

**Improvements made to solid-liquid separation
apparatuses, especially for the biological purification
of wastewater**

5 The present invention relates to apparatuses
for solid/liquid separation carried out by filtration
on membrane or textile materials. More particularly,
the invention relates to improvements made to
filtration apparatuses of the above type, intended more
10 specifically for the treatment of suspensions of sludge
resulting from physico-chemical or biological
purification operations (activated sludge, mixed
liquors). It applies especially to the purification of
wastewater by biological means.

15 It is known that the biological purification of
wastewater relies on the culturing of purifying
bacteria in specific systems. The system most commonly
used is activated sludge, that is to say a culture of
these bacteria in suspension in treated water, usually
20 called the mixed liquor. New systems, called mixed
cultures, make use of this sludge, mixing it with a
suspended medium material.

 The effectiveness and the reliability of these
systems rely on separation between this activated
25 sludge and the treated water, this separation
constituting clarification. At the present time, the
clarification is in almost all cases achieved by
settling, but in a few special cases by filtration.

 The essential characteristics of these two
30 known clarification techniques will be recalled below:

 - Secondary settling tanks or clarifiers are
plants designed to separate the mixed liquor from the
treated water by simple settling. The use of these
clarifiers in wastewater treatment stations has two
35 major limitations: firstly, the sludge concentration in
the biological basin is limited to six grammes of dry
matter per litre of mixed liquor, which translates to
large plant volumes, and, secondly, it is necessary, if
a nitrification step is carried out, to denitrify the

effluent so as to prevent flotation of the sludge in the plant and consequently the leakage of suspended matter into the treated water.

Moreover, most existing stations are confronted
5 with many problems which degrade the settlability of the sludge, especially the proliferation of filamentary bacteria causing expansion and foaming problems, variations in pH or in salinity, and influx of toxic products, which often result in the settling operation
10 being seriously disturbed.

In short, malfunctions of clarifiers are a frequent occurrence and often result in dramatic leakage of sludge into the subsequent treatment steps or into the natural environment: this lack of
15 reliability is therefore incompatible with the latest discharge standards.

- In clarification by filtration, the filtration is carried out by ultrafiltration membranes (having pore sizes of generally between 0.001 and
20 0.1 μm) or microfiltration membranes (having a pore size of generally between 0.05 and 5 μm). These separation processes, when applied to the field of biological sludge filtration, are generally known by the name MBR (membrane bioreactors). In all these
25 systems, energy is applied to the sludge, at the surface of the membrane, so as to limit membrane fouling and to increase the flow rates and/or the duration of the filtration.

A first type of MBR is characterized by the use
30 of a membrane located outside the biological basin for performing the separation, thereby making it possible to apply a large amount of useful energy to the surface of the membrane. In this case, the sludge is made to flow at a high rate through the filter, tangentially to
35 the membrane, so as to limit membrane fouling. The transfer pressure (TMP: transmembrane pressure) is between 0.5×10^5 Pa and 5×10^5 Pa. In this way, filtration outputs of about 50 to 200 l/h per m^2 of membrane are obtained. These outputs are maintained for

periods of about 1 to 2 weeks before the membrane becomes clogged up, the latter then being chemically regenerated. The main limitation of these MBRs stems from the energy consumption associated with making the
5 sludge flow through the filter. The high flow rates required entail in fact an electrical consumption of about 1 to 5 kWh per m³ of water treated. For this reason, the field of application of these MBRs is limited to small-capacity plants and more particularly
10 for highly contaminated effluents.

A second type of MBR is characterized by the fact that the filtration of the sludge is performed on membranes located within the biological basin. In this case, the filter is immersed directly in the biological
15 basin, turbulence being created by aeration and/or stirring within the sludge to be filtered. The treated water is collected under gravity or by suction pumping through the membrane, which translates to transfer pressures of generally between 0.1×10^5 Pa and 10^5 Pa.
20 The level of energy applied to the surface of the membrane is lower than in the case of the first type of MBR described above, thereby making it possible to reduce the energy consumption. However, the outputs obtained are no more than about 5 to 50 litres per hour
25 per m² of membrane. These low outputs therefore result in the use of large filter areas, the cost of which very greatly penalizes the process, especially for large-capacity plants and more particularly when the effluents are not highly concentrated.

