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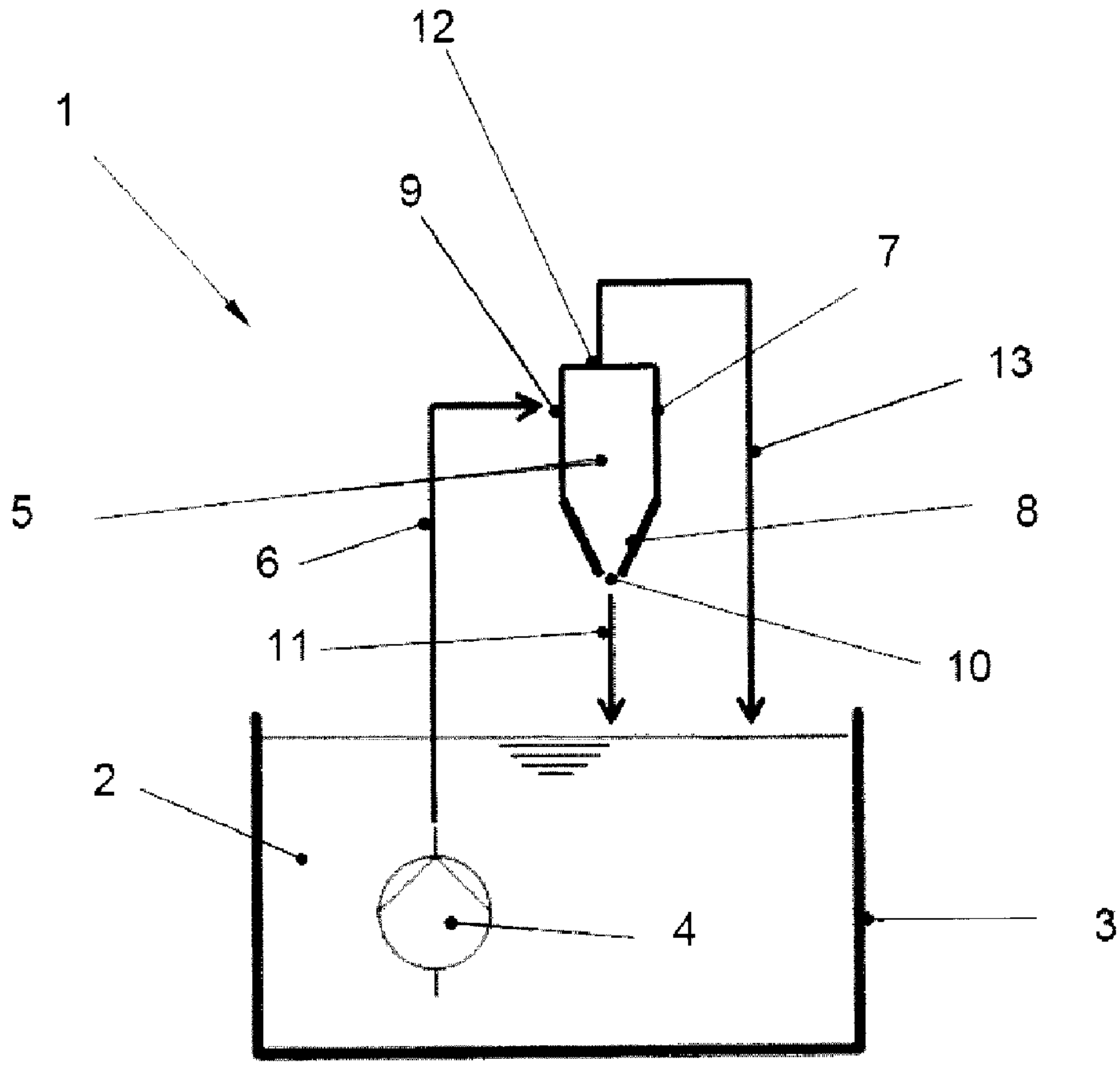
(72) **Inventeur/Inventor:**
NYHUIS, GEERT, CH

(73) **Propriétaire/Owner:**
DEMON GMBH, CH

(74) **Agent:** MCMILLAN LLP

(54) **Titre : PROCEDE ET INSTALLATION POUR TRAITER DES EAUX RESIDUAIRES CONTENANT DE L'AMMONIUM**
(54) **Title: PROCESS AND FACILITY FOR TREATING AMMONIUM-CONTAINING WASTEWATER**



(57) **Abrégé/Abstract:**
The invention relates to a process and a facility (1) for treating ammonium- containing wastewater (2) in a deammonification facility (1) having at least one activation tank (3). According to the invention, it is provided that activated sludge from the activation tank (3)

(57) **Abrégé(suite)/Abstract(continued):**
is introduced at least intermittently into a hydrocyclone (5) and that, after the separation of the activated sludge in the hydrocyclone (5) both the dense fraction and the light fraction which predominantly contains the aerobically ammonium-oxidizing bacteria (AOB) are returned to the at least one activation tank (3) of the facility (1). During the separation of the activated sludge in the hydrocyclone (5), the anaerobically ammonium-oxidizing bacteria (anammox) having a higher density than the aerobically ammonium-oxidizing bacteria (AOB) are sedimented on a roughened internal wall surface of the hydrocyclone (5) by the centrifugal and hydrodynamic forces in the hydrocyclone (5) and abrasive forces are generated by a relative motion between the rapidly moving anaerobically ammonium-oxidizing bacteria (anammox) and the stationary roughened internal wall surface of the hydrocyclone (5), via which abrasive forces an organic or inorganic plaque present on the ammonium-oxidizing bacteria (anammox), in particular Planctomycetes granules, is at least partly removed.

ABSTRACT

Process and facility for treating ammonium-containing wastewater

The invention relates to a process and a facility (1) for treating ammonium-containing wastewater (2) in a deammonification facility (1) having at least one activation tank (3). According to the invention, it is provided that activated sludge from the activation tank (3) is introduced at least intermittently into a hydrocyclone (5) and that, after the separation of the activated sludge in the hydrocyclone (5) both the dense fraction and the light fraction which predominantly contains the aerobically ammonium-oxidizing bacteria (AOB) are returned to the at least one activation tank (3) of the facility (1). During the separation of the activated sludge in the hydrocyclone (5), the anaerobically ammonium-oxidizing bacteria (anammox) having a higher density than the aerobically ammonium-oxidizing bacteria (AOB) are sedimented on a roughened internal wall surface of the hydrocyclone (5) by the centrifugal and hydrodynamic forces in the hydrocyclone (5) and abrasive forces are generated by a relative motion between the rapidly moving anaerobically ammonium-oxidizing bacteria (anammox) and the stationary roughened internal wall surface of the hydrocyclone (5), via which abrasive forces an organic or inorganic plaque present on the ammonium-oxidizing bacteria (anammox), in particular Planctomycetes granules, is at least partly removed.

