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☒ Patente de invención

☐ Patente de Modelo de Utilidad

☒ Capitulo I.

☐ Capitulo II.

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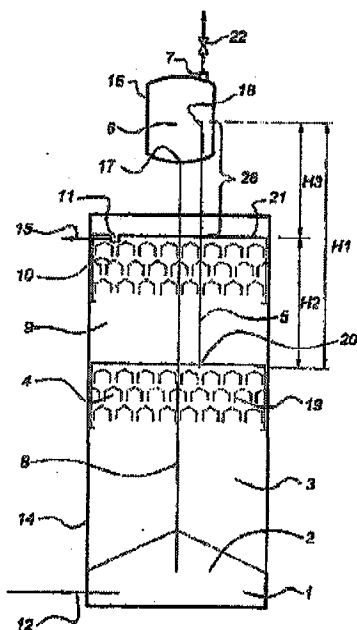
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ANEXOS

- ☒ Comprobante de pago de la tasa de presentación de la solicitud
- ☐ Comprobante de pago por reivindicación de prioridad
- ☐ Documento que acredite la existencia y representación legal cuando el solicitante sea persona Jurídica
- ☐ Poderes, si fuera el caso
- ☐ Documento de cesión del inventor al solicitante o a su causante
- ☐ Declaraciones
- ☒ Copia de la solicitud Internacional. (Resumen, descripción, reivindicación, Dibujos).
- ☒ Traducción de la solicitud internacional al castellano. (Resumen, descripción, reivindicación, Dibujos)
- ☐ Copia del examen preliminar efectuado por la IPEA
- ☐ De ser el caso, copia del contrato de acceso
- ☐ De ser el caso, documento que acredite la licencia o autorización de uso de conocimientos tradicionales de las comunidades indígenas
- ☐ De ser el caso, certificado de depósito del material biológico
- ☐ Arte final 12 x 12 y 6 x 6 cm
- ☐ De ser el caso, información sobre otras solicitudes de patente o títulos obtenidos en el extranjero por el mismo titular o su causante, relacionados parcial o totalmente con la invención de esta solicitud.
- ☒ Otros:
 1. Reporte internacional de búsqueda
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11) FIGURA CARACTERÍSTICA:



12) Solicitud concesión de la patente,

NOMBRE: DILIA RODRÍGUEZ D'ALEMAN

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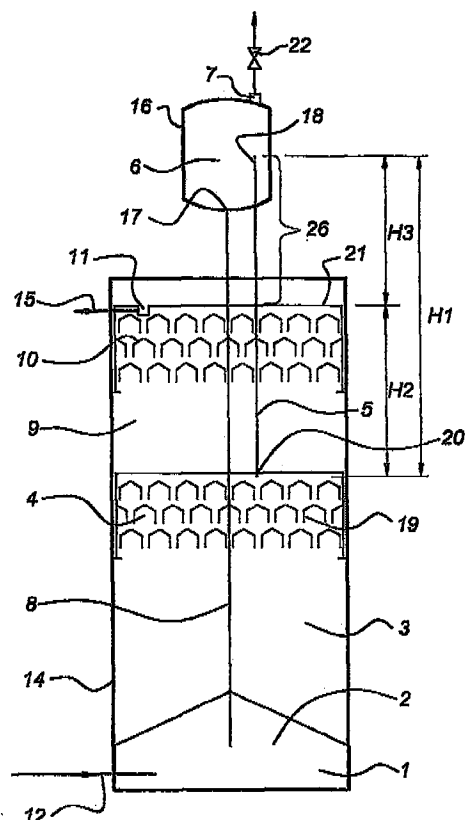
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(54) Title: ANAEROBIC PURIFICATION DEVICE



(57) Abstract: The present invention relates to an anaerobic purification device for purification of influent, comprising: a reactor tank; inlet means for introducing influent into the tank; water collecting means for collecting purified water; a gas collecting system for collecting gas from the fluid contained in the reactor; a gas-liquid separation device; a riser for passing liquid into the separation device by gas lifted caused by gas collected in the gas collecting system; a downer for returning liquid and sludge from the separation device into the lower tank section. According to the invention this device is characterized in that it is arranged to define, in the downer at the level of the liquid surface, a head pressure of at least about 1.4 m water column (about 0.14 bar). The invention also relates to a method for anaerobic purification device for purification of influent.

WO 2006/132523 A1

Anaerobic purification device

The present invention relates to an anaerobic purification device for purification of influent, such as wastewater, the anaerobic purification device comprising:

- 5 • a reactor tank;
- inlet means for introducing influent into the tank, the inlet means being located in the lower section of the tank;
- water collecting means, such as an overflow gutter, for collecting purified water, the water collecting means being provided at the upper section of the tank and
- 10 defining a liquid surface in said reactor tank;
- at least one gas collecting system for collecting gas from the fluid contained in the reactor, the at least one gas collecting system being arranged at a level below the water collecting means;
- a gas-liquid separation device arranged at a level above the water collecting means;
- 15 • at least one riser having a discharge opening debouching into the separation device, the at least one riser being connected to the at least one gas collecting system for raising fluid contained in the tank by gas lift action caused by gas collected in the at least one gas collection system;
- a downer having an inlet debouching into the separation device and an outlet
- 20 debouching in the lower section of the tank for returning liquid separated in the separation device, into the lower section of the tank.

Such a device is known from EP-A-170.332. According to this EP-A-170.332 one subjects wastewater that contains organic material to a process in which dissolved

25 organic material is broken down under anaerobic conditions. By contact with biomass that contains methane-producing microorganisms, methane is being produced which is separated from the liquid. The treated water (effluent) is removed via overflows weirs. EP-A-170.332 describes as starting point for that invention on page 1 lines 21-32: It has been found that with a residence time of several hours a purification of as much as 90%

30 can be reached. The extent to which such purification efficiency can be maintained over a long period also depends on the sludge retention. In particular, care must be taken to ensure that on average no more sludge is rinsed out of the reactor than can be formed in a certain period of time. If a high hydraulic flow is used with a low COD

concentration in the influent, there is a considerable risk that the internal settler will not be capable of preventing a large amount of sludge being flushed out. A factor which is of importance in this connection is the hydraulic surface loading of the settler. In the subsequent passage, EP-A-170.332 explains that the upward flowing water and the rising gas bubbles can stir up the biomass flocks and particles considerably. These can arrive into the uppermost part of the reactor where the gas collecting system is located. The turbulence produced can thus result in excessive quantities of biomass to be flushed out of the reactor. This limits the loading capacity of the reactor considerably.

10 The invention of EP 170 332 aims to overcome the disadvantages just described and to create a reactor in which the main gas load is taken away from an uppermost gas collecting system. For this purpose EP 170 332 provides at least one additional gas collecting system for collecting gas, which additional system is arranged at a distance below the upper collecting system. The additional system has a hydraulic link with at least one riser pipe for raising liquid by gas lift action, said riser pipe discharging into at least one separation device for separating gas and liquid. In view of the fact that gas is trapped at a considerable distance below the liquid level and is conveyed further via the riser pipe, an essentially turbulence-free flow can occur in the upper section of the reactor. This increases the loading capacity, whereas at the top, clean effluent is obtained. It is important that the liquid, which is carried along with the gas to the riser pipe, is separated and returned to the reactor: While a quiet, eddy-free flow is required at the top of the reactor, very good mixing of sludge and fluid is required at the bottom of the reactor. For this purpose the heavy sludge near the bottom has to be fluidized. In a preferred embodiment according to EP 170 332 this fluidization can be achieved in the bottom section of the reactor with the aid of energy obtained from the gas lifting liquid in the riser pipe. The lifted liquid is separated from the gas and, under influence of hydraulic gravity pressure, returned from the separation device, through a downer pipe, to the bottom section of the reactor chamber.

For economic reasons, it is becoming more and more interesting to make the reactor column as high as possible. In that case, there would be more reactor volume and more biomass, whereas the footprint – the square meters of surface area occupied by the reactor - is the same. On the other hand, the higher the reactor the heavier the column of biomass in the reactor will be. The heavier the column of biomass, the more difficult

it will be to maintain a good mixing and fluidization pattern near the bottom of the reactor. In some cases it may also happen that the biomass mixture becomes heavier due to the precipitation of inorganic material. Also in that case, it can be difficult to maintain a good fluidization.

5

A solution could be increasing the head pressure. However, prior art and experience teaches that, for a good mixture at the bottom of the reactor and overall functioning of the reactor, one requires, at the level of the liquid surface in the reactor, a head pressure of about 0.8 to 1 m water column (i.e. about 0.08-0.1 bar) in the downer, in order to
10 overcome the pressure loss, which is required for good distribution at the bottom in the sludge bed. Too low head pressures result in non-optimal mixing at the bottom of the reactor and/or a poorer performance of the reactor respectively the 'process carried out in the reactor' as a whole, whereas too high head pressure would result in very high shear forces on the biomass particles, and consequently destruction of the granular
15 material.

In practice at least about 80% of the head pressure is obtained from hydraulic pressure, whilst at most about 20% of the head pressure is obtained from gas pressure resulting from gas load situations during use. However in particular cases this has lead to
20 problems with fluidization of the sludge in the bottom of the reactor and/or quite irregular gas flows.

Thus although for economic reasons one would like to make the reactor column as high as possible, the reactor height is in practice limited, because of the effects and teaching
25 just mentioned.

The present invention has the objective to provide an anaerobic purification device for purification of influent, such as wastewater, with improved fluidization at the bottom of the reactor which also allows increasing the reactor height.

30

According to the invention this object is achieved by providing an anaerobic purification device for purification of influent, such as waste water, the anaerobic purification device comprising:

- a reactor tank;
- inlet means for introducing influent into the tank, the inlet means being located in the lower section of the tank;
- water collecting means, such as an overflow gutter, for collecting purified water, the water collecting means being provided at the upper section of the tank and defining a liquid surface in said reactor tank;
- at least one gas collecting system for collecting gas from the fluid contained in the reactor, the at least one gas collecting system being arranged at a level below the water collecting means;
- a gas-liquid separation device arranged at a level above the water collecting means;
- at least one riser having a discharge opening debouching into the separation device, the at least one riser being connected to the at least one gas collecting system for raising fluid contained in the tank by gas lift action caused by gas collected in the at least one gas collection system;
- a downer having an inlet debouching into the separation device and an outlet debouching in the lower section of the tank for returning liquid separated in the separation device, into the lower section of the tank;

characterized in that

- the purification device is arranged to define, in the downer at the level of the liquid surface, a head pressure of at least about 1.4 m (m stands for meter) water column (about 0.14 bar).

In this respect, the head pressure is defined as the difference in pressure, at the level of the liquid surface in the reactor (which level is defined by the water collecting means, such as an overflow gutter), between a point inside the downer and a point outside the downer but inside the tank.

According to a preferred embodiment of the invention, the head pressure is at least about 1.5 m water column (about 0.15 bar), preferably at least about 1.6 m water column (0.16 bar).

According to a further preferred embodiment of the invention, the head pressure is at least 1.8 – 2 m water column (about 0.18-0.2 bar), such as 2.5-3 m water column (0.25-0.3 bar) or more.

- 5 The invention as well as the above both advantageous embodiments will be explained below, as well as several further embodiments of the invention.

According to the invention solutions have been found to create more head pressure without decreasing the performance of the reactor as might have been expected, but
10 instead increase of performance came within reach.

The reactor can, according to the invention, be designed in such manner that the device itself defines a head pressure of at least about 1.4 m water column, i.e. in use the head pressure will be at least 1.4 meter water column due to structural features present in the device. According to the invention there are several solutions each involving there own
15 structural features.

A first solution is to place the gas-liquid separation device at a higher level above the reactor tank in order to allow for more hydraulic pressure. As a consequence, not only that part of the riser pipe extending above the liquid surface needs to be extended but
20 also the driving force of the gas for lifting water column to the gas-liquid-separation device. This can be done, for example, by increasing the length of the riser extending below the water surface, and/or by decreasing the flow resistance of the riser – for example by changing the diameter of the pipe –. Lowering the position where the gas is introduced into the riser creates more driving force for lifting the water column to the
25 separation device. The upward pressure created by the displaced water volume in the riser pipe generates the driving force to bring the water to the gas-liquid separation device.

