

Description
Purification method for effluent

[0001] The present invention relates to a filtration
5 device for wastewater purification, preferably for a
sewage treatment plant, to a sewage treatment plant
having such a filtration device, to a method of
purifying wastewater, in particular wastewater in a
sewage treatment plant, and also to the use of a
10 ceramic-based membrane for separating off
microorganisms, and if appropriate, also fine solids,
from wastewaters.

[0002] In addition to screens and settling tanks
15 which, in a first step, free wastewaters from coarse
components, conventional sewage treatment plants also
contain an activation tank and a secondary
clarification tank. In the activation tank,
microorganisms are used in order to decompose fecal
20 matter or other organic substances. The microorganisms
used are separated off again by sedimentation from the
wastewater subsequently to the activation tank, in the
secondary clarification tank and in part recirculated
to the activation tank. Complete separation of the
25 microorganisms is not possible by a sedimentation
process, and therefore microorganisms which are harmful
to health can sometimes pass into the environment
together with the wastewater. European union directives
for keeping water bodies clean, which guidelines have
30 already been substantially converted to national
legislation, however, prescribe on a Europe-wide basis
that only biologically clarified wastewater which is
essentially free from microorganisms may be allowed to
drain off into the environment. The microorganisms are
35 generally separated off by fine filters which reliably
separate off microorganisms.

[0003] In Germany, primarily in rural areas, in
particular in eastern Germany, predominantly for

technical or economic reasons, currently an estimated 5.3 million people are not connected to the municipal wastewater grid. Those affected, as a consequence of said EU directives, had to be provided with facilities by December 31 2005 either by connection to the municipal grid or by the operation of a small sewage treatment plant. This situation created a high demand for decentralized wastewater treatment plants which is maintained to date.

10

[0004] Small sewage treatment plants are relatively widely distributed, which sewage treatment plants consist of a round concrete container which again is subdivided into three chambers (preliminary clarification/activation tank/secondary clarification). The preliminary clarification is used in order first to remove coarse components from the wastewater mechanically or by simple sedimentation. The coarse components which are separated off must be pumped off at regular time intervals. The activation tank contains microorganisms which perform the biological purification, the secondary clarification tank serves for separating off the microorganisms which have been introduced and their recirculation to the activation tank and/or to the preliminary clarification tank. This equipment can be supplemented, for example, by a compressor which feeds oxygen to the activation tank via a membrane tube aerator, and also a submersible motor pump for transporting the excess sludge.

30

[0005] In an activation tank, in the course of time, excess clarified sludge forms which must be regularly drawn off by suction. Alternatively, what are termed moving-bed processes are also known in which the amount of excess sludge is generally drastically reduced. In contrast to the classical activation tank, in moving-bed processes, free-floating plastic bodies are employed which can fill up the activation tank

35

virtually completely. Microorganisms are found in this case both on the plastic bodies and also freely suspended in the water.

5 [0006] In recent years, as a further development of
the known moving-bed methods, increasingly what are
known as WSB® methods (fluidized bed-moving bed-biofilm
methods) have been able to become established. Such
methods are described, for example, in DE 10127554 and
10 also in DE 196 23 592. In these methods also, plastic
bodies serve as carriers which can be colonized by the
microorganisms. The microorganisms in WSB® methods are
however generally localized virtually completely on the
carrier material. Whereas in fluidized-bed methods
15 operations were originally carried out exclusively
anaerobically (without aeration), in WSB® methods, as a
result of the introduction of air, the plastic carriers
colonized by microorganisms are optimally and uniformly
distributed (or "fluidized") in the activated zone and
20 are situated in the moving suspension, which gave rise
to the name Wirbel-Schwebe-Bett (WSB®) [fluidized bed-
moving bed]. Even in the case of greatly varying
inflow, e.g. in the holiday period, the biological
system in the activation tank always remains intact.

25

[0007] However, there is also the problem in the case
of wastewater purification by a WSB® method that micro-
organisms are discharged into the environment, that is
to say microbe-containing wastewater is introduced into
30 the activated soil zone or into a receiving body of
water.

[0008] To avoid harmful microorganisms from being
introduced into the activated soil zone and/or to
35 enable treated wastewater to be able to be reused as
service water, the wastewater must therefore be
additionally filtered.