(Fig. 1)

Process and facility for treating ammonium-containing wastewater

The invention relates to a process for treating ammonium-containing wastewater in a deammonification facility having at least one activation tank, in which first ammonium is reacted to form nitrite by means of aerobically oxidizing bacteria (AOB) and then ammonium and nitrite are reacted to form elemental nitrogen by means of anaerobically ammonium-oxidizing bacteria (anammox), in particular by means of Planctomycetes, and in which sludge from the activation tank is fed to a hydrocyclone and therein is separated into a dense fraction which predominantly contains the anaerobically ammonium-oxidizing bacteria (anammox), and into a light fraction, wherein the dense fraction is returned to the activation tank.

In addition, the invention relates to a deammonification facility for treating ammonium-containing wastewater having at least one activation tank and having at least one hydrocyclone for separating sludge from the activation tank into a dense fraction which predominantly contains anaerobically ammonium-oxidizing bacteria (anammox) and a light fraction, wherein the hydrocyclone has a feed that is flow-connected to the activation tank for introducing the sludge, an underflow flow-connected to the activation tank for returning the separated dense fraction to the activation tank and an overflow for removing the separated light fraction from the hydrocyclone.

The activated-sludge process is a process for biological wastewater purification in sewage treatment plants. Here, the usually municipal wastewater is substantially freed from organic impurities, that is to say purified by the metabolic activity of aerobic chemoorganoheterotrophic microorganisms, termed activated sludge. The process begins after the separation or settling of the coarse fractions, which can be dewatered, separated, digested and burnt. For municipal wastewaters, this process belongs to the classical intensive treatment processes. The general usability is advantageous as is the good purification activity for wastewaters for decreasing the contents of suspended matter, the chemical oxygen demand (COD), the biochemical oxygen demand (BOD_5) and the nitrogen compounds (N).

Facilities in accordance with the activated-sludge process can be operated either continuously, i.e. in the continuous-flow mode (conventional activation facility), or discontinuously (SBR facility). In addition, there also exists what are termed membrane activation facilities in which the purified water is separated off from the sludge by means of a membrane. All variants have in common the fact that bacterial mass or biomass suspended in the water, which is also termed activated sludge, undertakes the biological purification of the wastewater. For this purpose, each facility has at least one activation tank in which the wastewater is admixed with the activated sludge and thereby brought into intensive contact with the activated sludge.

The biomass formed in the activation tank during the aerobic biological wastewater purification by the degradation of the wastewater components is termed activated sludge. It consists substantially of bacteria, fungi, protozoa, EPS and further components. Microscopic studies verify that activated sludge flocs are "activated" by bacteria and protozoa. Therefore, they are termed activated sludge. The activated sludge, in the technological use in the activated-sludge process, is generally present in the form of activated sludge flocs, which, in addition to live and dead biomass, contain adsorbed and enclosed organic compounds and minerals.

In the activated-sludge process, after the breakdown of the pollutants in the wastewater, via activated sludge, this sludge is separated from the purified water in what is termed the secondary sedimentation. A majority of the sludge that is separated off is returned to the activation tank as return sludge or recirculated sludge. As a result, it is ensured that the activated sludge concentration can be maintained in the activation tank. The activated flocs present in the return sludge renew the purification power of the activation. The non-recirculated, smaller volumetric flow rate of the activated sludge is termed excess sludge. The excess sludge is therefore the fraction of the activated sludge which is taken off and pumped into the sludge treatment for maintaining constancy of the desired biomass concentration. This removed biomass growth is generally fed together with the primary sludge to the sludge digestion and finally to the sludge dewatering.

In conventional sewage treatment plants, today, virtually exclusively, biological nitrification/denitrification is used for nitrogen elimination. Nitrogen elimination is taken to mean the conversion of biologically available nitrogen compounds such as ammonium (NH_4), nitrite (NO_2) and nitrate (NO_3) to elemental nitrogen (N_2) which is outgassed to the ambient air as a harmless end product. In nitrification, ammonium is oxidized by oxygen via the intermediate nitrite to form nitrate. In the subsequent denitrification, the nitrate is reduced in a first reduction step to nitrite and to nitrogen in a second reduction step.

The biological nitrification/denitrification has the disadvantage of a high oxygen demand and therewith high energy consumption. In addition, in the denitrification, organic carbon is consumed, which has a disadvantageous effect on the further purification process and the sludge properties.

In comparison with the nitrification/denitrification, in deammonification, only 40% of the oxygen is required, and the energy consumption for the nitrogen elimination is reduced by 60%. Deammonification is an autotrophic process in which no organic carbon is required. Therefore, the remaining purification process is more stable.

Deammonification is an efficient process for biological nitrogen elimination, e.g. also in the case of wastewaters having high ammonium concentrations. In biological deammonification with a suspended biomass, two groups of bacteria participate, firstly the aerobically ammonium-oxidizing bacteria (AOB), which react ammonium to form nitrite, and, secondly, the anaerobically ammonium-oxidizing and elemental nitrogen-producing bacteria (anammox), in particular Planctomycetes, which carry out this step using the previously produced nitrite.

The aerobically ammonium-oxidizing bacteria (AOB) produce, on the basis of the turnover of matter, ten times more new bacterial mass than the anaerobically ammonium-oxidizing bacteria (anammox). The residence time of the sludge in the one-sludge system must therefore be at least long enough that the slowly growing anaerobically ammonium-oxidizing bacteria (anammox) can accumulate.

Processes for the single-stage and/or two-stage deammonification are already adequately known, for example from WO 2007/033393 A1 or EP 0 327 184 B1.

Disadvantageous in this case are, in particular, the substantially longer generation times of the anaerobically ammonium-oxidizing bacteria (anammox), which are longer by the factor 10 than those of the aerobically ammonium-oxidizing bacteria (AOB). As a result, a stable system can only develop when the residence time of the sludge and/or of the bacteria in the tank is sufficiently large. This in turn causes large reaction volumes and correspondingly designed tanks.

In addition, a sufficiently high wastewater temperature (> 25°C) is a foundation for the existence and/or growth of the anaerobically ammonium-oxidizing bacteria (anammox). However, heating up the wastewater is energetically very expensive, for which reason the described processes are not economically useable or feasible in the case of wastewaters having low temperatures.

In addition, the presence of such bacterial groups (NOB) which convert the nitrite formed into nitrate under aerobic conditions proves to be disadvantageous. This group of bacteria has generation times shorter by the factor 10 compared with the anaerobically ammonium-oxidizing bacteria (anammox). To compensate for these differing generation times, it has already been contemplated to operate the aerated phase of the one-sludge system at a very low oxygen level (< 0.4 mg O_2/l). As a result, no or little oxygen is available to the nitrate-forming bacteria (NOB) for converting the nitrite, which in turn is highly advantageous for the anaerobically ammonium-oxidizing bacteria (anammox). The reduced oxygen supply during the aerated phase, however, has the disadvantage that the aerobic conversion of the ammonium to nitrite is also oxygen-limited and as a result proceeds very slowly.

The slow-growing Planctomycetes, which have a generation time longer by the factor 10 compared with the nitrite-forming bacteria (AOB), have the particular property that very many individual bacteria form a spherical aggregate, termed Planctomycetes granules. These Planctomycetes granules have a very high density (10^{10} bacteria/ml).