A preferred embodiment according to this first solution is characterized in that the at
30 least one riser (5) has a top part (26) which is defined as that part of the riser (5) extending upwards as from said liquid surface (21), and wherein said top part has a length (H3) which is at least about 1.2 m, preferably at least about 1.4 m, such as 1.6 – 2 m or more.

A second solution is to operate at a higher gas pressure in the gas-liquid separator. This second solution can be achieved, for example, by arranging the gas-liquid-separating process in an essentially closed vessel provided with means for keeping the gas
5 pressure at predetermined threshold value. In this way an extra head pressure of 0.3 to 1.0 m water column can be gained or even more if required. According to a preferred embodiment of this second solution, said threshold value is at least about 0.25 m water column (about 0.025 bar), such as at least about 0.5 m water column (about 0.05 bar). According to another preferred embodiment of this second solution, said threshold
10 value is at most about 1.5 m water column (about 0.15 bar), such as at most about 1.2 m water column (about 0.12 bar).

A third solution is improving the flow of fluid flowing through the downer. This can, for example, be achieved by providing means that allow the fluid to enter the downer
15 continuously and easily. According to an embodiment of this third solution, the gas-liquid-separation device comprises a vessel, wherein the inlet of the downer is conically shaped with respect to a vertical axis and with the taper in the downward direction, and wherein the discharge opening of the at least one riser is arranged to create a tangential fluid flow in the vessel around the conically shaped inlet of the downer.

20

A fourth solution is a combination of one or more of the three afore mentioned solutions or possible other solutions.

An important factor of influence is the quantity of gas production in the reactor, which
25 is a result of the applied COD loading and the COD conversion rate. A higher gas production per specific reactor surface (for instance expressed in $\text{m}^3\text{gas}/\text{m}^2\text{.h}$) causes a stronger gas lift, whereas at a lower gas production, the gas lift will slow down and will finally stop. As higher reactor columns will theoretically produce more $\text{m}^3\text{gas}/\text{m}^2\text{.h}$, the extra driving forces for more internal circulation flow or for lifting the water to a
30 higher gas-liquid separation device will be available. Applicant found, contrary to what was expected, that this additionally available driving force is of an amount substantially enough to allow, contrary to prevailing prejudices, an increase of head pressure by simple design measures in the anaerobic purification device.

Since the reactors can be operated in a very wide range of Volumetric Loading Rates (VLR), in general between 5 and 35 kg COD/m³.d, the correct dimensioning should take into account the most probable operational circumstances.

5

Now that for economic reasons, reactors higher than 20 m more often will to be constructed, it has been found that the internal circulation can be maintained or even improved by taking specific measures. Considering that the density of the biomass sludge is higher than water, that the downer pipe as well as the inlet distribution system causes a pressure loss and that the sludge bed has a certain resistance against fluidization, it has been found that for a "normal" gas pressure of 20 to 30 cm Water column, the gas lift needs to bring the water to a level of at least 1.2 m above the water level in the reactor, preferably 1.4 to 1.6 m and in some cases even above 2.2 m. In order to accommodate this for average reactor loads between 15 and 30 kg COD/m³.d, the total length of the riser pipe needs to be chosen such that the top part of the riser extending upwards as from said liquid surface - i.e. the length above the water collecting means, such as the overflow gutter - will be between at least about 10 %, such as at least about 15%, and/or at most about 30 %, such as at most about 25%, of the total length of the riser pipe. Alternatively, the gas pressure could be increased to 60 or 70 cm water column or even above 1.0 m water column. Also combinations of the two measures are possible, for instance raising the water column by the gas lift to 1.6 m and increasing the gas pressure to 60 cm water column in order to make a combined pressure or head pressure of 2.2 m water column. Taking these measures into account, reactor heights could be realized in the range of 24 to 36 m or even higher.

25

According to an advantageous embodiment of the invention, the device further comprises upper gas collecting means (10) for collecting and removing gas from the fluid contained in the tank (14), the upper gas collecting means (10) being provided between the water collecting means (11) and the at least one gas collecting system (4).

30

The present invention is also embodied by, and thus relates to, the use of an anaerobic purification device according to the invention.

The present invention is also embodied by, and thus relates to, a method of operating an anaerobic purification device for purification of influent, such as waste water, the anaerobic purification device comprising:

- a reactor tank;
- 5 • inlet means for introducing influent into the tank, the inlet means being located in the lower section of the tank;
- water collecting means, such as an overflow gutter, for collecting purified water, the water collecting means being provided at the upper section of the tank and defining a liquid surface in said reactor tank;
- 10 • at least one gas collecting system for collecting gas from the fluid contained in the reactor, the at least one gas collecting system being arranged at a level below the water collecting means;
- a gas-liquid separation device arranged at a level above the water collecting means;
- at least one riser having a discharge opening debouching into the separation device, 15 the at least one riser being connected to the at least one gas collecting system for raising fluid contained in the tank by gas lift action caused by gas collected in the at least one gas collection system;
- a downer having an inlet debouching into the separation device and an outlet debouching in the lower section of the tank for returning liquid separated in the 20 separation device, into the lower section of the tank;

characterized in that

the anaerobic purification device is operated with a head pressure of at least about 1.4 m water column (about 0.14 bar), said head pressure prevailing in the downer at the level of the liquid surface.

25

Advantages of the use according to the invention as well as the method according to the invention and its preferred embodiments according to claims 14-17, will be clear from the preceding explanation in relation to the device according to the invention.

30 In the next following the present invention will be further elucidated with reference to a drawing. In this drawing:

Figure 1 shows very schematically an anaerobic purification device according to the invention; and

Figures 2A en 2B show schematically a part of purification devices according to the invention to explain the term "head pressure".

The anaerobic purification equipment shown in Figure 1 comprises a tall container 14,
5 called reactor tank.

In the bottom end of the reactor tank 14, there is provided a mixing zone 2 for influent introduced via supply 12. As the skilled man knows, such a mixing zone 2 can be accomplished in several ways. One advantageous manner of accomplishing the mixing
10 zone is providing an inlet system in accordance with WO 92/01637.

In the upper part of the reactor tank, water-collecting means in the form of overflow gutters 11 or other means are fitted which are connected to an effluent drainpipe 15 for discharging purified effluent. The water-collecting means define the level of the liquid
15 surface 21 in the reactor tank 14. In case of overflow gutters 11, this level of the liquid surface 21 will be determined by the overflow edge of said gutters 11.

Within the reactor tank 14 two gas- collecting arrangements 4 and 10 for collecting and removing gas are fitted. Each of the gas collecting arrangements comprises a
20 multiplicity of hoods 19. Per gas collecting arrangement the hoods can be arranged in one layer or several layers, such as three layers as shown in the figure. Number 10 is, especially in the claims, called the upper gas collecting means and 4 is called, especially in the claims, the at least one gas collecting system. Figure 1 shows only one gas collecting system 4, but within the framework of the invention also two, three or
25 more gas collection systems could be provided. The upper gas collecting means 10 need not to be connected to the riser 5 and might be absent in case the fluid at this height of the tank is gas poor, or might be discharged separately to the gas liquid-separation device 6 or elsewhere.

30 Above the reactor there is provided a gas-liquid separation device 6. This gas-liquid separation device comprises an essentially closed vessel 16 – although also an open vessel is possible, see Figure 2 - having a gas outlet 7 for discharging gas such as biogas, a liquid outlet 17, and an inlet 18 for supplying a fluid containing the gas and

liquid to be separated. The liquid outlet 17 is the upper end of a downer pipe 8, or said differently the inlet of downer 8. The inlet 18 is the upper end of a riser pipe 5, or said differently the discharge opening of the riser. The gas outlet 7 is optionally provided with means 22, for keeping the gas pressure in the vessel at a predetermined threshold
5 value. Preferably the threshold value will have a minimum value of about 0.25 m water column (about 0.025 bar). Optionally the threshold value can have a maximum value of about 1.5 m water column (about 0.15 bar).

The riser 5 has a lower end with an inlet for drawing in fluid. This fluid is drawn in by
10 gas lift action caused by gas collected by the at least one gas collection system 4 (lower level separators). For this purpose the hoods 19 of the at least one gas collection system 4 are connected to the riser in such a way, that the collected gas creates the gas lift in the riser. As such all this concerning the riser is known from the prior art and can, as the skilled man knows, be realized in several manners.

15 The downer 8 extends from the gas-liquid separation device 6 to the bottom region of the tank 14. Under the influence of gravity, liquid from the separation device, which can – depending from where the biomass is located - contain biomass as well, is returned to the bottom of the tank. At the bottom of the tank this return flow causes
20 fluidization of the bed of biomass.

Figures 2A and 2B show highly schematically two different embodiments according to the invention, with the purpose to explain the term head pressure as used in this application. For corresponding parts, we used the same reference numbers as with
25 respect to Figures 1.

In both Figures 2A and 2B the head pressure P_{head} is the pressure difference between points A and B. Point A, having the pressure P_A , lies inside the downer 8 at the level of the liquid surface 21 in the tank 14. Point B, having the pressure P_B , lies outside the
30 downer, but inside the reactor at the same level of the liquid surface. The pressure caused by the water column H_W above the point A is called P_W . The pressure P_1 is the gas pressure just above the liquid level in the gas-liquid-separation device 6. P_2 is the

gas pressure just above the liquid level 21 in the reactor tank. All pressures are measured relative to the atmospheric pressure.

In the embodiment according to Figure 2A, the gas-liquid-separation device 6 comprises a closed vessel 16. In this closed vessel the gas pressure is P_1 . The reactor tank 14 has a so called open top. This means the top communicates with the environment so that the gas pressure P_2 in the top of the reactor is about the atmospheric pressure; thus about zero/relative to atmospheric pressure. However, the reactor tank can also have a closed top allowing the gas pressure P_2 to be different from the atmospheric pressure. Here for the head pressure applies:

$$P_{\text{head}} = P_A - P_B = P_W + P_1 - P_2$$

In the embodiment according to Figure 2B, the gas-liquid-separation device 6 has an open top and the reactor tank 14 has a closed top. Further the gas-liquid-separation device is arranged inside the reactor tank 14. Consequently the pressures P_1 and P_2 are identical. Here for the head pressure applies:

$$P_{\text{head}} = P_A - P_B = P_W + P_1 - P_1 = P_W$$

In Figure 2B, the head pressure would be the same when also the reactor tank 14 is an open tank.

During operation, fermentation takes place under anaerobic conditions as a result of contact between sludge granules or biomass flocks and substances soluble in water, such as fatty acids, methane being formed. In order to achieve a quiet, turbulence-free flow in the uppermost part of the reactor and to ensure that virtually no sludge is carried off with the effluent, the additional gas collecting means 4 are provided at a level, which is at a substantial distance below the overflow gutters 11. In separator 6 liquid and gas are separated from each other by gravity and the liquid gathers at the bottom section of the separator and is – as explained above – returned into the mixing zone 2 of the reactor tank via the downer 8 to support the mixing.

As a result of the fact that the gas has lifted the water well above the fluid in the reactor tank 14, the liquid column in the downer 8 produces a fairly powerful downward flow in the downer pipe 8, which provides extra mixing at the bottom of the reactor. In a

simple way the effect is therefore achieved that tranquility prevails at the top of the reactor and heavy sludge and influent at the bottom of the reactor are thoroughly mixed by turbulence.

- 5 In the Figures, number 20 indicates the position at which the gas - collected by the additional gas collection system- is introduced into the riser, H2 indicates the vertical distance between said gas introduction point 20 and the level of the water collection means 11 (effluent weirs/gutters), which level is in fact the fluid level 21 in the tank. H3 indicates the vertical distance between the discharge opening 18 of the riser 5 and
- 10 the level of the water collection means. H1 is essentially the sum of H2 and H3, i.e. $H1=H2+H3$. The length of H3 can be in the range of 10% to 30% of H1. The discharge opening of the riser(s) 18 is preferably located above the fluid level in the gas-liquid separator and designed in a way to create a tangential flow pattern in the gas-liquid separator device 6 for optimizing the separation process. The inlet opening to the
- 15 downer pipe 8 is preferably conically shaped to avoid gas entrapment and enable a constant downward flow.

- Within the scope of the invention various modifications are possible. The embodiments drawn and described are only examples. All the embodiments have in common that a
- 20 significant portion of the gas evolved during the fermentation is collected before it can reach the uppermost section of the reactor and that the liquid propelled up in this process by the gas-lifting action is separated from gas and the potential energy of the relatively heavy liquid column is used via a re-circulating flow to obtain the stirring necessary for a thorough mixing and fluidization at the bottom of the reactor. Power
- 25 which would have been released at the top of the reactor is now taken to the bottom. The load capacity of the reactor is considerably increased as a result of the tranquillity at the top near the water outlet and the turbulence at the bottom near the water inlet.