[0009] For instance, DE 19807890 describes a sewage treatment plant, the wastewater of which is filtered through submerged microfiltration membranes in order to pass it thereafter into a service water reservoir and reuse it. DE 20315451 describes a microfiltration device as a retrofitting set for a small sewage treatment plant which is connected downstream of the activation tank but upstream of the actual outlet of the sewage treatment plant.

[0010] In all cases here organic filter membranes are used which are arranged in a module form. However, organic filter membranes have the disadvantage that they can only be regenerated or chemically cleaned inadequately, so that all of these membranes must generally be renewed in relatively short time periods (< 1 year). In addition, organic membranes have only a restricted mechanical stability, such that at relatively high liquid pressures, they can easily be damaged. The use of organic membranes becomes particularly serious in the abovementioned moving-bed methods, in particular in the WSB® method, since in these, as a result of the plastic carrier particles which can move freely in the activation tank, mechanical defects on the organic membrane can be caused as a result of which the low-stability organic filter membranes can be destroyed within a short time.

[0011] The use of filter membranes is in addition linked with the fundamental problem that during filtration, a covering layer is deposited on the outer surface of the membrane (what is termed fouling) which provides a resistance to the material to be filtered. This leads to a drastic reduction in filter performance to total blockage and therefore to total loss of the filter membrane.

[0012] Detachment of this covering layer on the membrane requires regular cleaning. In this operation the permeate stream is reversed so that the previously filtered water is then pumped back through the filter
5 membrane in the opposite direction (backwashing). As a result, the covering layer is at least in part detached, as a result of which the efficiency of the filter performance is increased again for a certain time. However, this procedure generally requires
10 separate equipment. In addition, cleaning is at the cost of losing already filtered water which greatly reduces the efficiency of the overall system.

[0013] The object of the present invention is to
15 provide a simple and inexpensive solution for purifying wastewaters. This solution shall focus, in particular, on separating off microorganisms contained in wastewaters. Known prior art problems such as said destruction of filter membranes by biological or
20 mechanical action or the blockage of membranes and resultant complex cleaning steps must be avoided as completely as possible.

[0014] This object is achieved by the filtration
25 appliance having the features of claim 1, the sewage treatment plant having the features of claim 15, the method having the features of claim 18 and also the use having the features of claim 23. Preferred embodiments of the filtration appliance according to the invention
30 are shown in dependent claims 2 to 14. Dependent claims 16 and 17 relate to preferred embodiments of the sewage treatment plant according to the invention. In subclaims 19 to 22 and 24, preferred embodiments of the method according to the invention and also of the use
35 according to the invention are shown. The wording of all claims is hereby made a content of this description by reference.

[0015] A filtration appliance according to the invention for wastewater purification is provided in particular for use in a sewage treatment plant, in particular in a small sewage treatment plant. It is distinguished in that it comprises at least one ceramic-based membrane for separating off microorganisms.

[0016] A ceramic-based membrane is distinguished by resistance to biological or chemical action and also by high mechanical stability. In contrast to the organic filter membranes which are known from the prior art, which have been used to date in small sewage treatment plants, a filtration appliance according to the invention having a ceramic-based membrane may therefore be used without problems also in moving-bed methods, in particular also in small sewage treatment plants operated according to the WSB® method. It withstands without problems the biological action caused by the microorganisms and at the same time reliably separates these off. Fine solids and suspended matter can if appropriate also be reliably separated off. At the same time, it is resistant to mechanical action, for example due to plastic carrier particles floating in the activation tank. This becomes particularly positively noticeable with respect to maintenance intervals and lifetime of the membrane.

[0017] Preferably, a membrane of a filtration appliance according to the invention is a membrane plate made of a porous ceramic. In principle, the shape of the membrane plate may be freely chosen. For instance, round or rectangular membrane plates may be preferred, matched to the respective individual case.

[0018] In a preferred embodiment the membrane plate has a coating. This preferably comprises at least one separation layer which consists at least in part, in

some preferred embodiments, essentially completely, of nanoscale particles. Preferably, the separation layer has a fraction of nanoscale particles of at least 5% by weight, particularly preferably of at least 25% by weight, in particular of at least 40% by weight.

[0019] Nanoscale particles are taken to mean here particles having a median particle size of less than 1 μm , preferably less than 500 nm, in particular less than 100 nm, particularly preferably less than 50 nm. These size figures relate to values which were obtained by means of light-scattering experiments.