The wastewater that is to be treated contains, in addition to the ammonium that is to be broken down, organic substances, such as organic acids and further organic substances which are described by the overall parameter "dissolved COD" and can be up to some hundreds of mg/l (typically: 100-2000 mg/l). These organic substances are broken down by very rapid-growing heterotrophic bacteria. The heterotrophic bacteria frequently colonize the Planctomycetes granules and cover these with an organic covering layer or a plaque. The covering layer leads to a diffusion limitation and as a result makes more difficult the conversion of ammonium (NH_4) and nitrite (NO_2) into elemental nitrogen (N_2), since the substrate (NH_4 and NO_2) must first pass through this covering layer before it is available to the Planctomycetes for the conversion.

The wastewater that is to be treated, frequently wastewater from a sludge digestion (anaerobic stabilization of sewage sludge) or generally wastewater having elevated nitrogen concentrations, in addition to ammonium (NH_4) and organic degradable substances, also contains inorganic substances, such as, for example, calcium carbonate and/or struvite, which can likewise be deposited on the surface of the Planctomycetes granules. Also, suspended matter present in the wastewater which can be up to some hundreds of mg/l (typically 50-1000 mg/l) form or increase the covering layer of the Planctomycetes granules.

The covering of the Planctomycetes granules, owing to the diffusion limitation, leads to a great fall in performance of the deammonification facility. Comparative measurements between free, uncoated Planctomycetes granules and granules having a covering layer have shown a difference in the specific conversion rate of nitrogen (mg N/g DM) by the factor 4-6.

The deposits or the plaque on the Planctomycetes granules can be seen even with the naked eye. Free, uncoated granules are intensely red/rust-red, and the plaque-coated granules, depending on the degree of coating, are light reddish/brown to dark brown.

EP 2 163 524 B1 already discloses a process and a deammonification facility of the type mentioned at the outset. In the disclosed process, the excess sludge taken off for maintaining constancy of the biomass concentration in the facility is not disposed of and fed to the sludge digestion, but is fed to a hydrocyclone and therein separated into a dense fraction (underflow) and a light fraction (overflow). In this case the density differences of the two bacterial groups (anammox/AOB) present in the excess sludge are utilized in order to separate the excess sludge into a dense phase which predominantly contains the anerobically ammonium-oxidizing bacteria (anammox), and a light phase (AOB). By returning the bacterial group (anammox) present in the dense phase to the activation tank of the facility, the slow-growing bacterial group (anammox) is enriched in the activation tank.

The two sludge fractions that are to be separated, namely the light fraction and the dense fraction, differ markedly not only in density but also in biological characteristics. These are completely different groups of bacteria. The Planctomycetes granules consisting of a plurality of individual bacteria have, compared with the aerobically ammonium-oxidizing bacteria (AOB) present in the form of flocs, have a markedly greater density. Owing to the density differences present between the two bacterial groups, the excess sludge removed may be separated into a dense Planctomycetes-granule-containing phase, and a light phase containing the floc-type sludge fraction. The Planctomycetes granules, owing to the density differences, are considerably heavier than the flocs.

The object of the invention is to provide an improved process for treating ammonium-containing wastewater. In addition, the object of the invention is to provide an improved deammonification facility for treating ammonium-containing wastewater.

According to the invention, therefore, a process is provided for treating ammonium-containing wastewater, in which activated sludge from the activation tank is introduced at least intermittently into the hydrocyclone and in which after the separation of the activated sludge in the hydrocyclone both the dense fraction and the light fraction which predominantly contains the aerobically ammonium-oxidizing bacteria (AOB) are returned to the at least one activation tank of the facility, wherein during the separation of the activated sludge in the hydrocyclone, the anaerobically ammonium-oxidizing bacteria (anammox) having a higher density than the aerobically ammonium-oxidizing bacteria (AOB) are sedimented on a roughened internal wall surface of the hydrocyclone by the centrifugal and hydrodynamic forces in the hydrocyclone and abrasive forces are generated by a relative motion between the rapidly moving anaerobically ammonium-oxidizing bacteria (anammox) and the stationary roughened internal wall surface of the hydrocyclone, via which abrasive forces an organic or inorganic plaque present on the ammonium-oxidizing bacteria (anammox), in particular Planctomycetes granules, is at least partly removed.

An improved process is provided thereby for treating ammonium-containing wastewater, since a reaction of ammonium and nitrite to form elemental nitrogen via the anaerobically ammonium-oxidizing bacteria (anammox) is facilitated in that the organic or inorganic plaque representing a diffusion limitation on the anaerobically ammonium-oxidizing bacteria (anammox) present as Planctomycetes granules is removed. Here, the plaque is removed or washed off from the granules so gently that the granules themselves are not destroyed by the abrasive forces. Obtaining the granular structure is of elemental importance for the desired nitrogen conversion rate of the facility. By not only the dense fraction but also the light fraction, after the separation in the hydrocyclone, being returned to the same activation tank from which the activated sludge that was introduced into the hydrocyclone was also removed, the ratio of the bacterial species required for the deammonification, namely the anaerobically ammonium-oxidizing bacteria (anammox), in particular Planctomycetes granules, and the aerobically ammonium-oxidizing bacteria (AOB), in particular Nitrosomonas, is maintained in the facility or in the biological system. At the same time, by removing the plaque, the nitrogen conversion rate is increased. Since the aerobically ammonium-oxidizing bacteria present in floc form are predominantly present in the light fraction of the activated sludge, it is indispensible for an efficient deammonification and good nitrogen conversion rate that, in addition to the Planctomycetes granules, also the light fraction is returned to the activation tank.

In the hydrocyclone, therefore, the Planctomycetes granules present as an aggregate of a plurality of individual bacteria are deposited on the roughened internal wall surface of the hydrocyclone owing to their greater density compared with the aerobically ammonium-oxidizing bacteria present in floc form. This roughened internal wall surface has a greater roughness compared with an adjacent internal wall surface or an internal wall surface of a conventional hydrocyclone. In this case the internal wall surface can itself be roughened or have a surface coating which is rough or develops the greater roughness. Owing to the contact with the roughened internal wall surface, abrasive forces are introduced into the granules which are developed in such a manner that the organic or inorganic plaque on the granules is gently removed without destroying the aggregate of individual bacteria or the individual bacteria themselves. After the removal of the plaque, the granules are returned to the activation tank via the underflow of the hydrocyclone.

The aerobically ammonium-oxidizing bacteria (AOB) present in the form of flocs and predominantly in the light fraction are discharged from the overflow of the hydrocyclone via an internal and upwardly directed internal vortex developing in the hydrocyclone owing to their considerably lower density compared with the granules. As a result, these bacteria (AOB) do not come into an intense contact with the roughened internal wall surface in the cone, and so these bacterial flocs are not exposed to the abrasive forces and can be removed substantially undamaged from the hydrocyclone and returned to the activation tank. This means, the in any case poorer settling properties of the floc-type bacteria can at least be retained. A destruction of the floc structure, in contrast, would impair the settling properties in such a manner that the aerobically ammonium-oxidizing bacteria (AOB) necessary for the deammonification would be discharged together with the sludge water from the biological system or from the activation tank.