Claims

1] Anaerobic purification device for purification of influent, such as waste water, the anaerobic purification device comprising:

- 5 • a reactor tank (14);
- inlet means (12) for introducing influent into the tank (14), the inlet means (12) being located in the lower section of the tank (14);
- water collecting means (11), such as an overflow gutter, for collecting purified water, the water collecting means being provided at the upper section of the tank
- 10 (14) and defining a liquid surface (21) in said reactor tank (14);
- at least one gas collecting system (4) for collecting gas from the fluid contained in the reactor (14), the at least one gas collecting system (4) being arranged at a level below the water collecting means (11);
- a gas-liquid separation device (6) arranged at a level above the water collecting
- 15 means (11);
- at least one riser (5) having a discharge opening (18) debouching into the separation device (6), the at least one riser (5) being connected (20) to the at least one gas collecting system (4) for raising fluid contained in the tank (14) by gas lift action caused by gas collected in the at least one gas collection system (4);
- 20 • a downer (8) having an inlet (17) commencing into the separation device (6) and an outlet debouching in the lower section of the tank (14) for returning liquid separated in the separation device, into the lower section of the tank;

characterized in that

- 25 the purification device is arranged to define, in the downer (8) at the level of the liquid surface (21), a head pressure of at least about 1.4 m water column (about 0.14 bar).

2] Anaerobic purification device according to claim 1, wherein the head pressure is at least about 1.5 m water column (about 0.15 bar), preferably at least about 1.6 m water column (0.16 bar).

3] Anaerobic purification device according to claim 1, wherein the head pressure is at least 1.8 – 2 m water column (about 0.18-0.2 bar), such as 2.5-3 m water column (0.25-0.3 bar) or more.

4] Anaerobic purification device according to one of the preceding claims, wherein the at least one riser (5) has a top part (26) which is defined as that part of the riser (5) extending upwards as from said liquid surface (21), and wherein said top part has a
5 length (H3) which is at least about 10%, such as at least about 15%, of the total length (H1) of the at least one riser (5).

5] Anaerobic purification device according to one of the preceding claims, wherein the at least one riser (5) has a top part (26) which is defined as that part of the riser (5)
10 extending upwards as from said liquid surface (21), and wherein said top part has a length (H3) which is at most about 30%, such as at most about 25%, of the total length (H1) of the at least one riser (5).

6] Anaerobic purification device according to one of the preceding claims, wherein
15 the at least one riser (5) has a top part (26) which is defined as that part of the riser (5) extending upwards as from said liquid surface (21), and wherein said top part has a length (H3) which is at least about 1.2 m, preferably at least about 1.4 m, such as 1.6 – 2 m or more.

20 7] Anaerobic purification device according to one of the preceding claims, wherein the gas-liquid separation device (6) comprises an essentially closed vessel (16) provided with means (22) for keeping the gas pressure at a threshold value.

8] Anaerobic purification device according to claim 7, wherein said threshold
25 value is at least about 0.25 m water column (about 0.025 bar), such as at least about 0.5 m water column (about 0.05 bar).

9] Anaerobic purification device according to claim 7 or 8, wherein said threshold
30 value is at most about 1.5 m water column (about 0.15 bar), such as at most about 1.2 m water column (about 0.12 bar).

10] Anaerobic purification device according to one of the preceding claims, wherein the gas-liquid-separation device (6) comprises a vessel (16), wherein the inlet (17) of

19

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the downer (8) is conically shaped with respect to a vertical axis and with the taper in the downward direction, wherein the conically shaped inlet (17) is arranged inside the vessel (16), and wherein the discharge opening (18) of the at least one riser (5) is arranged to create a tangential fluid flow in vessel (16) around the conically shaped inlet (17) of the downer.

11] Anaerobic purification device according to one of the preceding claims, wherein said device further comprises upper gas collecting means (10) for collecting and removing gas from the fluid contained in the tank (14), the upper gas collecting means (10) being provided between the water collecting means (11) and the at least one gas collecting system (4).

12] Use of the anaerobic purification device according to one of the preceding claims.

13] Method of operating an anaerobic purification device for purification of influent, such as waste water, the anaerobic purification device comprising:

- a reactor tank (14);
- inlet means (12) for introducing influent into the tank (14), the inlet means (12) being located in the lower section of the tank (14); water collecting means (11), such as an overflow gutter, for collecting purified water, the water collecting means being provided at the upper section of the tank (14) and defining a liquid surface (21) in said reactor tank (14);
- at least one gas collecting system (4) for collecting gas from the fluid contained in the reactor (14), the at least one gas collecting system (4) being arranged at a level below the water collecting means (11);
- a gas-liquid separation device (6) arranged at a level above the water collecting means (11);
- at least one riser (5) having a discharge opening (18) debouching into the separation device (6), the at least one riser (5) being connected (20) to the at least one gas collecting system (4) for raising fluid contained in the tank (14) by gas lift action caused by gas collected in the at least one gas collection system (4);

- a downer (8) having an inlet (17) commencing into the separation device (6) and an outlet debouching in the lower section of the tank (14) for returning liquid separated in the separation device, into the lower section of the tank;

characterized in that

- 5 the anaerobic purification device is operated with a head pressure of at least about 1.4 m water column (about 0.14 bar), said head pressure prevailing in the downer (8) at the level of the liquid surface (21).

- 14] Method according to claim 13, wherein the head pressure is at least about 1.5 m
10 water column (about 0.15 bar), preferably at least about 1.6 m water column (0.16 bar).

- 15] Method according to claim 13, wherein the head pressure is at least 1.8 – 2 m
water column (about 0.18-0.2 bar), such as 2.5-3 m water column (0.25-0.3 bar) or
more,

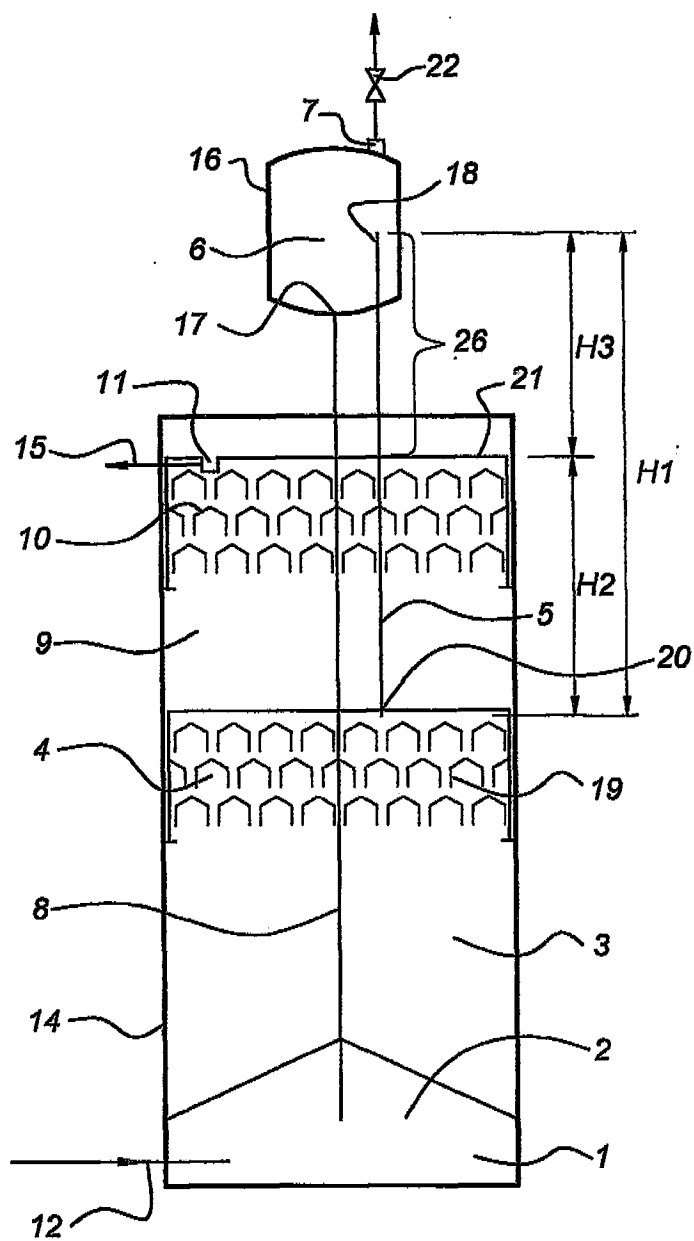
15

- 16] Method according to one of claims 13-15, wherein the gas-liquid separator
device (6) comprises an essentially closed vessel (16), and wherein the gas pressure
prevailing in said vessel (16) is at least about 0.3 m water column (about 0.03 bar),
such as at least about 0.5 m water column (about 0.05 bar).

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- 17] Method according to claim 16, wherein the gas pressure prevailing in said
vessel (16) is at most about 1.5 m water column (about 0.15 bar), such as at least about
1.2 m water column (about 0.12 bar).

Fig 1



INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2005/000423

A. CLASSIFICATION OF SUBJECT MATTER C02F3/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C02F B01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data, COMPENDEX, BIOSIS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 602 416 B1 (ROSSMANITH PETER) 5 August 2003 (2003-08-05) column 2, line 10 - column 4, line 22; claims 1-11; figure 1	1-17
X	US 6 063 273 A (HABETS ET AL) 16 May 2000 (2000-05-16) column 3, line 1 - line 59; claims 1-8; figure 1	1-4, 6, 10, 12
A	EP 0 170 332 A (PAQUES B.V) 5 February 1986 (1986-02-05) cited in the application page 4, line 9 - page 6, line 33; figure 1	1-17
A	US 2003/085171 A1 (KHUDENKO BORIS M) 8 May 2003 (2003-05-08) paragraphs '0026!', '0029!', '0032!', '0033!; claims 1-20; figures 1, 2, 7, 8	1-17

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"G" document member of the same patent family

Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/NL.2005/000423

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DISPOSITIVO DE PURIFICACIÓN ANAERÓBICA

CAMPO DE LA INVENCION

La presente invención se relaciona con un
5 dispositivo de purificación anaeróbica para purificación de
flujo entrante, tal como agua residual, el dispositivo de
purificación anaeróbica comprende:

- un tanque de reactor;
- medios de entrada para introducir flujo
10 entrante en el tanque, los medios de entrada se localizan
en la sección inferior del tanque;

- medios de recolección de agua, tal como un
canal de desbordamiento, para recolectar agua purificada,
los medios de recolección de agua se proporcionan en la
15 sección superior del tanque y definen una superficie de
líquido en el tanque de reactor;

- al menos un sistema de recolección de gas
para recolectar gas del fluido contenido en el reactor, al
menos un sistema de recolección de gas que se dispone en un
20 nivel por debajo de los medios de recolección de agua;

- un dispositivo de separación de gas-líquido
dispuesto en un nivel sobre los medios de recolección de
agua;

- al menos un tubo vertical de subida que
25 tiene una abertura de descarga que desemboca en el

dispositivo de separación, al menos un tubo vertical de subida que se conecta al menos en un sistema de recolección de gas para elevar el fluido contenido en el tanque por la acción de elevación de gas causada por el gas recolectado en al menos un sistema de recolección de gas;

- un tubo vertical de bajada que tiene una entrada que desemboca en el dispositivo de separación y una salida que desemboca en la sección inferior del tanque para regresar el líquido separado en el dispositivo de separación, dentro de la sección inferior del tanque.

