of air 8 which supplies air through a line 9. This reactor is intended for aerobic processes.

Figures 6 and 7 illustrate reactors equipped with stirring means for use in anaerobic processes, but which otherwise are similar to the reactor on figure 1. On figure 6 the stirring means is a motor-operated propeller stirrer 10, and on figure 7 a circulation pump 11 in an attached circulation tube 12.

Claims

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1. A method for water purification in which waste water is allowed to flow through a reactor containing carriers on which biofilm will grow, which promotes a desired conversion of impurities, characterized by using carriers which are particulate elements which have been prepared from a soft plastic, optionally recycled plastic, and are in the form of pieces of a tube with internal separating walls, the carriers having:

- a) a surface which is at least 1.5 times as large as the outer surface of a smooth element of the same dimensions, and
- b) a density in the range 0.90 to 1.20, normally 0.92 to 0.98, particularly 0.92 to 0.96 kg/dm³, and
- c) some of the surface protected against biofilm wear during use, and
- d) walls which allow easy passage of water, and
- e) linear dimensions in the range 0.2-3 cm, particularly 0.5-1.5 cm,

wherein the carriers with biofilm are kept suspended and moving in the water in a reactor with inlet and outlet and optionally mixing means; and wherein sludge which leaves the reactor is not returned to the reactor.

2. A method according to claim 1, characterized by using carriers having a surface which is at least 2 times as large as the outer surface of a smooth element of the same dimensions.
3. A method according to any of claims 1 and 2, characterized by using carriers having linear dimensions in the range 0.2-3 cm, particularly 0.5-1.5 cm.
4. A method according to any of claims 1-3, characterized by using carriers which have been prepared from a soft plastic, optionally resirculated plastic, and are in the form of pieces of a tube with internal separating walls.
5. A method according to any of claims 1-4, characterized by using carriers which are pieces of an extruded plastic tube.
6. A method according to claim 5, characterized by using carriers which are pieces of an extruded tube having separating walls in the longitudinal direction of the tube inside the circumference, and fins on the outside in the longitudinal direction.
7. Reactor (1) for aerobic, anoxic or anaerobic water purification, comprising inlet (4) and outlet (5,6) means, characterized in that it contains a large number of carriers (2) for biofilm, which are used in the process according to any of claims 1-6, the volume of the carriers in an empty reactor

representing 30-70 % of the reactor volume, and means for suspending and moving said carriers within the reactor.

8. Reactor according to claim 7, characterized in that it comprises a sieve means (3) for separating the carriers from the liquid at the outlet (5).
9. Reactor according to any of claim 7 and 8 for aerobic water purification, characterized in that it comprises means for the admixture of air (8) which is supplied with air through an air-inlet (9).
10. Reactor according to any of claims 7 and 8 for anaerobic water purification, characterized in that it comprises mixing means in the form of a mechanical stirrer (10) or a circulation pump (11).

Patentansprüche

1. Methode zur Reinigung von Wasser, in welchem Schmutzwasser durch einen Reaktor fließt, der Träger enthält auf welchen ein Biofilm wächst, der die gewünscht Umwandlung der Verunreinigungen fördert, gekennzeichnet durch die Verwendung von Trägern bestehend aus Plastikelementen
 - a) mit einer Oberfläche die mindestens 1,5-fach so groß wie die Außenfläche eines weichen Elements der gleichen Dimension sind, und
 - b) mit einer Dichte im Bereich von 0.90 bis 1.20, normalerweise 0.92 bis 0.98, insbesondere 0.92 bis 0.96 kg/dm³, und
 - c) wobei Teile der Oberfläche gegen den Verschleiß des Biofilms während der Benutzung geschützt sind, und
 - d) mit Wänden, die ein leichtes Durchfließen des Wassers erlauben, worin die Träger mit dem Biofilm suspendiert gehalten werden und sich im Wasser in einem Reaktor mit Einlaß und Auslaß und gegebenenfalls Mischeinrichtungen bewegen.
2. Methode gemäß Anspruch 1, gekennzeichnet durch die Verwendung von Trägern mit einer Oberfläche, die mindestens 2-fach so groß wie die Außenfläche eines weichen Elements der gleichen Dimension ist.
3. Methode gemäß einem der Ansprüche 1 und 2, gekennzeichnet durch die Verwendung von Trägern linearer Dimension im Bereich von 0,2