Moreover, there are other filtration processes which combine high-output performance with low energy consumption but, to various degrees, these known processes prove to be unsuitable for the filtration of concentrated biological suspensions. These processes
30 include frontal-filtration processes in which the filtration is carried out on a medium with coarse pores covered with a preformed prelayer (addition of a diatomaceous suspension, etc.) providing the actual separation (cartridge filters, etc.), such systems
35

operating in a discontinuous manner, by "filtration/unclogging/prelayer formation" cycles. The filtration periods are characterized by a greater increase in the transfer pressure due to the build-up of matter on the surface of the prelayer and to the migration of fine particles into this layer. This pressure structures the deposition on the surface of the coarse filtration medium. When the pressure reaches a critical value of about 10^5 Pa to 10^6 Pa, the "prelayer + trapped particles" combination rendered coherent by the pressure is removed by a very vigorous washing operation using countercurrent water or air. Unfortunately, these processes are difficult to apply to the filtration of biological suspensions since these particles are usually highly compressible: when the suspensions are concentrated, the rapid growth of the deposit of particles on the surface of the filtration medium results in a dramatic increase in the hydraulic resistance, which in turn results in cessation of filtration.

In conclusion, the MBR filtration techniques constitute, for low-capacity plants, a satisfactory technical alternative to conventional settling-based clarification processes; on the other hand, their construction and/or running costs remain higher than those of the said conventional processes. For large capacities, greater than a few thousands of m^3 per day, there is at the present time no satisfactory solution. The present invention is specifically aimed at providing a solution to this problem.

Consequently, the subject of the present invention is an apparatus for the separation of a solid/liquid suspension by filtration, especially of sludge from a biological or physico-chemical purification liquor, on a textile or membrane filter material, characterized in that it consists of at least one plate immersed in the suspension to be treated, the said plate being inclined with respect to the vertical and made in the form of a cavitied plate, comprising

one or more compartments, only the lower face of which is covered with the filter medium, the upper face being solid, the internal volumes of the said plate being connected to a manifold or to a duct which gathers the treated water, and gas-flushing means are provided, these being positioned at a lower level than the filter medium so that the gas bubbles emitted by the said flushing means flow away along the filter medium.

According to one embodiment of this invention, the separation apparatus consists of several cavitied plates having one or more compartments, the said plates preferably being arranged parallel to each other. They may be equidistant from each other or separated from each other with a variable spacing.

According to the present invention, the treated water may be recovered by the said manifold or the said duct either at the top or side of the said plate or plates, or at the bottom of the latter, the latter method of operation preventing or at least limiting any deposit build-up.

According to a preferred embodiment of this separation apparatus, the said plate or plates is or are inclined at approximately 5 to 60 degrees with respect to the vertical. In the illustrative embodiment in which several plates are provided, the spacing of the latter is preferably between approximately 0.5 and 20 cm.

According to the present invention, the filter medium is preferably a coarse medium made of a membrane or textile material having a pore size of between 0.2 and 100 μm .

According to the present invention, the gas-flushing means may be produced in the form of an array of air diffusers placed beneath the filter membranes. These diffusers may be placed at the bottom of the biological basin or tank receiving the apparatus, and their orifices emerge under the filtration plate or plates or in the lower part of the said tank.

According to another embodiment of the invention, the gas-flushing means are incorporated into the said plate or plates, these means being made in the form of separate chambers which extend the lower part of each plate and are fed with gas via a feed pipe, each of the said chambers being provided with at least one discharge opening which is positioned so that the gas bubbles flow away along the filter medium of each plate.

According to the invention, the gas may be air, oxygen, ozonized gas or an inert gas and its flow rate is preferably about 0.05 to 10 m³/h per linear metre of plate width.

According to the invention, the gas is injected continuously, discontinuously, periodically or randomly, at a constant or variable flow rate.

Further features and advantages of the present invention will emerge from the description given below with reference to the appended drawing which depicts two illustrative embodiments, these being devoid of any limiting character. In the drawing:

- Figure 1 is a schematic vertical sectional view showing a separation plant employing a first embodiment of the apparatus according to the present invention; and

- Figure 2 is a schematic view similar to Figure 1, depicting a second illustrative embodiment of the present invention.

As will have been understood from the above description, the invention consists in carrying out the filtration at low pressure (of between 10 and 10⁴ Pa, preferably about 10² Pa) on a textile or membrane material. It will be noted that the filtration pressure is much less than the values used at the present time.