ANTECEDENTES DE LA INVENCION

Tal dispositivo se conoce de EP-A-170.332. De acuerdo con este EP-A-170.332, se somete agua residual que contiene material orgánico a un proceso en el cual el material orgánico disuelto se descompone bajo condiciones anaeróbicas. En contacto con la biomasa que contiene microorganismos que producen metano, se produce metano el cual se separa del líquido. El agua tratada (efluente) se remueve mediante vertederos de desbordamiento. El EP-A-170.332 describe como punto de partida para esa invención en la página 1, líneas 21-32: Se ha encontrado que con un tiempo de residencia de varias horas puede alcanzarse una purificación de tanto como 90%. El grado al cual puede mantenerse tal eficiencia de purificación durante un largo

periodo depende también de la retención de sedimento. En particular, debe tenerse cuidado para asegurar que en promedio no se eleve más sedimento fuera del reactor que puede formarse en un cierto periodo de tiempo. Si se
5 utiliza un flujo hidráulico elevado con una concentración baja de COD en el flujo entrante, existe un riesgo considerable de que el sedimentador interno no será capaz de evitar que una gran cantidad de sedimento se descargue. Un factor el cual es de importancia en esta conexión es la
10 carga de superficie hidráulica del sedimentador. En el paso subsiguiente, EP-A-170.332 explica que el agua que fluye hacia arriba y las burbujas de gas emergentes pueden mezclar los copos y partículas de biomasa considerablemente. Estos pueden alcanzar la parte más alta
15 del reactor en donde se ubica el sistema de recolección de gas. La turbulencia producida de esta manera puede resultar en cantidades excesivas de biomasa que se descargan del reactor. Esto limita la capacidad de carga del reactor considerablemente.

20 La invención de EP 170 332 pretende superar las desventajas recién descritas y crear un reactor en el cual la carga de gas principal se sustrae de un sistema de recolección de gas superior. Para este propósito, EP 170 332 proporciona al menos un sistema de recolección de gas
25 adicional para recolectar gas, cuyo sistema adicional se

dispone en una distancia debajo del sistema de recolección superior. El sistema adicional tiene una unión hidráulica con al menos un tubo vertical de subida para elevar el líquido por la acción de la elevación del gas, el tubo vertical de subida se descarga en al menos un dispositivo de separación para separar gas y líquido. En vista del hecho de que el gas se atrapa en una distancia considerable por debajo del nivel de líquido y se transporta además a través del tubo vertical de subida, puede ocurrir un flujo esencialmente libre de turbulencia en la sección superior del reactor. Esto incrementa la capacidad de carga, mientras que en la parte superior, se obtiene el efluente limpio. Es importante que el líquido, el cual se transporta junto con el gas al tubo vertical de subida, se separe y regrese al reactor: Mientras se requiere un flujo en calma, libre de turbulencia en la parte superior del reactor, se requiere una excelente mezcla de sedimento y fluido en el fondo del reactor. Para este propósito, el sedimento denso cerca del fondo tiene que fluidizarse. En una modalidad preferida de acuerdo con EP 170 332, esta fluidización puede lograrse en la sección inferior del reactor con la ayuda de energía obtenida a partir del líquido de elevación de gas en el tubo vertical de subida. El líquido elevado se separa del gas y, bajo la influencia de presión de gravedad hidráulica, se regresa desde el dispositivo de separación,

a través de un tubo vertical de bajada, hasta la sección inferior de la cámara del reactor.

Por razones económicas, se vuelve más y más interesante crear una columna del reactor tan alta como sea posible. En ese caso, puede existir más volumen de reactor y más biomasa, mientras que el espacio - metros cuadrados del área superficial ocupada por el reactor - sea el mismo. Por otro lado, entre más elevado sea el reactor, más pesada será la columna de biomasa en el reactor. Entre más pesada sea la columna de biomasa, más difícil será mantener un buen mezclado y el patrón de fluidización cerca del fondo del reactor. En algunos casos, puede suceder también que la mezcla de biomasa se vuelva más pesada debido a la precipitación de material inorgánico. También en ese caso, puede ser difícil mantener una buena fluidización.

Una solución podría incrementar la presión de descarga. Sin embargo, la técnica anterior y la experiencia enseña que, para una buena mezcla en el fondo del reactor y el funcionamiento total del reactor, se requiere, en el nivel de la superficie de líquido en el reactor, una presión de descarga de una columna de agua de aproximadamente 0.8 a 1 m (es decir, aproximadamente 0.08-0.1 bar) en el sedimentador, con el fin de superar la pérdida de presión, la cual se requiere para buena distribución en el fondo en el lecho de sedimento.

Presiones de descarga muy bajas resultan en un mezclado no
óptimo en el fondo del reactor y/o un rendimiento más pobre
del reactor respectivamente del 'proceso llevado a cabo en
el reactor' en conjunto, mientras que una presión de
5 descarga muy elevada puede resultar en fuerzas cortantes
muy elevadas en las partículas de biomasa, y
consecuentemente la destrucción del material granular.

En la práctica, al menos aproximadamente 80% de
la presión de descarga se obtiene de la presión hidráulica,
10 mientras que como máximo 20% de la presión de descarga se
obtiene de la presión de gas que resulta de las situaciones
de carga de gas durante el uso. Sin embargo, en casos
particulares, esto ha conducido a problemas con
fluidización del sedimento en el fondo del reactor y/o
15 flujos de gas bastante irregulares.

De este modo, aunque por razones económicas se
deseara crear la columna de reactor tan alta como sea
posible, la altura del reactor está en práctica limitada,
debido a los efectos y enseñanzas recién mencionados.

20

SUMARIO DE LA INVENCION

La presente invención tiene el objetivo de
proporcionar un dispositivo de purificación anaeróbica para
purificación de flujo entrante, tal como agua residual, con
25 fluidización mejorada en el fondo del reactor el cual

también permite incrementar la altura del reactor.

De acuerdo con la invención este objeto se logra al proporcionar un dispositivo de purificación anaeróbica para purificación de flujo entrante, tal como agua residual, el dispositivo de purificación anaeróbica comprende:

- un tanque de reactor;
- medios de entrada para introducir flujo entrante en el tanque, los medios de entrada se localizan en la sección inferior del tanque;

- medios de recolección de agua, tal como un canal de desbordamiento, para recolectar agua purificada, los medios de recolección de agua se proporcionan en la sección superior del tanque y definen una superficie de líquido en el tanque de reactor;

- al menos un sistema de recolección de gas para recolectar gas a partir del fluido contenido en el reactor, al menos un sistema de recolección de gas que se dispone en un nivel por debajo de los medios de recolección de agua;

- un dispositivo de separación de gas-líquido dispuesto en un nivel sobre los medios de recolección de agua;

- al menos un tubo vertical de subida que tiene una abertura de descarga que desemboca en el

dispositivo de separación, al menos un tubo vertical de subida que se conecta al menos a un sistema de recolección de gas para elevar el fluido contenido en el tanque por acción de elevación de gas causada por el gas recolectado en al menos un sistema de recolección de gas;

- un sedimentador que tiene una entrada que desemboca en el dispositivo de separación y una salida que desemboca en la sección inferior del tanque para regresar líquido separado en el dispositivo de separación, dentro de la sección inferior del tanque.

caracterizado en que

el dispositivo de purificación se dispone para definir, en el sedimentador en el nivel de la superficie de líquido, una presión de descarga de al menos aproximadamente 1.4 m (m significa metro) de columna de agua (aproximadamente 0.14 bar).

En este aspecto, la presión de descarga se define como la diferencia de presión, en el nivel de la superficie de líquido en el reactor (cuyo nivel se define por los medios de recolección de agua, tal como un canal de desbordamiento), entre un punto dentro del tubo vertical de bajada y un punto fuera del sedimentador, pero dentro del tanque.

De acuerdo con una modalidad preferida de la invención, la presión de descarga es una columna de agua de

al menos aproximadamente 1.5 m (aproximadamente 0.15 bar), de preferencia una columna de agua de al menos aproximadamente 1.6 m (0.16 bar).

De acuerdo con una modalidad preferida adicional de la invención, la presión de descarga es una columna de agua de al menos 1.8-2 m (aproximadamente 0.18-0.2 bar), tal como una columna de agua de 2.5-3 m (0.25-0.3 bar) o más.

La invención así como ambas modalidades ventajosas anteriores se explicarán posteriormente, así como varias modalidades adicionales de la invención.

De acuerdo con la invención, se han encontrado soluciones para crear más presión de descarga sin disminuir el rendimiento del reactor como puede haberse esperado, pero en cambio el incremento del rendimiento viene dentro de su capacidad.

El reactor puede, de acuerdo con la invención, diseñarse de tal manera que el dispositivo mismo define una presión de descarga de una columna de agua de al menos aproximadamente 1.4 m, es decir, en uso la presión de descarga será una columna de agua de al menos 1.4 metros debido a las características estructurales presentes en el dispositivo. De acuerdo con la invención, existen varias soluciones que implican cada una sus propias características estructurales.

Una primera solución es colocar el dispositivo de separación de gas-líquido en un nivel más elevado sobre el tanque de reactor con el fin de permitir más presión hidráulica. Como una consecuencia, no sólo esa parte del tubo vertical de subida que se extiende sobre la superficie de líquido necesita extenderse, sino también la fuerza directriz del gas para elevar la columna de agua al dispositivo de separación de gas-líquido. Esto puede hacerse, por ejemplo, al incrementar la longitud del tubo vertical de subida que se extiende debajo de la superficie acuosa, y/o al disminuir la resistencia de flujo del tubo vertical de subida - por ejemplo, al cambiar el diámetro del tubo. El descenso de la posición en donde el gas se introduce en el tubo vertical de subida crea más fuerza directriz para elevar la columna de agua al dispositivo de separación. La presión hacia arriba creada por el volumen de agua desplazada en el tubo vertical de subida genera la fuerza directriz que traslada el agua al dispositivo de separación de gas-líquido.

Una modalidad preferida de acuerdo con esta primera solución se caracteriza en que al menos un tubo vertical (5) de subida tiene un parte (26) superior la cual se define como aquella parte del tubo vertical (5) de subida que se extiende hacia arriba a partir de la superficie (21) de líquido, y en donde la parte superior

tiene una longitud (H3) la cual es al menos aproximadamente 1.2 m, de preferencia al menos aproximadamente 1.4 m, tal como 1.6-2 m o más.

Una segunda solución es para operar a una presión de gas más elevada en el separador de gas-líquido. Esta segunda solución puede lograrse, por ejemplo, disponiendo el proceso de separación de gas-líquido en un recipiente esencialmente cerrado provisto con medios para mantener la presión de gas en un valor de umbral predeterminado. De este modo, puede obtenerse una presión de descarga extra de columna de agua de 0.3 a 1.0 m si se requiere. De acuerdo con una modalidad preferida de esta segunda solución, tal valor de umbral es una columna de agua de al menos aproximadamente 0.25 m (aproximadamente 0.025 bar), tal como una columna de agua de al menos aproximadamente 0.5 m (aproximadamente 0.05 bar). De acuerdo con otra modalidad preferida de esta segunda solución, tal valor de umbral es una columna de agua de como máximo aproximadamente 1.5 m (aproximadamente 0.15 bar), tal como una columna de agua de a lo sumo aproximadamente 1.2 m (aproximadamente 0.12 bar).

Una tercera solución es mejorar el flujo de fluido que fluye a través del sedimentador. Esto puede, por ejemplo, lograrse al proporcionar medios que permiten al fluido entrar al sedimentador continua y fácilmente. De acuerdo con una modalidad de esta tercera solución, el

dispositivo de separación de gas-líquido comprende un recipiente, en donde la entrada del tubo vertical de bajada está en forma cónica con respecto a un eje vertical y con la unión cónica en la dirección descendente, y en donde la
5 abertura de descarga de al menos un tubo vertical de subida se dispone para crear un flujo de fluido tangencial en el recipiente alrededor de la entrada en forma cónica del tubo vertical de bajada.

Una cuarta solución es una combinación de una o
10 más de las tres soluciones mencionadas anteriormente u otras soluciones posibles.

Un factor importante de influencia es la cantidad de producción de gas en el reactor, la cual es un resultado de la carga de COD aplicada y el índice de conversión de
15 COD. Una producción de gas más elevada por superficie de reactor específica (por ejemplo expresada en $m^3\text{gas}/m^2.h$) provoca una elevación más fuerte de gas, mientras que en una producción de gas más baja, la elevación del gas se desacelerará y finalmente se detendrá. Ya que las columnas
20 del reactor más altas producirán teóricamente más $m^3\text{gas}/m^2.h$, las fuerzas motrices extras para flujo de circulación más interna o para elevar el agua a un dispositivo de separación de gas-líquido más elevado estarán disponibles. El solicitante encuentra, contrario a
25 lo que se espera, que esta fuerza directriz adicionalmente

disponible sea de una cantidad sustancialmente suficiente para permitir, por el contrario a los prejuicios prevalecientes, un incremento de la presión de descarga por simples medidas de diseño en el dispositivo de purificación anaeróbica.