The specific conversion rate of nitrogen (mg N/g DM) is increased by the factor 4-6 by the process according to the invention and the removal of the organic or inorganic plaque acting as diffusion limitation from the Planctomycetes granules.

In practice, it has, furthermore, proved particularly advantageous that the activated sludge in the hydrocyclone is exposed to centrifugal forces of 30 to 180 times the acceleration due to gravity. In the case of centrifugal forces of this order of magnitude and high velocities of the activated sludge resulting therefrom, in particular of the dense fraction, the plaque on the Planctomycetes granules is virtually completely removed. At low values, no or only very low ablation of the plaque proceeds, and at relatively large values, the granules consisting of a plurality of individual bacteria, or the individual bacteria themselves, are destroyed.

In addition, it is found to be advantageous that the dense fraction and the light fraction of the activated sludge that are separated in the hydrocyclone are each completely returned to the activation tank. The return ensures that the activated sludge introduced from the activation tank into the hydrocyclone is completely returned to the same activation tank and therefore a balanced ratio between the bacterial species participating in the deammonification (anammox, AOB) is available in the activation tank of the facility.

An advantageous development of the present process is also achieved in that during the separation of the activated sludge in the hydrocyclone, the dense fraction predominantly containing the anaerobically ammonium-oxidizing bacteria contacts the roughened internal wall surface arranged in a conical segment of the hydrocyclone and then is removed therefrom via an underflow of the hydrocyclone and the light fraction predominantly containing the aerobically ammonium-oxidizing bacteria (AOB) contacts a smooth internal wall surface in a cylindrical segment of the hydrocyclone and is then removed therefrom via an overflow of the hydrocyclone. This means that the abrasive forces act solely on the Planctomycetes granules and thereby remove the organic or inorganic plaque, while the aerobically ammonium-oxidizing bacteria (AOB) exclusively come into contact with the smooth internal wall surface of the cylindrical segment. As a result, a destruction of the aerobically ammonium-oxidizing bacteria present in the form of flocs can be prevented. The selected roughness of the internal wall surface depends on the diameter of the cylindrical segment of the hydrocyclone. The greater the diameter of the cylindrical segment, the greater should be the selected roughness. In experiments, it has been found that the surface should have a granularity of up to 100 µm.

A particularly advantageous development of the process according to the invention is also provided in that after a first predetermined time period in which activated sludge is introduced into the hydrocyclone and is separated into a dense fraction and a light fraction and both the dense fraction and the light fraction are returned to the activation tank, excess sludge taken off during a second predetermined time period from the activation tank is fed to the hydrocyclone instead of activated sludge, wherein the excess sludge is separated in the hydrocyclone into a dense fraction and a light fraction, and solely the dense fraction is returned to the activation tank or is collected and fed to an activation tank of a second facility, while the light phase is disposed of.

During the first time period, the Planctomycetes granules present in the dense fraction are washed and/or the organic or inorganic plaque present on the granules is at least partly removed. In contrast, during the second time period, via the disposal of the light fraction and the return of the dense fraction to the activation tank of the facility, the slow-growing group of the anaerobically ammonium-oxidizing bacteria (anammox) are enriched in the biological system and/or in the activation tank. The fraction of the anaerobically ammonium-oxidizing bacteria (anammox) can be elevated during the second time period in such a manner that the reaction volume of the tank is correspondingly decreased and the process stability of the facility increased.

In this case, it has proved to be particularly relevant in practice that a length of the first time period is greater than a length of the second time period. In practice, it has proved to be advantageous that the length of the first time period is roughly 1.5 to 4 times the length of the second time period. Particularly preferably, activated sludge is introduced into the hydrocyclone 70% of the total running time of the hydrocyclone and excess sludge is introduced 30% of the total running time. Here, the length of the respective time period is adapted in dependence on the number, the respective size of the hydrocyclones, and the size of the activation tank, and also the nitrogen conversion rate of the facility that is to be achieved.

According to the invention, it is further provided that alternately and consecutively, during a first time period, activated sludge is introduced into the hydrocyclone, and during a second time period, excess sludge is introduced. This means that, following the introduction of excess sludge during the second time period, again a first time period follows in which then activated sludge is introduced into the hydrocyclone.

According to the invention, therefore, a deammonification facility is provided for treating ammonium-containing wastewater, in which the sludge that is introduced into the hydrocyclone is formed as activated sludge and the overflow of the hydrocyclone for returning the separated light fraction which predominantly contains aerobically ammonium-oxidizing bacteria (AOB) to the activation tank is flow-connected to the activation tank, and in which the at least one hydrocyclone has a cylindrical segment and a conical segment, wherein an internal wall surface of the conical segment is roughened at least in sections and the roughened internal wall surface of the conical segment has a greater roughness than an internal wall surface of the cylindrical segment.

Such a configuration of the hydrocyclone and the flow-connection of the hydrocyclone to the activation tank provides an improved deammonification facility for treating ammonium-containing wastewater. By means of the facility according to the invention, the organic or inorganic plaques situated on the Planctomycetes granules can be gently and, in the process, particularly effectively, removed. The removal of the plaques acting as a diffusion limitation substantially facilitates the reaction of ammonium and nitrite to form elemental nitrogen via the Planctomycetes.

The conical segments of the hydrocyclone having a greater roughness than the cylindrical segment ensures that the abrasive forces required for removing the plaque are introduced solely into the dense fraction. Since the light fraction, owing to the lower density, is discharged through the overflow by the upwardly directed internal vortex forming in the hydrocyclone, the light fraction does not come into direct contact with the roughened internal wall surface in the conical segment of the hydrocyclone. Therefore, no abrasive forces are introduced into the light fraction, and so the bacteria (AOB) present in floc form in the light fraction are not destroyed. This is highly advantageous, in particular because of the significantly poorer settling properties of this sludge fraction. A destruction would lead to further impairment of the settling properties, in consequence of which these bacteria would be discharged from the biological system or from the activation tank, and would no longer be available for the deammonification.

It has proved particularly relevant in practice that the internal wall surface of the conical segment of the hydrocyclone has at least in sections a roughness having a granularity of up to 100 μm. In the case of a higher granularity, the anaerobically ammonium-oxidizing bacteria present in the aggregate, namely the Planctomycetes granules, would be destroyed. The roughness that is to be selected in the individual case depends here in particular on the selected diameter of the hydrocyclone. The greater the diameter of the cylindrical segment of the hydrocyclone, the greater should be the selected roughness.

One embodiment of the invention provides that the internal wall surface of the conical segment has a surface coating having the greater roughness. Here, the surface coating and the internal wall surface of the conical segment could be formed in one piece, or the surface coating could be firmly bonded, for example by gluing, to the internal wall surface of the conical segment.