[0020] According to the invention, the membrane plate coating mentioned may consist exclusively of the at least one separation layer. In a particularly preferred embodiment, the coating, however, further comprises at least one further porous layer which is arranged between the membrane plate and the at least one separation layer. The at least one separation layer is preferably the outer layer at which the microorganisms are essentially separated off.

[0021] The coating situated on the membrane plate preferably has a thickness between 100 nm and 150 μm , preferably between 500 nm and 100 μm , in particular from approximately 25 μm to 60 μm . These values preferably also apply to the cases in which the coating consists of the at least one further porous layer and the at least one separation layer.

[0022] The thickness of the at least one separation layer is preferably in the range between 100 nm and 75 μm , in particular in the range between 5 μm and 50 μm , in particular approximately 25 μm .

[0023] The thickness of the at least one further porous layer is preferably in the range between 100 nm

and 75 μm , in particular in the range between 5 μm and 50 μm , in particular approximately 25 μm .

5 [0024] The porous ceramic of the membrane plate (substrate) has pores preferably having a diameter between 100 nm and 10 μm , particularly preferably between 500 nm and 6 μm , in particular between 500 nm and 3 μm .

10 [0025] The at least one further porous layer has pores preferably having a diameter between 500 nm and 2 μm , particularly preferably between 500 nm and 1 μm , in particular between 600 nm and 900 nm.

15 [0026] In the case of a membrane plate provided with at least one separation layer, in particular the pore size of the at least one separation layer is very important for separating off the microorganisms. Preferably, a separation layer has pores having a
20 diameter between 1 nm and 1400 nm, more preferably between 50 nm and 500 nm, in particular between 50 nm and 300 nm, particularly preferably between 200 nm and 300 nm.

25 [0027] The pore size of possibly underlying layers generally does not directly affect the separation of the microorganisms. However, it is preferred that underlying layers have larger pores than the separation layer. Particularly preferably, with respect to the
30 pore size, there is a gradient to the outer separation layer. For instance, it is preferred that the pore sizes decrease towards the outside.

[0028] In preferred embodiments having at least one
35 further porous layer between the at least one separation layer and the membrane plate, the size of the pores of the at least one further porous layer is between the size of the pores of the separation layer

(smallest pore sizes) and the size of the pores of the membrane plate (which has the largest pores). This applies in particular to the mean values of pore sizes within the layers (since the pore size is frequently non-uniform within a layer, if appropriate overlapping with respect to the absolute pore sizes can occur, such that, for example, the size of the largest pores of the at least one separation layer can exceed the size of the smallest pores of the at least one further porous layer).

[0029] The porous ceramic of the membrane plate is preferably a ceramic based on a metal oxide, in particular based on aluminum oxide. In addition to oxidic ceramics such as aluminum oxide ceramics, in further preferred embodiments, non-oxidic ceramics can also be used.

[0030] The nanoparticles of the separation layer are preferably oxidic nanoparticles, in particular aluminum oxide particles. In addition, in particular, also nanoparticles of zirconium dioxide or titanium dioxide or else mixtures of said oxidic nanoparticles can be preferred. For particularly thin separation layers, in particular zeolites are very highly suitable. In further preferred embodiments, the nanoparticles can also be non-oxidic nanoparticles.

[0031] In a particularly preferred embodiment of the filtration appliance according to the invention, the membrane plate has internally at least one channel for the outflow of purified wastewater. Preference, however, is given to a plurality of channels which are preferably arranged in parallel to one another which extend uniformly over the interior of the membrane plate.

[0032] A filtration appliance as claimed in the

present invention has preferably at least 2 membrane plates. Depending on the individual case, the number of membrane plates can vary greatly. For instance, for purifying relatively small amounts of wastewater, filtration appliances having 3 to 15, in particular 3-10, membrane plates can be preferred. If larger amounts of wastewater are produced, however, filtration appliances having several hundred membrane plates are also conceivable.

10

[0033] A filtration appliance according to the invention has preferably a modular structure which enables the number of membrane plates to be varied in accordance with the respective requirements.

15

[0034] In a particularly preferred embodiment of the filtration appliance according to the invention, the at least 2 membrane plates are arranged essentially in parallel to one another. In this case it is further preferred that the distance between a plurality of membrane plates which are arranged essentially in parallel to one another is essentially always the same.