Ya que los reactores pueden operarse en un intervalo muy amplio de índices de Carga Volumétrica (VLR), en general entre 5 y 35 kg COD/m³.d, el dimensionamiento correcto debe tenerse en cuenta en las circunstancias operacionales más probables.

Ahora que por razones económicas, los reactores más altos de 20 m se construirán más frecuentemente, se ha encontrado que la circulación interna puede mantenerse o incluso mejorarse al tomar medidas específicas. Al considerar que la densidad del sedimento de biomasa es más elevado que el agua, que el tubo vertical de bajada así como el sistema de distribución de entrada causa una pérdida de presión y que el lecho de sedimento tiene una cierta resistencia contra la fluidización, se ha encontrado que para una presión de gas "normal" de una Columna de agua de 20 a 30 cm, la elevación del gas necesita trasladar el agua a un nivel de al menos 1.2 m sobre el nivel del agua en el reactor, de preferencia 1.4 a 1.6 m y en algunos casos incluso sobre 2.2 m. Con el fin de acomodar esto para cargas de reactor promedio entre 15 y 30 kg de COD/m³.d,

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necesita elegirse la longitud total del tubo vertical de subida de manera que la parte superior del tubo vertical de subida se extienda hacia arriba a partir de la superficie de líquido - es decir, la longitud sobre los medios de recolección de agua, tal como el canal de desbordamiento - 5 estará entre al menos aproximadamente 10%, tal como al menos aproximadamente 15% y/o como máximo aproximadamente 30%, tal como a lo sumo aproximadamente 25% de la longitud total del tubo vertical de subida. Alternativamente, la 10 presión del gas podría incrementarse a una columna de 60 ó 70 cm o incluso una columna arriba de 1.0 m. También, son posibles combinaciones de dos medidas, por ejemplo, elevando la columna de agua por la elevación de gas a 1.6 m e incrementando la presión de gas a una columna de agua de 15 60 cm con el fin de lograr una presión combinada o presión de descarga de columna de agua de 2.2 m. Al tomar en cuenta estas medidas, se pudieron realizar alturas de reactor en el intervalo de 24 a 36 m o incluso más altas.

De acuerdo con una modalidad ventajosa de la 20 invención, el dispositivo comprende además medios (10) de recolección de gas superior para recolectar y remover gas del fluido contenido en el tanque (14), los medios (10) de recolección de gas superior se proporcionan entre los medios (11) de recolección de agua y al menos un sistema 25 (4) de recolección de gas.

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La presente invención se manifiesta también por, y se relaciona de este modo, al uso de un dispositivo de purificación anaeróbica de acuerdo con la invención.

La presente invención se manifiesta también por, y se relaciona de este modo, a un método para abrir un dispositivo de purificación anaeróbica para purificación de fluido entrante, tal como agua residual, el dispositivo de purificación anaeróbica comprende:

- un tanque de reactor;
- medios de entrada para introducir flujo entrante en el tanque, los medios de entrada se localizan en la sección inferior del tanque;
- medios de recolección de agua, tal como un canal de desbordamiento, para recolectar agua purificada, los medios de recolección de agua se proporcionan en la sección superior del tanque y definen una superficie de líquido en el tanque de reactor;
- al menos un sistema de recolección de gas para recolectar gas a partir del fluido contenido en el reactor, al menos un sistema de recolección de gas que se dispone en un nivel por debajo de los medios de recolección de agua;
- un dispositivo de separación de gas-líquido dispuesto en un nivel sobre los medios de recolección de agua;

- al menos un tubo vertical de subida que tiene una abertura de descarga que desemboca en el dispositivo de separación, al menos un tubo vertical de subida que se conecta al menos a un sistema de recolección de gas para elevar fluido contenido en el tanque por acción de elevación de gas causada por el gas recolectado en al menos un sistema de recolección de gas;

- un sedimentador que tiene una entrada que desemboca en el dispositivo de separación y una salida que desemboca en la sección inferior del tanque para regresar líquido separado en el dispositivo de separación, dentro de la sección inferior del tanque;

caracterizado en que

el dispositivo de purificación anaeróbica se opera con una presión de descarga de una columna de agua de al menos aproximadamente 1.4 m (aproximadamente 1.4 bar), la presión de descarga prevaleciente en el sedimentador en el nivel de la superficie de líquido.

Ventajas del uso de acuerdo con la invención así como el método de acuerdo con la invención y sus modalidades preferidas de acuerdo con las reivindicaciones 14-17, serán claros a partir de la explicación precedente en relación con el dispositivo de acuerdo con la invención.

BREVE DESCRIPCIÓN DE LAS FIGURAS

A continuación, siguiendo la presente invención se explicará además con referencia a un dibujo. En este dibujo:

5 La Figura 1 muestra muy esquemáticamente un dispositivo de purificación anaeróbica de acuerdo con la invención; y

Las Figuras 2A y 2B muestran esquemáticamente una parte de dispositivos de purificación de acuerdo con la invención para explicar el término "presión de descarga".

DESCRIPCIÓN DETALLADA DE LA INVENCIÓN

El equipo de purificación anaeróbica mostrado en la Figura 1 comprende un contenedor 14 alto, llamado tanque de reactor.

En el extremo inferior del tanque 14 del reactor, se proporciona una zona 2 de mezclado para flujo entrante introducido a través del suministro 12. Como el experto lo sabe, una zona 2 de mezclado puede lograrse en varias formas. Una manera ventajosa para conseguir la zona de mezclado es proporcionar un sistema de entrada de acuerdo con WO 92/01637.

En la parte superior del tanque de reactor, se adaptan medios de recolección de agua en la forma de canales 11 de desbordamiento u otros medios los cuales se

conectan a un drenaje 15 de efluente para descargar efluente purificado. Los medios de recolección de agua definen el nivel de la superficie 21 de líquido en el tanque 14 del reactor. En el caso de canales 11 de desbordamiento, este nivel de la superficie 21 de líquido se determinará por la grilla del desbordamiento de tales canales 11.

Dentro del tanque 14 del reactor, se adaptan dos disposiciones 4 y 10 de recolección de gas para recolectar y remover gas. Cada una de las disposiciones de recolección de gas comprende una multiplicidad de campanas 19. Por cada disposición de recolección de gas, las campanas pueden disponerse en una capa o varias capas, tal como tres capas como se muestra en la figura. El número 10, especialmente en las reivindicaciones, se llama el medio de recolección de gas superior y 4 se llama, especialmente en las reivindicaciones, al menos un sistema de recolección de gas. La Figura 1 muestra sólo un sistema 4 de recolección de gas, pero dentro del marco de la invención podrían proporcionarse también dos, tres o más sistemas de recolección de gas. El medio 10 de recolección de gas superior no necesita conectarse al tubo vertical 5 de subida y podría estar ausente en caso de que el fluido a esta altura del tanque sea gas pobre, o podría descargarse de forma separada al dispositivo 6 de separación de gas-

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líquido o en otro sitio.

Sobre el reactor se proporciona un dispositivo 6 de separación de gas-líquido. Este dispositivo de separación de gas-líquido comprende un recipiente 16 esencialmente cerrado - aunque también un recipiente abierto es posible, véase la Figura 2 - que tiene una salida 7 de gas para descargar gas tal como biogas, una salida 17 de líquido y una entrada 18 para suministrar un fluido que contiene el gas y el líquido que se separan. La salida 17 de líquido es el extremo superior del tubo vertical 8 de bajada, o de forma diferente la entrada del tubo vertical 8 de bajada. La entrada 18 es el extremo superior de un tubo vertical 5 de subida, o de forma diferente la abertura de descarga del tubo vertical de subida. La salida 7 de gas se proporciona opcionalmente con medios 22, para mantener la presión de gas en el recipiente en un valor de umbral predeterminado. De preferencia, el valor de umbral tendrá un valor máximo de una columna de agua de aproximadamente 0.25 m (aproximadamente 0.025 bar). Opcionalmente, el valor de umbral puede tener un valor máximo de una columna de agua de aproximadamente 1.5 m (aproximadamente 0.15 bar).

El tubo vertical 5 de subida tiene un extremo inferior con una entrada para extraer el fluido. Este fluido se extrae por acción de elevación de gas causada por

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el gas recolectado por al menos un sistema 4 de recolección de gas (separadores de nivel inferior). Para este propósito, las campanas 19 de al menos un sistema 4 de recolección de gas se conectan al tubo vertical de subida de tal modo, que el gas recolectado crea la elevación de gas en el tubo vertical de subida. Como tal, todo esto relacionado con el tubo vertical de subida se conoce a partir de la técnica anterior y puede, como el experto sabe, realizarse en varias maneras.

10 El tubo vertical 8 de bajada se extiende desde el dispositivo 6 de separación de gas-líquido a la región inferior del tanque 14. Bajo la influencia de gravedad, el líquido a partir del dispositivo de separación, el cual puede -dependiendo de dónde se ubique la biomasa - contener
15 biomasa también, se regresa al fondo del tanque. En el fondo del tanque este retorno de flujo causa fluidización del lecho de la biomasa.

Las Figuras 2A y 2B muestran muy esquemáticamente dos diferentes modalidades de acuerdo con la invención, con
20 el propósito de explicar el término de presión de descarga como se utiliza en esta solicitud. Para partes correspondientes, se utilizan los mismos números de referencia como con respecto a la Figura 1.

Tanto en las Figuras 2A como 2B, la presión de
25 descarga $P_{descarga}$ es la diferencia de presión entre los

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puntos A y B. El Punto A, que tiene la presión P_A , yace dentro del tubo vertical 8 de bajada en el nivel de la superficie 21 de líquido en el tanque 14. El Punto B, que tiene la presión P_B , yace fuera del tubo vertical de bajada, pero dentro del reactor en el mismo nivel de la superficie de líquido. La presión causada por la columna de agua H_w sobre el punto A se llama P_w . La presión P_1 es la presión de gas justo sobre el nivel de líquido en el dispositivo 6 de separación de gas-líquido. P_2 es la presión de gas justo sobre el nivel 21 de líquido en el tanque de reactor. Todas las presiones se miden con relación a la presión atmosférica.

En la modalidad de acuerdo con la Figura 2A, el dispositivo 6 de separación de gas-líquido comprende un recipiente 16 cerrado. En este recipiente cerrado, la presión de gas es P_1 . El tanque 14 del reactor tiene un así llamado techo abierto. Esto significa que el techo se comunica con el ambiente de manera que la presión de gas P_2 en el techo del reactor es aproximadamente la presión atmosférica; así aproximadamente cero/relativo a la presión atmosférica. Sin embargo, el tanque de reactor puede también tener un techo cerrado que permite a la presión de gas P_2 ser diferente de la presión atmosférica. Aquí para la presión de descarga se aplica:

$$P_{\text{descarga}} = P_A - P_B = P_w + P_1 - P_2$$

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En la modalidad de acuerdo con la Figura 2B, el dispositivo 6 de separación de gas-líquido tiene un techo abierto y el tanque 14 del reactor tiene un techo cerrado. Además, el dispositivo de separación de gas-líquido se dispone dentro del tanque 14 del reactor. Consecuentemente, las presiones P_1 y P_2 son idénticas. Aquí, para las presiones de descarga se aplica:

$$P_{\text{descarga}} = P_A - P_B = P_w + P_1 - P_1 = P_w$$

En la Figura 2B, la presión de descarga sería la misma cuando también el tanque 14 del reactor sea un tanque abierto.

Durante la operación, la fermentación tiene lugar bajo condiciones anaeróbicas como un resultado del contacto entre los gránulos de sedimento o copos de biomasa y sustancias solubles en agua, tales como ácidos grasos, metano que se forma. Con el fin de lograr un flujo en calma, libre de turbulencia en la parte más alta del reactor y para asegurar que virtualmente ningún sedimento se separe con el efluente, se proporcionan medios 4 de recolección de gas adicional en un nivel, el cual está a una distancia sustancial por debajo de los canales 11 de desbordamiento. En el separador 6, se separan el líquido y el gas entre sí por gravedad y las acumulaciones de líquido en la sección inferior del separador y - como se explica anteriormente - regresan a la zona 2 de mezclado del tanque

de reactor mediante el tubo vertical 8 de bajada para mantener el mezclado.