It has proved to be particularly advantageous here that the hydrocyclone consists at least in part of a dimensionally-stable plastic and/or the surface coating consists of aluminium oxide. This embodiment of the hydrocyclone ensures a simple and reproducible production of the hydrocyclone. Here, the hydrocyclone can be produced by injection moulding, wherein the aluminium oxide forming the surface coating is applied into the mould into or onto the core before introduction of the plastic. During the cooling operation, the aluminium oxide then bonds with the internal wall surface of the hydrocyclone to form a one-piece component. Owing to the inclusion of the aluminium oxide in the surface of the hydrocyclone, a process-safe fixing of the aluminium oxide to the internal wall surface results. Depending on the desired granularity of the surface coating, either the amount and/or the grain size of the aluminium oxide can be adapted.

A particularly simple possibility is also achieved in that the surface coating is constructed as a film or as a woven fabric. This could then be fixed by firm bonding to the relevant surfaces of the hydrocyclone.

According to the invention it is further provided that the greater roughness of the internal wall surface of the conical segment can be generated by a mechanical and/or chemical processing technique. In this case, the roughness can therefore be introduced directly on or in the internal wall surface of the hydrocyclone.

An advantageous embodiment of the present invention provides that the internal wall surface of the cylindrical segment is constructed so as to be smooth. In this case, a destruction of the aerobically ammonium-oxidizing bacteria on contact with the internal wall surface of the cylindrical segment is prevented.

The invention permits various embodiments. For further clarification of the basic principle thereof, one of these is shown in the drawing and is described hereinafter. In the figure

Fig. 1 shows a facility for treating ammonium-containing wastewater in a simplified schematic representation;

Fig. 2 shows the flow conditions in a hydrocyclone presented in Figure 1, in a perspective view;

Fig. 3 shows the hydrocyclone presented in Figure 1 in a side view.

Figure 1 shows a deammonification facility 1 for treating ammonium-containing wastewater 2. The facility 1 can be constructed as an SBR facility (Sequencing Batch Reactor), as a conventional activation facility with secondary clarification, or else what is termed a membrane facility having a membrane for retention of the biomass. The facility 1 has at least one activation tank 3, in which the wastewater 2 is admixed with, and brought into intense contact with, suspended biomass or activated sludge.

By means of a pump 4, activated sludge consisting of a sludge-water mixture is fed from the activation tank 3 to a hydrocyclone 5 (directional arrow 6). The hydrocyclone 5 has a cylindrical segment 7 and a conical segment 8. The cylindrical segment 7 has a diameter between 50 mm and 250 mm. The hydrocyclone 5 is charged via the pump 4 with a delivery pressure which, depending on the diameter of the cylindrical segment 7 of the hydrocyclone 5, is between 1.1 bar and 2.1 bar. Via a feed 9 opening out into the cylindrical segment 7, the activated sludge is introduced into the hydrocyclone 5 and therein is separated into a dense fraction which predominantly contains anaerobically ammonium-oxidizing bacteria (anammox), in particular Planctomycetes granules, and into a light fraction, which predominantly contains aerobically ammonium-oxidizing bacteria (AOB), in particular Nitrosomonas. The dense fraction is removed from the hydrocyclone 5 through the conical segment 8 via an underflow 10 and returned to the activation tank 3 (directional arrow 11). The light fraction is likewise returned to the activation tank 3 through an overflow 12 of the hydrocyclone 5 (directional arrow 13). Therefore, all of the activated sludge introduced into the hydrocyclone 5 from the activation tank 3 is also returned to the same activation tank 3, although divided into a dense fraction and a light fraction. Here, the dense fraction comprises approximately 80%, and the light fraction approximately 20%, of the activated sludge introduced in the feed 9 of the hydrocyclone 5.

Figure 2 illustrates the flow conditions in the hydrocyclone 5 shown in Figure 1 and Figure 3 shows the hydrocyclone 5 in a side view. The activated sludge from the activation tank 3 is introduced via the feed 9 tangentially into the cylindrical segment 7 of the hydrocyclone 5. The activated sludge is thereby forced into a circular path and flows downwards in a downwardly directed outer vortex 14. Via a tapering in the conical segment 8 of the hydrocyclone 5, the volumes are displaced inwards and there is a damming in the lower region of the conical segment 8, which leads to the formation of an inner, upwardly directed, inner vortex 15 which escapes from the hydrocyclone 5 through the overflow 12. The dense fraction is on an internal wall surface 16 of the hydrocyclone 5 and removed from the hydrocyclone 5 through the underflow 10, while the lighter fraction is removed from a hydrocyclone 5 via the overflow 12. The activated sludge, in the hydrocyclone 5 shown, is exposed to centrifugal forces of 30 to 180 times the acceleration due to gravity g.

The internal wall surface 16 of the conical segment 8 facing the interior 17 of the hydrocyclone 5 has a roughened surface coating 18 which has a greater roughness than an internal wall surface 19 of the cylindrical segment 7 likewise facing the interior 17 of the hydrocyclone 5. The surface coating 18 has a granularity of up to 100 µm and is formed, for example, by aluminium oxide which is bonded in one piece to the plastic material of the hydrocyclone 5. The selected roughness of the surface coating 18 depends on the diameter of the selected hydrocyclone 5. The greater the diameter of the cylindrical segment 7, the greater should be the selected roughness of the surface coating 18.

In the deammonificiaton of the ammonium-containing wastewater 2 in the activation tank 3 of the facility 1, first, by means of aerobically oxidizing bacteria (AOB), ammonium is reacted to form nitrite. Then, by means of anaerobically ammonium-oxidizing bacteria (anammox), in particular by means of Planctomycetes, ammonium and nitrite are reacted to form elemental nitrogen. The Planctomycetes in this case are present as granules composed of a plurality of individual bacteria which have a substantially greater density compared with the aerobically ammonium-oxidizing bacteria (AOB) present in the form of flocs. The activated sludge situated in the activation tank 3 is therefore introduced tangentially into the hydrocyclone 5 through the feed 9. In the hydrocyclone 5, on account of the prevailing centrifugal and flow forces, the activated sludge is separated into a dense fraction which contains the anaerobically ammonium-oxidizing bacteria (Planctomycetes granules) having a higher density, and a light fraction which predominantly contains the aerobically oxidizing (floc-type) bacteria. Via the contact and a relative motion between the rapidly moving anaerobically ammonium-oxidizing bacteria (anammox) in the dense fraction with a stationary roughened internal wall surface 16 of the hydrocyclone 5, an organic and/or inorganic plaque arranged on the Planctomycetes granules is at least partly removed, before the dense fraction is then removed from the hydrocyclone 5 through the underflow 10. The light fraction, in contrast, is removed from the hydrocyclone 5 (directional arrow 20 shown dashed in Figure 3) without significant contact with the roughened internal wall surface 16 in the conical segment 8 by means of the inner vortex 15 formed. Both the dense fraction and the light fraction of the activated sludge, after separation in the hydrocyclone 5, are completely returned to the activation tank 3.

The abrasive forces and/or the abrasive effect can be optimally adjusted by a combination of the size of the hydrocyclone 5, in particular the diameter of the cylindrical section 7, the roughness of the internal wall surface 16 in the conical segment 8, and the running time of the hydrocyclone 5 in combination with the size of the biological system and/or the volume of the activation tank 3.