20

[0035] As has already been described, the shape of a membrane plate in a filtration appliance according to the invention can in principle be selected freely, depending on the individual case. The same applies in principle also to the dimensions of a membrane plate, wherein the length or width of a membrane plate generally does not exceed 150 cm. For instance, in a preferred embodiment, a rectangular membrane plate has a length of approximately 50 cm and a width of approximately 11 cm.

25

30

[0036] The thickness of a membrane plate in a filtration appliance according to the invention is here generally preferably in the range between 0.15 mm and 20 mm, in particular between 0.5 mm and 10 mm. In a

35

particularly preferred embodiment, a membrane plate has a thickness of approximately 6 mm.

5 [0037] A sewage treatment plant according to the invention is distinguished in that it has at least one filtration appliance as claimed in the present invention. Preferably, a sewage treatment plant according to the invention is a small sewage treatment plant, in particular having a purification output for 1 to 5000 persons (up to a resident figure of 5000).

10 [0038] The filtration device according to the invention has already been adequately explained. The corresponding parts of the description are hereby explicitly incorporated herein by reference.

15 [0039] Preferably, a sewage treatment plant as claimed in the present invention has at least one activation tank for wastewater. In this the wastewater is biologically purified by microorganisms.

20 [0040] In a further preferred embodiment of the sewage treatment plant according to the invention, at least one secondary clarification tank for wastewater is connected downstream of the at least one activation tank.

25 [0041] A filtration device according to the invention can in this case be connected not only directly to an activation tank but also to a secondary clarification tank.

30 [0042] As has already been mentioned, the present invention also comprises a method of purifying wastewater, in particular in a sewage treatment plant. This is distinguished in that microorganisms situated in the wastewater are separated off by means of at least one ceramic-based membrane.

[0043] The method according to the invention preferably comprises a biological purification of the wastewater by microorganisms in at least one activation tank.

5 [0044] In a further preferred embodiment a method as claimed in the present invention comprises a secondary clarification of the wastewater in at least one secondary clarification tank.

10 [0045] The present invention likewise relates to the use of a ceramic-based membrane as filter for separating off microorganisms from wastewaters.

15 [0046] In a preferred embodiment of the use according to the invention, the ceramic-based membrane is a membrane plate made of a porous ceramic which is provided with an, if appropriate, multilayer coating which comprises a separation layer which consists at least in part of nanoscale particles.

20 [0047] Not only the membrane plate, but also the coating comprising the separation layer have been described in the context of the explanations of the filtration appliance according to the invention. Here also, correspondingly, reference is made to the relevant parts of the description.

25 [0048] The above and other advantages of the invention will become apparent from the description of the following example and the figures in combination with the subclaims. The individual features of the invention can be implemented each alone or in combination with one another. The examples and figures serve only for illustration and for better understanding of the invention and are in no way to be understood as being restrictive.

30

[0049] In the figures:

Fig. 1: shows on the left: membrane plates for a preferred embodiment of the filtration device according to the invention having channels for conducting away purified water. In each case the exits of a plurality of channels in the membranes which are arranged in parallel to one another may be seen. The channels serve for conducting away the purified wastewater.

On the right: microscopic detail of a cross section through a membrane plate which is suitable according to the invention. In the lower region (dark) the relatively coarse-grained structure of the porous ceramic of the membrane plate may be seen. At the top (light) the significantly finer structure of a thin coating (here only consisting of a separation layer) on the porous ceramic may be seen.

Fig. 2: shows an SEM image of a section through a membrane plate which is suitable according to the invention. Three layers may be seen, namely on the left the separation layer, in the center a further porous layer and on the right a membrane plate made of a porous ceramic. The layers and the membrane plate itself each consist of aluminum oxide. The separation layer and the further porous layer each have a thickness of approximately 25 μm . The thickness of the membrane plate is up to 3.25 mm. The pore size decreases toward the separation layer from 4000 to 6000 nm (membrane plate) through approximately 800 nm (central further porous layer) to approximately 200 nm (separation layer).

Fig. 3: shows a filtration appliance according to the invention having ten membrane plates arranged in parallel to one another.