Como un resultado del hecho que el gas ha elevado el pozo acuífero sobre el fluido en el tanque 14 del reactor, la columna de líquido en el tubo vertical 8 de bajada produce un flujo descendente bastante poderoso en el tubo vertical 8 de bajada, el cual proporciona mezclado extra en el fondo del reactor. En una simple forma, el efecto se logra por lo tanto, por lo que prevalece la calma en el techo del reactor y el sedimento denso y el flujo entrante en el fondo del reactor se mezclan completamente por turbulencia.

En las Figuras, el número 20 indica la posición en la cual el gas - recolectado por el sistema de recolección de gas adicional - se introduce dentro del tubo vertical de subida, H2 indica la distancia vertical entre el punto 20 de introducción de gas y el nivel de los medios 11 de recolección de agua (vertederos/canales de efluente), cuyo nivel es de hecho el nivel 21 de fluido en el tanque. H3 indica la distancia vertical entre la abertura 18 de descarga del tubo vertical 5 de subida y el nivel de los medios de recolección de agua. H1 es esencialmente la suma de H2 y H3, es decir, $H1 = H2 + H3$. La longitud de H3 puede estar en el intervalo de 10% a 30% de H1. La abertura de descarga del o de los tubos 18 verticales de subida se

ubica de preferencia sobre el nivel de fluido en el separador de gas-líquido y se diseña en una forma que crea un patrón de flujo tangencial en el dispositivo 6 de separador de gas-líquido para optimizar el proceso de separación. La abertura de entrada al tubo vertical 8 de bajada se forma de preferencia cónicamente para evitar atrapamiento de gas y permite un flujo descendente constante.

Dentro del alcance de la invención, son posibles varias modificaciones. Las modalidades ilustradas y descritas son solamente ejemplos. Todas las modalidades tienen en común que una porción notable del gas desarrollado durante la fermentación se recolecta antes de que pueda alcanzar la sección más alta del reactor y que el líquido impulsado en este proceso por la acción de elevación de gas se separa del gas y la energía potencial de la columna de líquido relativamente pesada se utiliza mediante un flujo de re-circulación para obtener la agitación necesaria para un mezclado y fluidización directa en el fondo del reactor. La potencia, la cual había sido liberada en el techo del reactor se conduce ahora al fondo. La capacidad de carga del reactor se incrementa considerablemente como un resultado de la calma en el techo cerca de la salida de agua y la turbulencia en el fondo cerca de la entrada de agua.

NOVEDAD DE LA INVENCION

Habiendo descrito la presente invención se considera como novedad y por lo tanto se reclama como propiedad lo descrito en las siguientes reivindicaciones.

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REIVINDICACIONES

1. Un dispositivo de purificación anaeróbica para purificación de fluido entrante, tal como agua residual, el dispositivo de purificación anaeróbica está caracterizado porque comprende:

- un tanque de reactor (14);
- medios de entrada (12) para introducir flujo entrante en el tanque (14), los medios de entrada (12) se localizan en la sección inferior del tanque (14);
- 15 • medios de recolección de agua (11), tal como un canal de desbordamiento, para recolectar agua purificada, los medios de recolección de agua se proporcionan en la sección superior del tanque (14) y definen una superficie (21) de líquido en el tanque de reactor (14);
- 20 • al menos un sistema de recolección de gas (4) para recolectar gas a partir del fluido contenido en el reactor (14), al menos un sistema de recolección (4) de gas que se dispone en un nivel por debajo de los medios de recolección de agua (11);
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- un dispositivo (6) de separación de gas-líquido dispuesto en un nivel sobre los medios de recolección de agua (11);

- al menos un tubo vertical de subida (5) que
5 tiene una abertura de descarga (18) que desemboca en el dispositivo de separación (6), al menos un tubo vertical de subida (5) que se conecta (20) al menos a un sistema de recolección de gas (4) para elevar fluido contenido en el tanque (14) por acción de elevación de gas causada por el
10 gas recolectado en al menos un sistema de recolección de gas (4);

- un sedimentador (8) que tiene una entrada (17) que desemboca en el dispositivo de separación (6) y una salida que desemboca en la sección inferior del tanque
15 (14) para regresar líquido separado en el dispositivo de separación, dentro de la sección inferior del tanque.

caracterizado porque

el dispositivo de purificación se dispone para
definir, en el sedimentador (8) en el nivel de la
20 superficie de líquido (21), una presión de descarga de una columna de agua de al menos aproximadamente 1.4 m (aproximadamente 0.14 bar).

2. El dispositivo de purificación anaeróbica de conformidad con la reivindicación 1, caracterizado porque
25 la presión de descarga es una columna de agua de al menos

aproximadamente 1.5 m (aproximadamente 0.15 bar), de preferencia al menos aproximadamente una columna de agua de 1.6 m (0.16 bar).

3. El dispositivo de purificación anaeróbica de conformidad con la reivindicación 1, caracterizado porque la presión de descarga es una columna de agua de al menos aproximadamente 1.8-2 m (aproximadamente 0.18-0.2 bar), tal como una columna de agua de 2.5-3 m (0.25-0.3 bar) o más.

4. El dispositivo de purificación anaeróbica de conformidad con una de las reivindicaciones anteriores, caracterizado porque al menos un tubo vertical de subida (5) tiene una parte superior (26) la cual se define como aquella parte del tubo vertical de subida (5) que se extiende hacia arriba a partir de la superficie de líquido (21), y en donde la parte superior tiene una longitud (H3) la cual es al menos aproximadamente 10%, tal como al menos aproximadamente 15% de la longitud total (H1) de al menos un tubo vertical de subida (5).

5. El dispositivo de purificación anaeróbica de conformidad con una de las reivindicaciones anteriores, caracterizado porque al menos un tubo vertical de subida (5) tiene una parte superior (26) la cual se define como aquella parte del tubo vertical de subida (5) que se extiende hacia arriba a partir de la superficie de líquido (21), y en donde la parte superior tiene una longitud (H3)

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la cual es como máximo aproximadamente 30%, tal como a lo sumo aproximadamente 25% de la longitud total (H1) de al menos un tubo vertical de subida (5).

5 6. El dispositivo de purificación anaeróbica de conformidad con una de las reivindicaciones anteriores, caracterizado porque al menos un tubo vertical de subida (5) tiene una parte superior (26) la cual se define como aquella parte del tubo vertical de subida (5) que se extiende hacia arriba a partir de la superficie de líquido
10 (21), y en donde la parte superior tiene una longitud (H3) la cual es al menos aproximadamente 1.2 m, de preferencia al menos aproximadamente 1.4 m, tal como 1.6-2 m o más.

7. El dispositivo de purificación anaeróbica de conformidad con una de las reivindicaciones anteriores,
15 caracterizado porque el dispositivo de separación de gas-líquido (6) comprende un recipiente (16) esencialmente cerrado provisto con medios (22) para mantener la presión de gas en un valor de umbral.

8. El dispositivo de purificación anaeróbica de
20 conformidad con la reivindicación 7, caracterizado porque el valor de umbral es una columna de agua de al menos aproximadamente 0.25 m (aproximadamente 0.025 bar), tal como una columna de agua de al menos aproximadamente 0.5 m (aproximadamente 0.05 bar).

25 9. El dispositivo de purificación anaeróbica de

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conformidad con la reivindicación 7 u 8, caracterizado porque el valor de umbral es una columna de agua de al menos aproximadamente 1.5 m (aproximadamente 0.15 bar), tal como una columna de agua de a lo sumo aproximadamente 1.2 m (aproximadamente 0.12 bar).

10. El dispositivo de purificación anaeróbica de conformidad con una de las reivindicaciones anteriores, caracterizado porque el dispositivo de separación de gas-líquido (6) comprende un recipiente (16), en donde la entrada (17) del tubo vertical de bajada (8) de cónicamente configurado con respecto a un eje vertical y con la unión cónica en la dirección descendente, en donde la entrada formada cónicamente (17) se dispone dentro del recipiente (16), y en donde la abertura de descarga (18) de al menos un tubo vertical de subida (5) se dispone para crear un flujo de fluido tangencial en el recipiente (16) alrededor de la entrada cónicamente formada (17) del tubo vertical de bajada.

11. El dispositivo de purificación anaeróbica de conformidad con una de las reivindicaciones anteriores, caracterizado porque el dispositivo comprende además medios de recolección de gas superior (10) para recolectar y remover gas del fluido contenido en el tanque (14), los medios de recolección de gas superior (10) se proporcionan entre los medios de recolección de agua (11) y al menos un

sistema de recolección de gas (4).

12. El uso de un dispositivo de purificación anaeróbica de conformidad con una de las reivindicaciones anteriores.

5 13. El método para operar un dispositivo de purificación anaeróbica para purificación de flujo entrante, tal como agua residual, el dispositivo de purificación anaeróbica está caracterizado porque comprende:

- 10 • un tanque de reactor (14);
- medios de entrada (12) para introducir flujo entrante en el tanque (14), los medios de entrada (12) se localizan en la sección inferior del tanque (14); medios de recolección de agua (11), tal como un canal de
- 15 desbordamiento, para recolectar agua purificada, los medios de recolección de agua se proporcionan en la sección superior del tanque (14) y definen una superficie de líquido (21) en el tanque de reactor (14);
- al menos un sistema de recolección de gas
- 20 (4) para recolectar gas a partir del fluido contenido en el reactor (14), al menos un sistema de recolección de gas (4) que se dispone en un nivel por debajo de los medios de recolección de agua (11);
- un dispositivo de separación de gas-líquido
- 25 (6) dispuesto en un nivel sobre los medios de recolección



de agua (11);

• al menos un tubo vertical de subida (5) que tiene una abertura de descarga (18) que desemboca en el dispositivo de separación (6), al menos un tubo vertical de subida (5) que se conecta (20) al menos a un sistema de recolección de gas (4) para elevar fluido contenido en el tanque (14) por acción de elevación de gas causada por el gas recolectado en al menos un sistema de recolección de gas (4);

10 • un tubo vertical de bajada (8) que tiene una entrada (17) que comienza en el dispositivo de separación (6) y una salida que desemboca en la sección inferior del tanque (14) para regresar líquido separado en el dispositivo de separación, dentro de la sección inferior
15 del tanque;

caracterizado porque

el dispositivo de purificación anaeróbica se opera con una presión de descarga de una columna de agua de al menos aproximadamente 1.4 m (aproximadamente 0.14 bar),
20 la presión de descarga prevalece en el tubo vertical de bajada (8) en el nivel de la superficie de líquido (21).

14. El método de conformidad con la reivindicación 13, caracterizado porque la presión de descarga es una columna de agua de al menos aproximadamente
25 1.5 m (aproximadamente 0.15 bar), de preferencia una

columna de agua de al menos aproximadamente 1.6 m (0.16 bar).

15. El método de conformidad con la reivindicación 13, caracterizado porque la presión de descarga es una columna de agua de al menos aproximadamente 1.8-2 m (aproximadamente 0.18-0.2 bar), tal como una columna de agua de 2.5-3 m (0.25-0.3 bar) o más.