CLAIMS

1. Process for treating ammonium-containing wastewater (2) in a deammonification facility (1) having at least one activation tank (3), in which first ammonium is reacted to form nitrite by means of aerobically oxidizing bacteria and then ammonium and nitrite are reacted to form elemental nitrogen by means of anaerobically ammonium-oxidizing bacteria, and in which sludge from the activation tank (3) is fed to a hydrocyclone (5) and therein is separated into a dense fraction which predominantly contains the anaerobically ammonium-oxidizing bacteria, and into a light fraction, wherein the dense fraction is returned to the activation tank (3) characterized in that activated sludge from the activation tank (3) is introduced at least intermittently into the hydrocyclone (5) and in that, after the separation of the activated sludge in the hydrocyclone (5) both the dense fraction and the light fraction which predominantly contains the aerobically ammonium-oxidizing bacteria are returned to the at least one activation tank (3) of the facility (1), wherein during the separation of the activated sludge in the hydrocyclone (5), the anaerobically ammoniumoxidizing bacteria having a higher density than the aerobically ammonium-oxidizing bacteria are sedimented on a roughened internal wall surface (16) of the hydrocyclone (5) by the centrifugal and hydrodynamic forces in the hydrocyclone (5) and abrasive forces are generated by a relative motion between the rapidly moving anaerobically ammonium-oxidizing bacteria and the stationary roughened internal wall surface (16) of the hydrocyclone (5), via which abrasive forces an organic or inorganic plaque present on the ammoniumoxidizing bacteria is at least partly removed.

2. Process according to Claim 1, characterized in that the dense fraction and the light fraction of the activated sludge that are separated in the hydrocyclone (5) are each completely returned to the same activation tank (3).

3. Process according to Claims 1 or 2, characterized in that during the separation of the activated sludge in the hydrocyclone (5), the dense fraction predominantly containing the anaerobically ammonium-oxidizing bacteria contacts the roughened internal wall surface (16) arranged in a conical segment (8) of the hydrocyclone (5) and then is removed therefrom via an underflow (10) of the hydrocyclone (5) and the light fraction predominantly containing the aerobically ammonium-oxidizing bacteria contacts a smooth internal wall surface (19) in a cylindrical segment (7) of the hydrocyclone (5) and is then removed therefrom via an overflow (12) of the hydrocyclone (5).

4. Process according to any one of the claims 1 to 3, characterized in that, after a first predetermined time period in which activated sludge is introduced into the hydrocyclone (5) and is separated into a dense fraction and a light fraction and both the dense fraction and the light fraction are returned to the activation tank (3), excess sludge taken off during a second predetermined time period from the activation tank (3) is fed to the hydrocyclone (5) instead of activated sludge, wherein the excess sludge is separated in the hydrocyclone (5) into a dense fraction and a light fraction, and solely the dense fraction is returned to the activation tank (3) or is collected and fed to an activation tank of a second facility, while the light phase is disposed of.

5. Process according to any one of the claims 1 to 4, characterized in that a length of the first time period is greater than a length of the second time period.

6. Process according to any one of the claims 1 to 5, characterized in that the length of the first time period is roughly 1.5 to 4 times the length of the second time period.

7. Process according to any one of the claims 1 to 6, characterized in that, alternately and consecutively, during a first time period, activated sludge is introduced into the hydrocyclone (5), and during a second time period, excess sludge is introduced.

8. Deammonification facility (1) for treating ammonium-containing wastewater (2) having at least one activation tank (3) and having at least one hydrocyclone (5) for separating sludge from the activation tank (3) into a dense fraction which predominantly contains anaerobically ammonium-oxidizing bacteria, and a light fraction, wherein the hydrocyclone (5) has a feed that is flow-connected to the activation tank (3) for introducing the sludge, an underflow (10) flow-connected to the activation tank (3) for returning the separated dense fraction to the activation tank (3) and an overflow (12) for removing the separated light fraction from the hydrocyclone (5), characterized in that the sludge that is introduced into the hydrocyclone (5) is formed as activated sludge and the overflow (12) of the hydrocyclone (5) for returning the separated light fraction which predominantly contains aerobically ammonium-oxidizing bacteria to the activation tank (3) is flow-connected to the activation tank (3), and in that the at least one hydrocyclone (5) has a cylindrical segment (7) and a conical segment (8), wherein an internal wall surface (16) of the conical segment (8) is roughened at least in sections and the roughened internal wall surface (16) of the conical segment (8) has a greater roughness than an internal wall surface (19) of the cylindrical segment (7).

9. Facility (1) according to Claim 8, characterized in that the roughened internal wall surface (16) of the conical segment (8) of the hydrocyclone (5) has a roughness having a granularity of up to 100 μm at least in sections.

10. Facility (1) according to Claim 8 or 9, characterized in that the internal wall surface (16) of the conical segment (8) has a surface coating (18) having the greater roughness.

11. Facility (1) according to any one of the Claims 8 to 10, characterized in that the surface coating (18) and the internal wall surface (16) of the conical segment (8) are formed in one piece or in that the surface coating (18) is firmly bonded to the internal wall surface (16) of the conical segment (8).

12. Facility (1) according to any one of the Claims 8 to 11, characterized in that the hydrocyclone (5) consists at least in part of a dimensionally-stable plastic and the surface coating (18) consists of aluminium oxide.

13. Facility (1) according to any one of the Claims 8 to 12, characterized in that the surface coating (18) is constructed as a film or as a woven fabric.

14. Facility (1) according to any one of the Claims 8 to 13, characterized in that the greater roughness of the internal wall surface (16) of the conical segment (8) can be generated by a mechanical processing technique, a chemical processing technique, or a combination of the mechanical and the chemical processing technique.

15. Facility (1) according to any one of the Claims 8 to 14, characterized in that the internal wall surface (19) of the cylindrical segment (7) is constructed so as to be smooth.