The principle upon which the invention is based consists in creating at the surface of the filter medium the hydraulic conditions that make it possible to maintain a layer of material of sufficiently small

thickness in such a way that the transfer pressure remains low.

Thus, as mentioned above and as will be described in detail below, these hydraulic conditions
5 are provided by means for flushing the layer of the filtration medium with gas.

Reference will now be made to Figure 1 which shows a first illustrative embodiment of the filtration apparatus forming the subject of the present invention.
10 In this non-limiting illustrative embodiment, the apparatus comprises several plates.

This filtration apparatus, denoted in its entirety by the reference 10, is immersed in the tank 12 containing the suspension to be treated which is
15 admitted at 18. This apparatus 10 consists here of a plurality of cavitied plates, such as 14, comprising one or more compartments, these plates being placed in the tank 12 in an inclined manner, preferably at an angle of 5 to 60 degrees to the vertical. In this non-
20 limiting illustrative embodiment, the plates 14 are placed parallel to each other with a specific spacing, for example of between approximately 0.5 and 20 cm. In this illustrative embodiment, the plates 14 are equidistant: this is merely one example, the spacing
25 between the plates possibly varying. The treated water, after being filtered through the plates 14, is collected by a duct 20 which, in this illustrative embodiment, is provided in the upper part of the tank 12, the treated water then being removed from the
30 latter via the discharge orifice 22. Of course, without departing from the scope of the invention, the treated water may be recovered at any point in the filter module, that is to say from each plate 14, for example at the bottom of the permeate-collecting chambers of
35 the plates 14, thereby preventing or at least limiting any deposit build-up.

As a variant, the treated water may be recovered using a duct, especially in the side part of the said plate or plates.

The concentrated sludge is discharged from the tank 12 via the discharge orifice 28.

Placed on the lower surface 16 of each of the plates 14 is the filtration medium produced in the form of a medium made of a membrane or textile material having a pore size of between 0.2 and 100 μm .

According to the present invention, in the non-limiting illustrative embodiment depicted in the drawing, the gas-flushing means are provided at the bottom of the tank 12, beneath the inclined plates such as 14, the gas bubbles emitted by these flushing means flowing away along the filter medium, that is to say along the lower surface 16 of each of the plates. According to the invention, the gas thus injected has a flow rate of about 0.05 to 10 m^3 per hour per linear metre of plate width, the gas possibly being injected continuously, discontinuously, periodically or randomly, with a constant or variable flow rate.

The plates 14 are characterized by three parameters: their width, their height and their thickness. The flow rate of injected gas per linear metre of plate applies to the width of these plates. This flow rate is independent of the height or of the thickness of the said plates, which means that this gas flow rate would be the same for a plate 0.5 metres or 3 metres in height, for example.

In the illustrative embodiment depicted in Figure 1, the means for producing this gas-flushing operation are made in the form of a plurality of diffusers, such as 24, positioned under the filtration modules 14 at the bottom of the tank 12, these being fed with pressurized gas via a pipe 26.

The illustrative embodiment depicted in Figure 2 is identical to that described above with reference to Figure 1 except for the design of the means allowing the lower surface 16 of each inclined plate 14 to be flushed with gas. In this alternative embodiment, the diffusers are incorporated into the plates such as 14. These diffusers are therefore in the form of separate

chambers such as 30, forming the bottom of each cavitied plate 14, these cavities being fed with gas via the pipe 26 and the gas bubbles being emitted via at least one opening such as 32 provided in each
5 chamber such as 30, so that the gas bubbles flow away along the filter medium provided on the lower surface 16 of each plate.

In the present invention, the flushing gas may be air, oxygen, ozonized gas (thereby allowing aerobic
10 treatments to be carried out in the separation plant 12) or an inert gas (thereby allowing anoxic treatments to be carried out in the tank 12).

It should be emphasized that the above-mentioned embodiment of this separation apparatus
15 according to the present invention is advantageous given that the use of plates similar to the plates 14, described above, but placed vertically, would have a lower performance since, in order to guarantee contact between the gas bubbles and the filter medium,
20 necessary for controlling the deposits on the said filter medium, it would be necessary:

- to inject more gas;
- to have fine control of the hydraulics in the liquid stream so as to avoid the formation of
25 preferential flows; in the latter case, there would be the risk of subaerated regions forming that would rapidly clog up. Such operation would result in the process being heterogeneous and therefore resulting in a great reduction in its performance;
- 30 - to limit the height of the plates in order to prevent the formation of filtrate recirculation currents from the compartments towards the mass of liquid to be filtered, the said recirculation currents being induced by differences in density between the
35 bubble-laden, and therefore less dense, liquid and the degassed, and therefore more dense, filtrate.