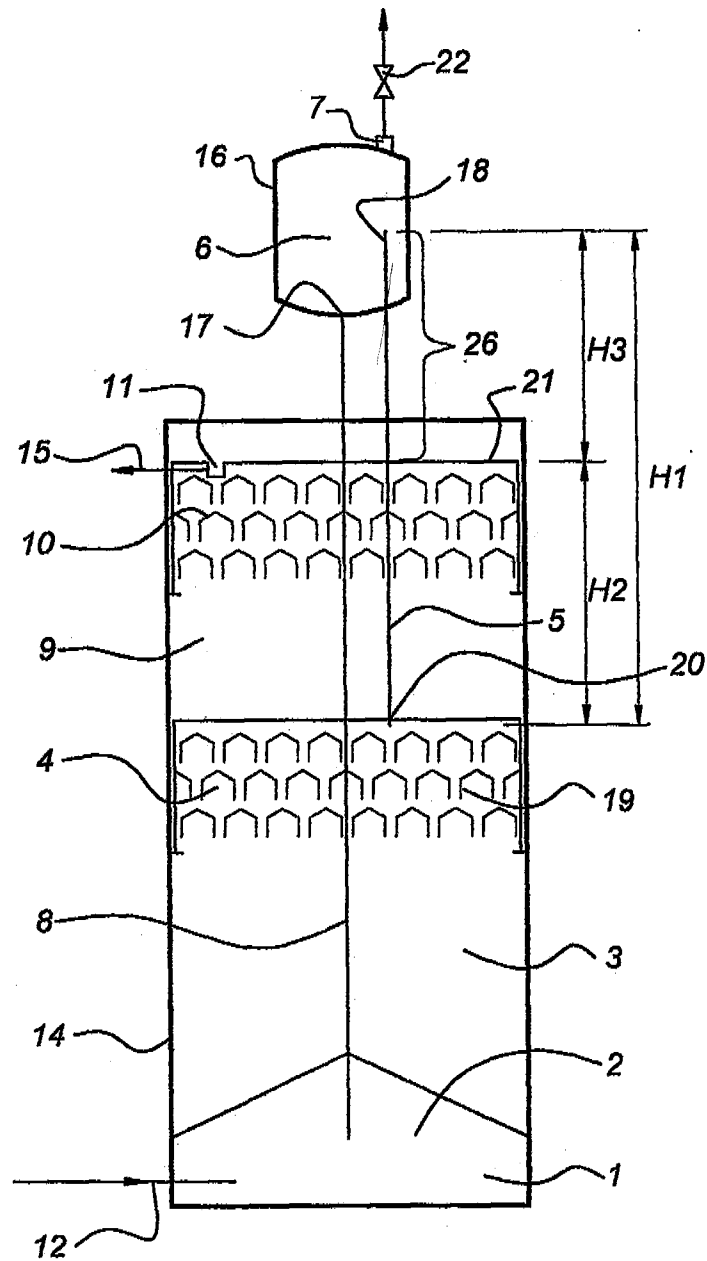
16. El método de conformidad con una de las reivindicaciones 13-15, en donde el dispositivo separador de gas-líquido (6) comprende de un recipiente (16) esencialmente cerrado, y en donde la presión de gas que prevalece en el recipiente (16) es una columna de agua de al menos aproximadamente 0.3 m (aproximadamente 0.03 bar), tal como una columna de agua de al menos aproximadamente 0.5 m (aproximadamente 0.05 bar).

17. El método de conformidad con la reivindicación 16, caracterizado porque la presión de gas que prevalece en el recipiente (16), es una columna de agua de como máximo aproximadamente 1.5 m (aproximadamente 0.15 bar), tal como una columna de agua de a lo sumo aproximadamente 1.2 m (aproximadamente 0.12 bar).

RESUMEN DE LA INVENCION

La presente invención se relaciona con un dispositivo de purificación anaeróbica para purificación de flujo entrante, que comprende: un tanque de reactor; medios de entrada para introducir flujo entrante al tanque; medios de recolección de agua para recolectar agua purificada; un sistema de recolección de gas para recolectar gas a partir del fluido contenido en el reactor; un dispositivo de separación de gas-líquido; un tubo vertical de subida para hacer pasar líquido dentro del dispositivo de separación por gas elevado causado por gas recolectado en el sistema de recolección de gas; un tubo vertical de bajada para hacer regresar líquido y sedimento desde el dispositivo de separación dentro de la sección de tanque inferior. De acuerdo con la invención, este dispositivo se caracteriza porque se dispone para definir, en el tubo vertical de bajada al nivel de la superficie de líquido, una presión de descarga de una columna de agua de al menos aproximadamente 1.4 m (aproximadamente 0.14 bar). La invención también se relaciona con un método para un dispositivo de purificación anaeróbica para purificación de flujo entrante.

Fig 1





US006602416B1

(12) **United States Patent**
Rossmanith

(10) **Patent No.: US 6,602,416 B1**
 (45) **Date of Patent: Aug. 5, 2003**

(54) **METHOD AND A DEVICE FOR THE PURIFICATION OF WASTE WATERS**

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PCT Pub. Date: Jan. 11, 2001

(30) **Foreign Application Priority Data**

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(52) **U.S. Cl. 210/603; 210/608; 210/194**

(58) **Field of Search 210/603, 608,**
 210/194, 260

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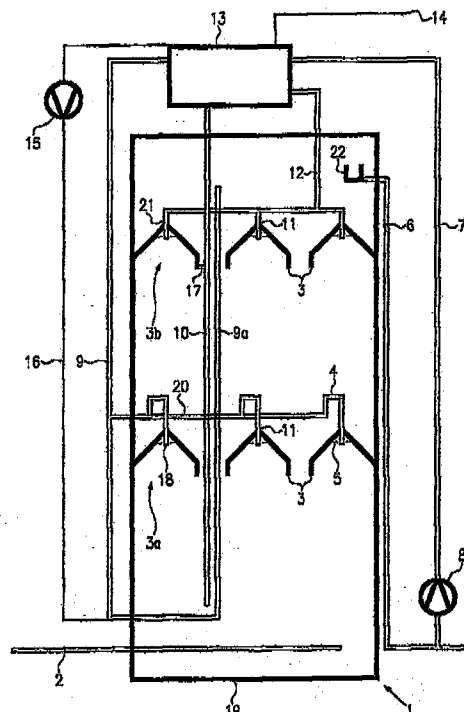
Primary Examiner—Fred Prince

(74) *Attorney, Agent, or Firm—Young & Thompson*

(57) **ABSTRACT**

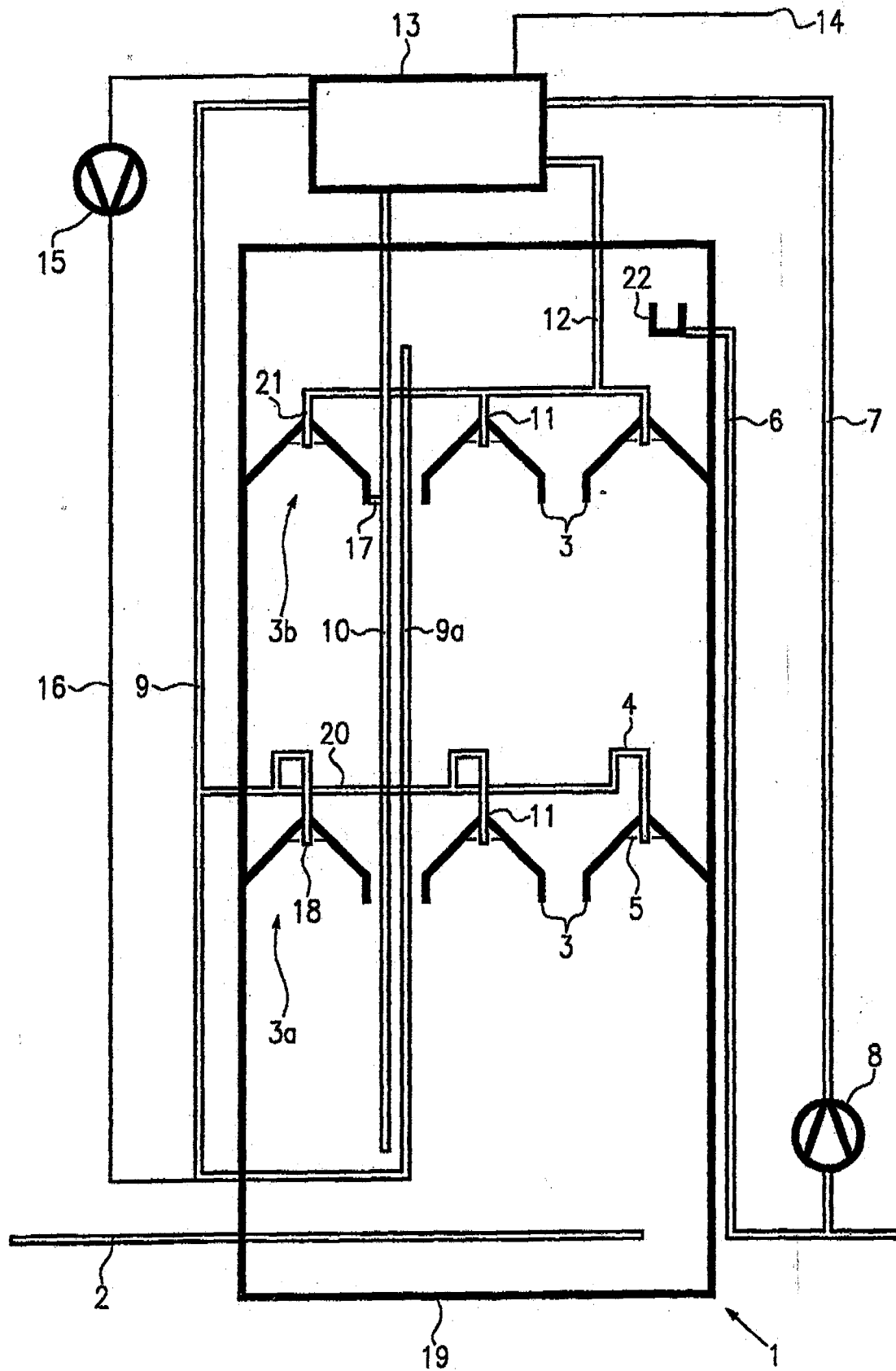
A method and a device for purifying waste water is described, in particular for an anaerobic purification, in a container receiving a medium under the development of gas, wherein the gas developing is caught by a gas collector, ingredients of the medium entrained by the gas are separated and the ingredients separated are passed back into the medium below the gas collector. In order to improve the purification effect in a constructively simple manner, it is suggested to take in medium from the upper portion of the container by a gas lifting effect of the rising gas and to conduct it back into the container.

11 Claims, 1 Drawing Sheet



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METHOD AND A DEVICE FOR THE PURIFICATION OF WASTE WATERS

FIELD OF THE INVENTION

The invention refers to a device for purifying waste water of the type described in the preamble of claim 1.

BACKGROUND OF THE INVENTION

A method of this type is known from EP 0 170 332 B1. The known device operates anaerobic, preferably according to the UASB method (upflow anaerobe sludge blanket) in which a container is used in whose lower portion the waste water to be purified is conducted and from whose upper portion the purified water is let off. Anaerobic micro organisms are active in the container. Stacked gas collectors in the form of hoods are located in the waste water inlet and the overflow for the purified water. The upper portion of the hoods is connected to a gas-sludge separation means via a line. The action of the micro organisms generates gas, which settles down on the sludge so that this sludge floats towards the top as so-called scum. This scum is caught by the hood and gradually emits its gas so that it becomes heavier and sinks back to the ground as so-called sinking sludge. The gas emitted by the pellets rises together with the free gas bubbles caught by the hoods towards the top in the lines and thereby entrains scum particles and fluid that was separated in the gas-sludge separation chamber. The gas is purposefully carried away while the fluid entrained, which may also contain sludge particles, reaches a penstock, which leads back to the bottom of the container. The purified waste water reaches a discharge line in the upper portion of the container via an overflow and is drawn off there. However, it proved that the purification power of such containers still needs to be improved.

SUMMARY OF THE INVENTION

Thus, the invention is based on the object of providing a method and a device for purifying waste water by means of which the purification effect is optimized in a constructively simple manner.

The object is solved by the features cited in claim 1. By the method according to the invention of again sucking on medium from the upper portion of the container and introducing it into the purification circle, a circulation of the medium in the container is started or enforced, which leads to a substantially improved purification effect, wherein by the utilization of the gas lifting effect of the already separated gas, this improved purification effect neither requires energy nor complicated constructive modifications for instance in already existing containers.

In a useful manner, the medium taken-in is conducted back into the container together with those ingredients of the medium that were entrained during the gas accumulation.

Claim 3 describes an especially preferred device for carrying out the method according to the invention.

To realize the improved purification effect according to the invention, only one additional line exists between the upper portion of the container and the gas collection line which can of course also easily be retrofit in already existing containers.

Advantageous embodiments of the device according to the invention can be derived from subclaims 4 to 10.

BRIEF DESCRIPTION OF THE DRAWING

An embodiment of the device according to the invention to carry out an embodiment of the method according to the invention can be derived from the enclosed only FIGURE.

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FIG. 1 shows a device 1 according to the invention for the anaerobic purification of waste water according to the UASB method, which, however, is only shown schematically. The device is a development of the device that is described in the unpublished German patent application 198 15 616 to which reference is hereby made.

DETAILED DESCRIPTION OF THE INVENTION

The device 1 includes an upright standing container 19 into which a waste water line 2 opens in the bottom portion in which a sinking sludge zone provided with micro organisms is located. The waste water line may be provided with one of the conventional distributor systems for the waste water, which, however, is not shown.