Example

- 5 [0050] In a long-term experiment, a study was made of how stably a filtration appliance according to the invention behaves on operation (moving-bed method). In this study moldings made of plastic (K1 Biofilm Carrier Elements from Kaldness, 3103 Tønsberg, Norway) were
- 10 constantly in contact with the membrane of a filtration appliance according to the invention. Even after a plurality of weeks, however, neither damage nor wear of the membrane could be observed, and the membrane throughput was also very satisfactory.

Patent claims

1. A filtration appliance for wastewater purification, preferably for a sewage treatment plant, in particular for a small sewage treatment plant, comprising at least one ceramic-based membrane for separating off microorganisms.
5
2. The filtration appliance as claimed in claim 1, characterized in that the membrane is a membrane plate made of a porous ceramic.
10
3. The filtration appliance as claimed in claim 2, characterized in that the membrane plate has a coating which comprises a separation layer which consists at least in part of nanoscale particles.
15
4. The filtration appliance as claimed in claim 3, characterized in that the coating comprises at least one further porous layer which is arranged between the membrane plate and the separation layer.
20
5. The filtration appliance as claimed in one of claims 3 or 4, characterized in that the coating has a thickness between 100 nm and 150 μm , preferably between 500 nm and 100 μm , in particular from approximately 25 μm to 60 μm .
25
6. The filtration appliance as claimed in one of claims 2 to 5, characterized in that the porous ceramic of the membrane plate has pores having a diameter between 100 nm and 10 μm , particularly preferably between 500 nm and 6 μm , in particular between 500 nm and 3 μm .
30
35
7. The filtration appliance as claimed in one of claims 3 to 6, characterized in that the

separation layer has pores having a diameter between 1 nm and 1400 nm, preferably between 50 nm and 300 nm, particularly preferably between 200 nm and 300 nm.

5

8. The filtration appliance as claimed in one of claims 2 to 7, characterized in that the porous ceramic of the membrane plate is an oxidic ceramic, in particular based on aluminum oxide.

10

9. The filtration appliance as claimed in one of claims 3 to 8, characterized in that the nanoparticles of the separation layer are oxidic nanoparticles which are preferably selected from the group having aluminum oxide, zirconium dioxide, titanium dioxide and mixtures thereof.

15

10. The filtration appliance as claimed in one of claims 2 to 9, characterized in that the membrane plate has internally at least one channel for the outflow of purified wastewater.

20

11. The filtration appliance as claimed in one of claims 2 to 10, characterized in that it has at least 2 membrane plates.

25

12. The filtration appliance as claimed in claim 11, characterized in that the at least two membrane plates are arranged essentially in parallel to one another.

30

13. The filtration appliance as claimed in claim 12, characterized in that the distance between a plurality of membrane plates which are arranged essentially in parallel to one another is essentially always the same.

35

14. The filtration appliance as claimed in one of

claims 2 to 13, characterized in that the membrane plate has a thickness between 0.15 mm and 20 mm, preferably between 0.5 mm and 10 mm, in particular of approximately 6 mm.

5

15. A sewage treatment plant, in particular small sewage treatment plant, characterized in that it has at least one filtration appliance as claimed in one of claims 1 to 14.

10

16. The sewage treatment plant as claimed in claim 15, characterized in that it has at least one activation tank for wastewater.

15 17. The sewage treatment plant as claimed in one of claims 15 or 16, characterized in that it has at least one secondary clarification tank for wastewater.

20 18. A method of purifying wastewater, in particular in a sewage treatment plant, characterized in that microorganisms situated in the wastewater are separated off by means of at least one ceramic-based membrane.

25

19. The method as claimed in claim 18, comprising a biological purification of the wastewater by microorganisms in at least one activation tank.

30 20. The method as claimed in claim 18 or claim 19, comprising a secondary clarification of the wastewater in at least one secondary clarification tank.

35 21. The method as claimed in one of claims 18 to 20, characterized in that the microorganisms are separated off from the wastewater by at least one filtration appliance as claimed in one of claims 1

to 14.

22. The method as claimed in claim 21, characterized
in that the microorganisms are separated off by a
5 filtration appliance having membrane plates
arranged in parallel to one another.
23. The use of a ceramic-based membrane as filter for
separating off microorganisms from wastewaters.
- 10 24. The use as claimed in claim 23, characterized in
that the ceramic-based membrane is a membrane
plate made of a porous ceramic which is provided
with an, if appropriate, multilayer coating which
15 comprises a separation layer which consists at
least in part of nanoscale particles.