The inclined arrangement of the filter plates 14 according to the present invention guarantees effective contact between the gas bubbles and the

filter medium and offers the possibility, by varying the gas flow rate (continuously or in sequences), the size of the bubbles formed and the angle of inclination of the plates, of independently adjusting:

- 5 - the rate of replenishment of the layer of material deposited on the filter medium;
- the thickness of this layer, and therefore the filtration output and the rate of clogging.

10 Of course, it remains the case that the present invention is not limited to the embodiments described and/or mentioned above; on the contrary, it encompasses all alternative embodiments thereof.



CLAIMS

1. Apparatus for the separation of a solid/liquid suspension by filtration, especially of the sludge of a biological or physico-chemical purification liquor, on a textile or membrane filter material, characterized in that it consists of at least one plate (14) immersed in the suspension to be treated, the said plate being inclined with respect to the vertical and made in the form of a cavitied plate, comprising one or more compartments, only the lower face (16) of which is covered with the filter medium (14), the upper face being solid, the internal volumes of the said cavitied plate being connected to a manifold or to a duct (20) which gathers the treated water, and gas-flushing means (24; 30) are provided, these being positioned below the said plate (14) so that the gas bubbles emitted by the said flushing means flow away along the filter medium.
2. Separation apparatus according to Claim 1, characterized in that it comprises a plurality of cavitied plates (14) having one or more compartments.
3. Separation apparatus according to Claim 2, characterized in that the said plates (14) are arranged parallel to each other.
4. Apparatus according to either of Claims 2 and 3, characterized in that the said plates (14) are equidistant.
5. Apparatus according to either of Claims 2 and 3, characterized in that the said plates (14) are separated from each other with a variable spacing.
6. Apparatus according to one of Claims 2 to 5, characterized in that the said plates (14) are arranged with a spacing of between approximately 0.5 and 20 cm.
7. Apparatus according to any one of the preceding claims, characterized in that the treated water is recovered by the manifold (20) at the top or side of the said plate or plates (14).
8. Apparatus according to any one of Claims 1 to 6, characterized in that the treated water is recovered



by the manifold (20) at the bottom of the said plate or plates (14).

9. Apparatus according to any one of the preceding claims, characterized in that the said plate or plates
5 (14) is or are inclined at 5 to 60 degrees with respect to the vertical.

10. Apparatus according to any one of the preceding claims, characterized in that the filter medium is a coarse medium made of a membrane or textile material
10 having a pore size of between approximately 0.2 and 100 μm .

11. Apparatus according to any one of the preceding claims, characterized in that the gas-flushing means are produced in the form of an array of diffusers (24),
15 this being placed beneath the said plate or plates (14), especially at the bottom of the tank (12) receiving the apparatus, and their orifices emerge under the filtration plate or plates (14) or in the lower part of the said tank.

20 12. Apparatus according to any one of Claims 1 to 10, characterized in that the gas-flushing means are incorporated into the said plate or plates (14) and they are made in the form of separate chambers (30) which extend the lower part of each plate (14) and are
25 fed with gas via a feed pipe (26), each of the said chambers (30) being provided with at least one discharge opening (32) for the gas, which is positioned so that the gas bubbles flow away along the filter medium of the plate (14) or of each plate.

30 13. Apparatus according to any one of the preceding claims, characterized in that the gas for flushing the filter medium is air, oxygen or ozonized gas.

14. Apparatus according to any one of Claims 1 to 12, characterized in that the gas for flushing the
35 filter medium is an inert gas.

15. Apparatus according to any one of the preceding claims, characterized in that the flow rate of the flushing gas per linear metre of the plate (14) width is about 0.05 to 10 m^3/h .



16. Apparatus according to any one of the preceding claims, characterized in that the flushing gas is injected discontinuously, periodically or randomly, at a constant or variable flow rate.
- 5 17. Apparatus according to any one of the preceding claims, characterized in that the flushing gas is injected continuously.
18. Apparatus according to any one of the preceding claims, characterized in that it operates at a pressure of between 10 and 10^4 Pa.
- 10 19. Apparatus according to any one of the preceding claims, characterized in that it operates at a pressure of approximately 10^2 Pa.