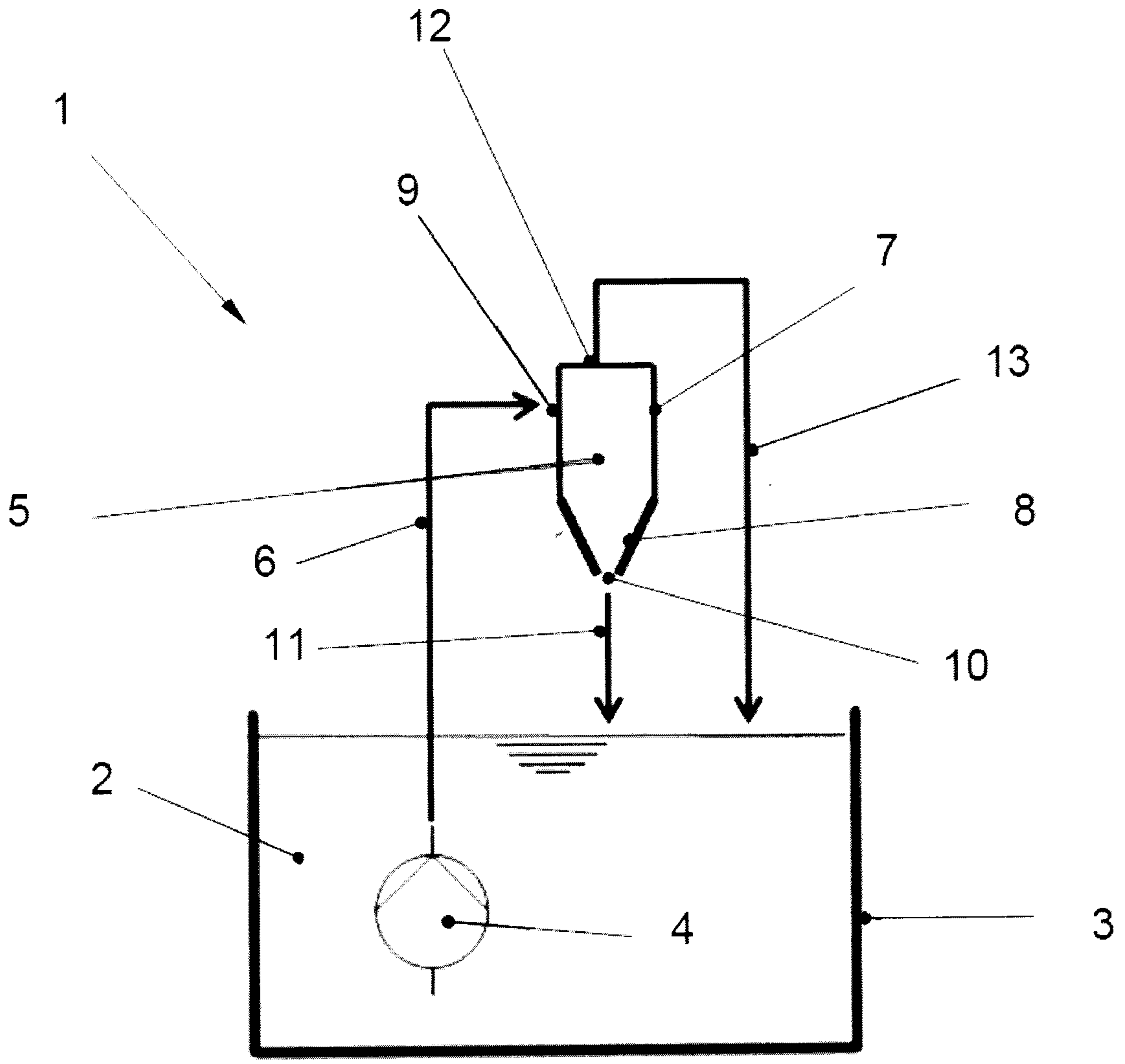


Figure 1

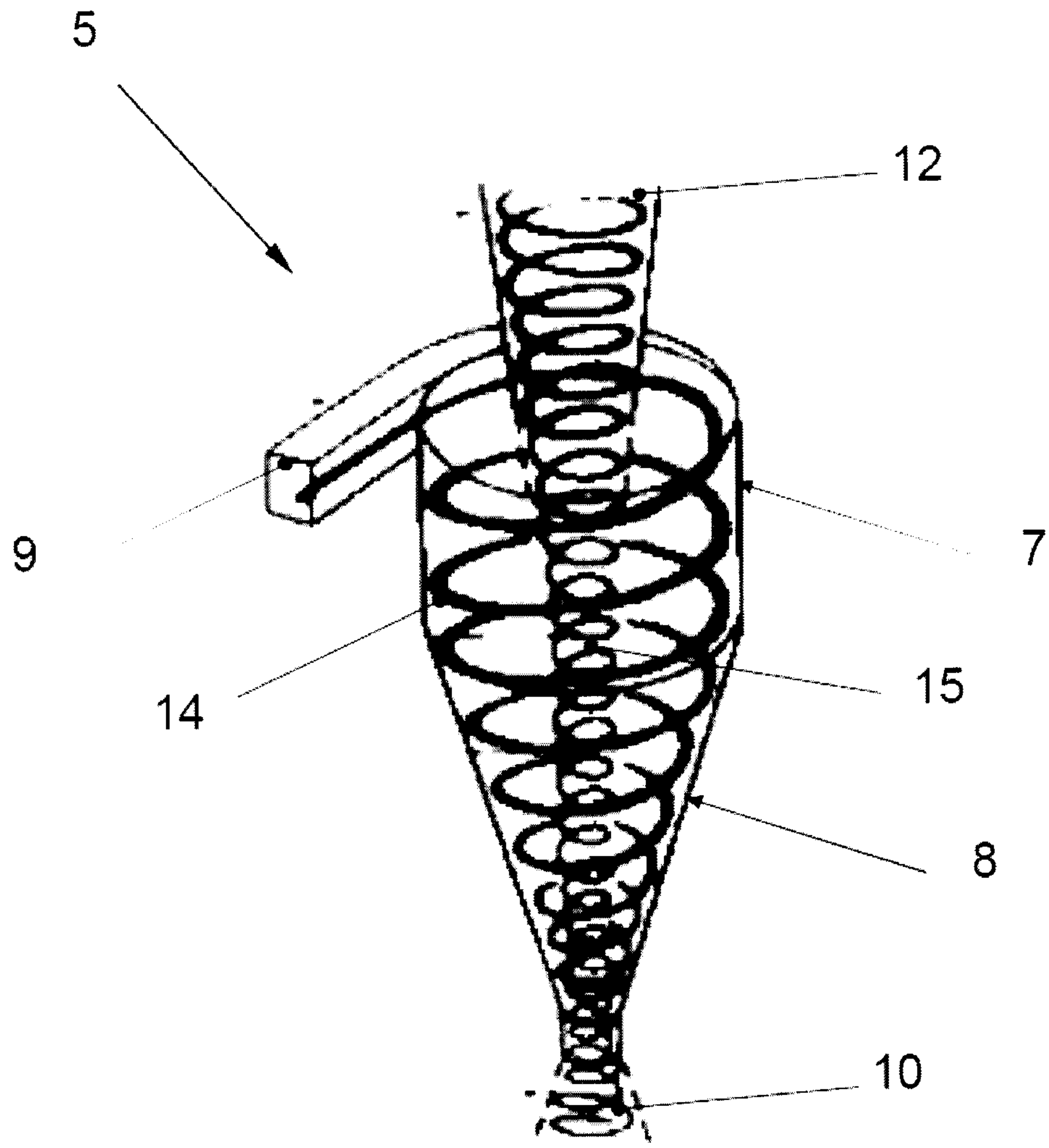


Figure 2

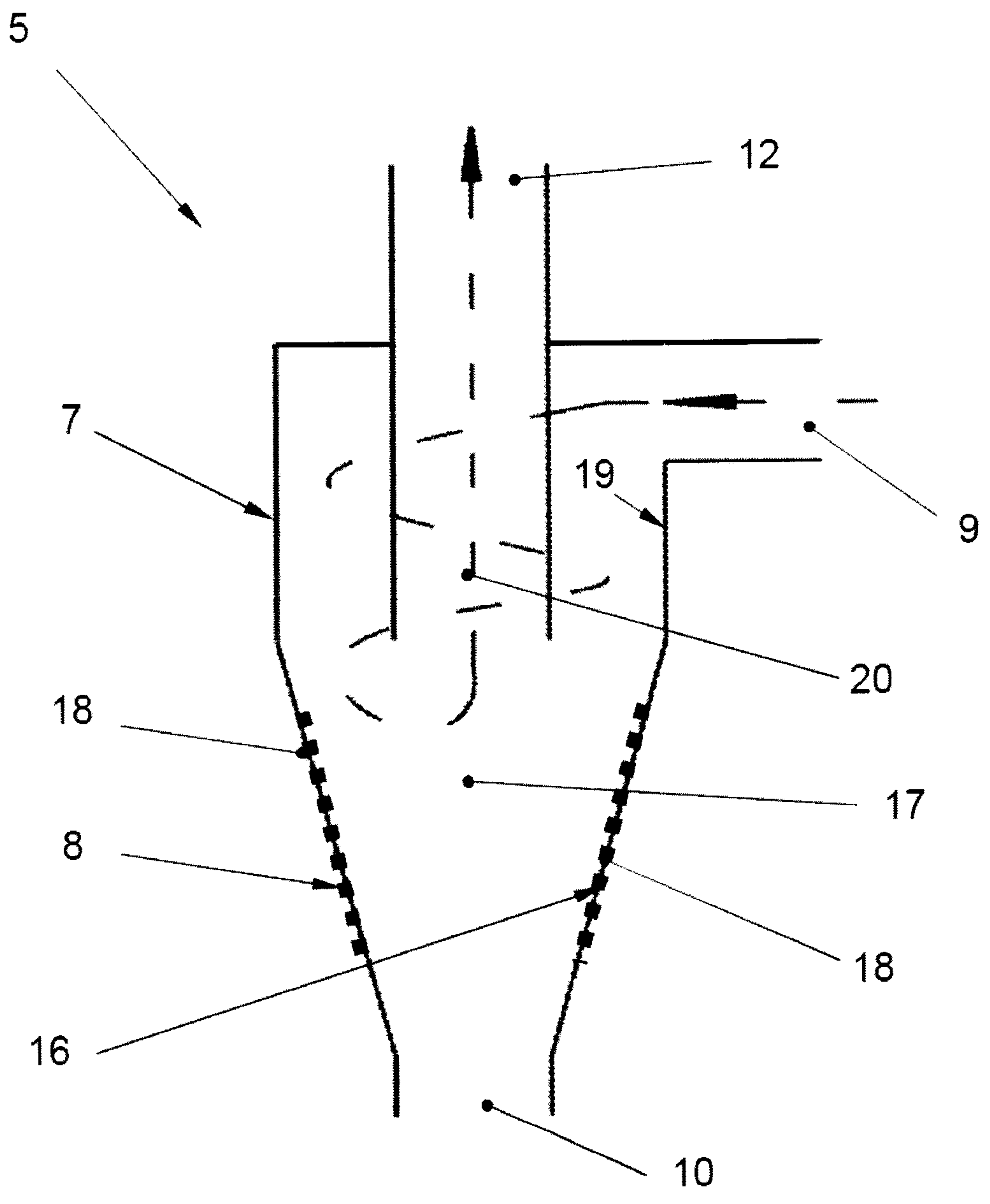
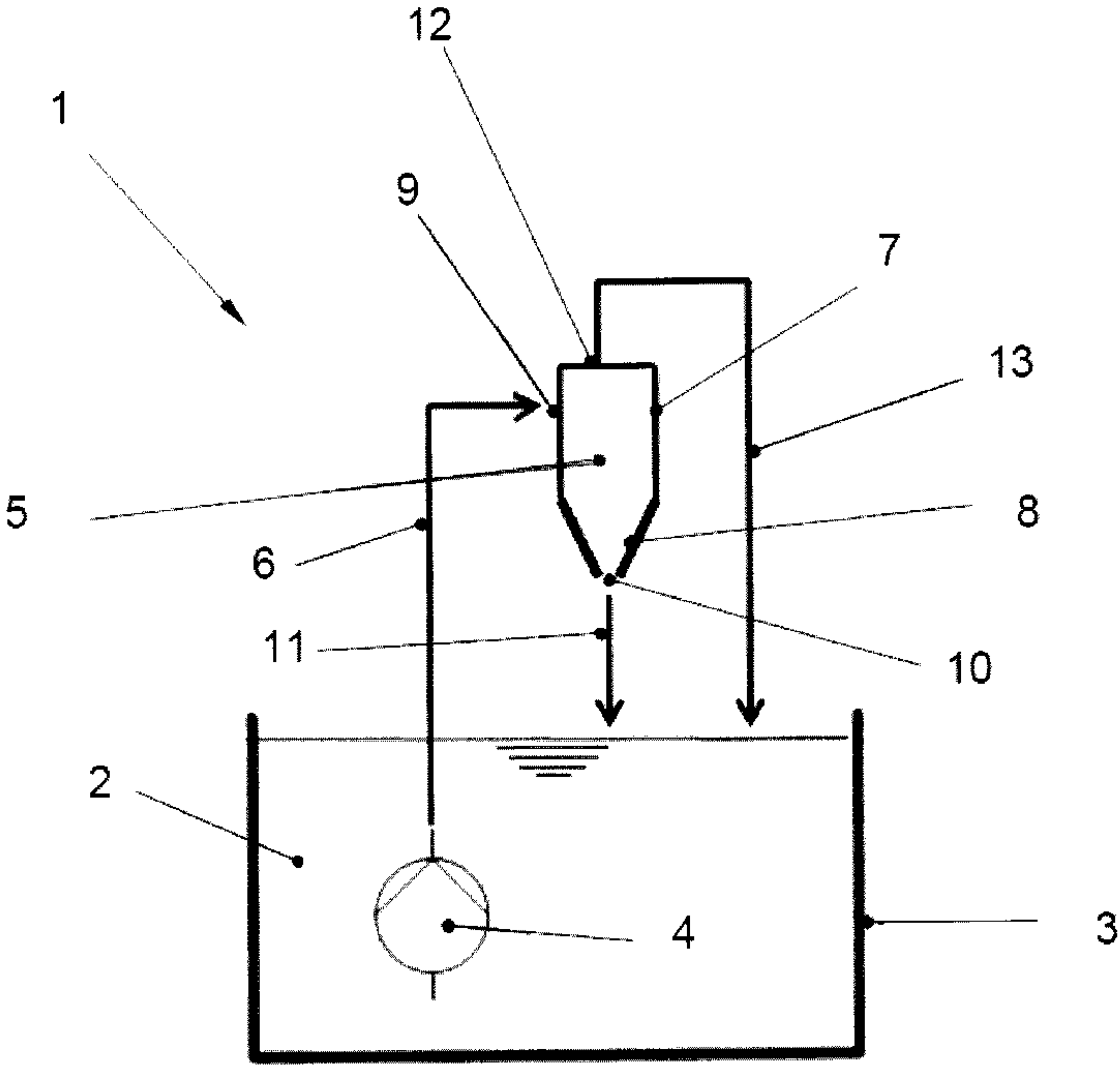


Figure 3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