A plurality of gas collectors 3 are arranged in a manner stacked across the height of the container. In the embodiment shown, the gas collectors 3 are grouped into two systems, i.e. into a lower system 3a and into an upper system 3b. Each of the gas collectors 3 is provided in the form of one of the known gas collector hoods having a downwardly pointing opening, which extends across the largest horizontal cross section of the hood and which has a vertical cross section tapering towards the top. However, different forms of gas collectors may also be used.

The gas collectors 3 of the lower system 3a of the container 19 according to the invention comprise lines 18 extending through its ridge of the roof 11 and which are welded in a gastight manner to the ridge 11. Each of the lines 18 projects from the ridge of the roof 11 a little bit further, preferably 0.1 to 0.4 times the height of the gas collector hood, downwardly into the gas collector hood and comprises a horizontal opening possibly provided with sludge repelling means. Above the ridge of the roof 11, the lines 18 have an inverted U-shaped bend 4, which is connected to a discharge line 20. The opening of the inverted U-shaped curvature 4 into the discharge line 20 or the opening of the discharge line 20 into a total collector line formed as a riser 9 is located some centimeters, preferably between 5 and 10 cm, above the opening of the line 18 below the ridge of the roof 11. The line 20, which is connected to all gas collectors 3 of the system 3a, opens into the riser 9, i.e. a pipeline having a cross section that is significantly diminished compared to the cross section of the container 19. The riser 9 leads upwardly into a gas-sludge separation means 13 arranged above the container 19. A sinking line 10 leads from this gas-sludge separation means 13 back into the container 19 and opens with a downwardly projecting, horizontal opening below the lower system 3a, and shortly above or within a sinking sludge zone formed in the container 19.

The upper system 3b of the gas collector hoods 3 usually serves for retaining scum for preventing this scum from reaching the purified waste water. The gas collectors 3 of the upper system 3b also comprise lines 21 opening upwardly over the ridge of the roof 11, however, said lines opening without the U-shaped bend 4 of the system 3a into a discharge line 12, which in turn leads into the gas-sludge separation means 13. Below the ridge of the roof 11, the lines 21 are formed as the lines 18 of system 3a.

Some or all of the gas collectors 3 of the upper system 3b may be connected to the sinking line 10 via a pipeline 16. The pipeline is located in the part of the gas collector 3 in which scum preferably collects.

Above the upper system 3b, an overflow 22 for the purified water is located which determines the water level in the container 19, said overflow opening into a water line 6.

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A return line 7, which is provided with a pump 8, leads out of the water line 6 and back into the gas-sludge separation means 13. A first gas line 14 leads out of the gas-sludge separation means 13, said gas line guiding away the collected bio gas for further processing, e.g. for the generation of energy. A further gas line 16 leads out of the gas-sludge separation means 13, with a pump 15 also being connected into said gas line. The gas line 16 leads into the lower portion of the riser 9 so that the gas can be returned for supporting the lifting effect.

The riser 9 leads below the discharge line 20 with a suction line 9a into the upper portion of the container 19 and opens there below the overflow 22 for the purified water, i.e. shortly below the water level.

The device according to the invention operates according to the following method. The waste water to be purified, e.g. organically highly contaminated water from the food or paper industry, is conducted through the waste water line into the lower portion of the container 19 and into the sinking sludge layer existing there, which is provided with micro organisms, preferably in the form of conventional sludge pellets. The micro organisms decompose the organic contaminations of the waste water, which leads to the generation of gas. The gas rises in the form of gas bubbles towards the top and also gets caught on the sludge pellets, so that they become lighter and start to float. The gas and the gas-containing pellets floating in the form of scum reach the portion of the first system 3a and are caught by the gas collectors 3. The gas collects in a gas cushion 5 below the ridge of the roof 11 and above a layer formed of scum, which also gradually outputs its gas and sinks back as sinking sludge. The gas reaches the U-shaped bend 4 via the line 18. In this curvature a gas cushion is formed, which prevents rising and entraining of scum in the line 20. Thereby only the gas reaches the riser 9 via the line 20. There, the gas causes a strong, rising flow and thereby a vacuum at the intake opening of the intake line 9a. This vacuum causes medium from the upper portion of the container including the still existing ingredients, i.e. in particular substantially purified water with scum residue retained by the overflow or possibly residue gas, to be taken in and to be conducted back into the gas-sludge separation means 13 together with the entrained particles and the gas from the gas collectors. The mixture of gas, taken-in sinking sludge and water from the upper portion of the container 19 and from the portion below the gas collector is separated in the gas-sludge separation means 13, wherein the gas normally is conducted via lines 14 for further processing. The entrained sludge collects and is flushed by the water downwards via the sinking line 10 into the container 19, where it is relieved below the system 3a into the container, sinks back to the ground and causes turbulences there so that the micro organisms are rinsed by the waste water again and therefore find optimum conditions of life. Moreover, the waste water is subjected to a second cleaning process, and it is taken care that not too much residue sludge collects at the overflow 22, that there is a risk of the residue sludge being entrained into the purified water. Finally, an advantageous internal reactor circulation is generated in this manner without external energy, e.g. for a pump, having to be supplied. When the sludge sinks down from the separation means 13 through the sinking line 10, scum is taken in via the tube 17, said scum having collected below the gas collectors 3 of the upper systems 3b. This enforces the swirling effect effected by the returned sludge. A further enforcement of the swirling effect caused by the sludge sinking back may be achieved by the aid of a small quantity of waste water that is already purified, which is

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taken by pump 8 of the water line 6 and which is pumped back via line 7 into the separation means 13 where it helps effectively flushing out the sludge through the sinking line 10.

The intake, in particular the start of the device 1, may be supported in that gas or also air is pumped into the riser 9 via the line 16 and the pump 15.

The scum and the gas bubbles, which were not yet caught by the lower system 3a or which have exited again when the collection capacity was exceeded, reach the area of the upper system 3b and are caught by the gas collectors 3 there. The gas collecting in the ridge 11 is conducted via the straight, vertical lines 21 and the line 12 into the separation means 13, whereas the scum layer is either discharged via the tube 17 or, after outputting the gas, sinks back to the ground. The purified waste water flows into the overflow 22 and there reaches the water line 6.

If needed, the device according to the invention may also be operated additionally anaerobic, wherein oxygen at a quantity of 1 to 3 volume percent is added to the gas-sludge separation means 13 for instance to obtain a biological oxidation of the sulfur prevailing in the gas. A return of the gas via the pump 15 and the line 16 is not carried out.

Usually, anaerobic decomposition processes have an optimum between 25° C. and 37° C. By the higher flows it is possible to lower the reaction temperature. The optimum temperature for the method according to the invention is between 10 and 37° C. This means a significant saving of energy, since a heating of the waste water is no longer required.

Furthermore, the upper reactor chambers of high reactors may be provided with a higher density of pellet foam, thereby further increasing the efficiency. In the case of especially protein-containing or starch-containing waste waters, which form so-called floating coagulates, these waste waters may safely be conducted back into the ground portion.

As a modification of the embodiment described and shown, more than two gas collector systems may be provided, or the container may contain only gas collectors of the lower gas collector system if they are capable of keeping away the scum from the overflow for the purified water. In the case of particularly small reactor heights, the pump for returning the gas into the riser may operate permanently. The riser may extend in the interior of the container and the sinking line may extend outside the container. It is also possible to conduct the sinking sludge not into the separation means but via a branch line from the riser directly into the container. If it is ensured that only gas or predominantly gas reaches the riser, the gas collectors may be equipped without the U-shaped bend or with another gas-separation means, or they may be connected with such a gas-separation means connected in front of the riser. Finally, the medium taken in via the intake line, in particular if it contains few gas, or no more gas, does not have to be conducted via the separation means but it may directly reach into the container.

What is claimed is:

1. A method of purifying waste water, in particular an anaerobic purification, in a container receiving a medium under the development of gas, wherein the gas developing is caught by a gas collector, ingredients of the medium entrained by the gas are separated and the ingredients separated are passed back into the medium below the gas collector, characterized in that caused by a gas lifting effect of the rising gas, medium is taken in via an intake line from the upper portion of the container above the gas collector and is conducted back into the container.

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2. A method as claimed in claim 1, characterized in that the medium taken in from the upper portion of the upper container is returned together with the ingredients separated from the gas into the lower portion of the container.

3. A device for purifying waste water, in particular by an anaerobic purification, comprising a container (19) receiving the medium, a waste water intake (2), an outtake (22) for purified water, at least one gas collector (3) arranged in the container (19) and a line (18, 4) leading upwardly from the upper portion of the gas collector, characterized in that above the gas collector (3) in the upper portion of the container (19) an orifice of an intake line (9a) is arranged, wherein the line (18) of the gas collector (3) opens into the intake line (9a) in a manner that the gas coming from the gas collector (3) can be used as a gas lifter for taking in the medium into the intake line (9a).

4. A device as claimed in claim 3, characterized in that the intake line (9a) together with the line (18) opens into a gas collector line (9), which leads into a gas-sludge separation means (13) from which a sinking line (10) leads back into the container (19) below the gas collector (3).

5. A device as claimed in claim 4, characterized in that a gas separation means (4) is provided in the gas collector (3).

6. A device as claimed in claim 5, characterized in that the gas separation means is formed of a substantially inverted

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U-shaped bend (4) of the line (18) upwardly leading out of the gas collector (3).

7. A device as claimed in claim 4, characterized in that a pipeline (17) from the lower portion of the gas collector (3) opens into the sinking line (10).

8. A device as claimed in claim 4, characterized in that a first system (3a) of a plurality of gas collectors (3) is provided in the container (19), said gas collectors being provided with upwardly extending lines (18) having a U-shaped bend, and that a second system (3b) of a plurality of gas collectors (3) is provided above the first system (3a).

9. A device as claimed in claim 8, characterized in that the pipeline (17) is provided between the gas collectors (3) of the second system (3b) and the sinking line (10).

10. A device as claimed in claim 3, characterized in that an additional gas line (16) opens into a riser (9).

11. A device as claimed in claim 3, characterized in that a first system (3a) of a plurality of gas collectors (3) is provided in the container (19), said gas collectors being provided with upwardly extending lines (18) having a U-shaped bend, and that a second system (3b) of a plurality of gas collectors (3) is provided above the first system (3a).

* * * * *



US006063273A

United States Patent [19]**Habets et al.**[11] **Patent Number:** **6,063,273**[45] **Date of Patent:** **May 16, 2000**[54] **APPARATUS FOR THE BIOLOGICAL PURIFICATION OF WASTE WATER**[75] Inventors: **Leonard Hubertus Alphonsus Habets, Sneek; Antonius Johannes Hendrikus Hyacinthus Engelaar, Oppenhuizen; Sjoerd Hubertus Jozef Vellinga, Tjalleberd, all of Netherlands**

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[73] Assignee: **Paques B.V., Balk, Netherlands****FOREIGN PATENT DOCUMENTS**[21] Appl. No.: **09/306,413**

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[22] Filed: **May 6, 1999**

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WO 96/23735 8/1996 WIPO .

Related U.S. Application Data

[63] Continuation of application No. PCT/NL97/00592, Oct. 29, 1997.

Primary Examiner—Thomas G. Wyse*Attorney, Agent, or Firm*—Young & Thompson[30] **Foreign Application Priority Data**

Nov. 6, 1996 [NL] Netherlands 1004455

[51] Int. Cl.⁷ C02F 3/30; C02F 3/12; C02F 1/24

[52] U.S. Cl. 210/188; 210/218; 210/256; 210/195.1

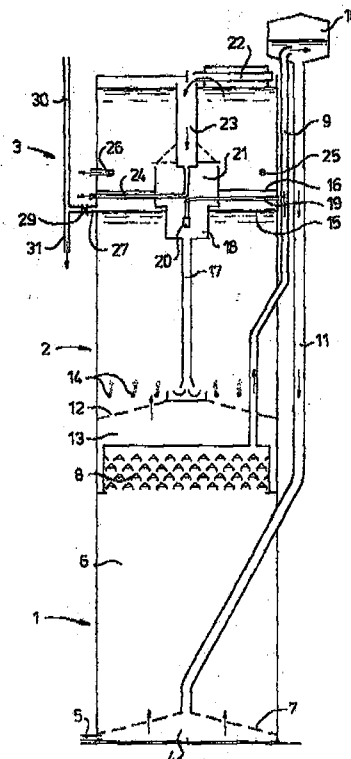
[58] Field of Search 210/603, 605, 210/180, 188, 195.1, 196, 197, 202, 207, 218, 220, 256, 261, 262

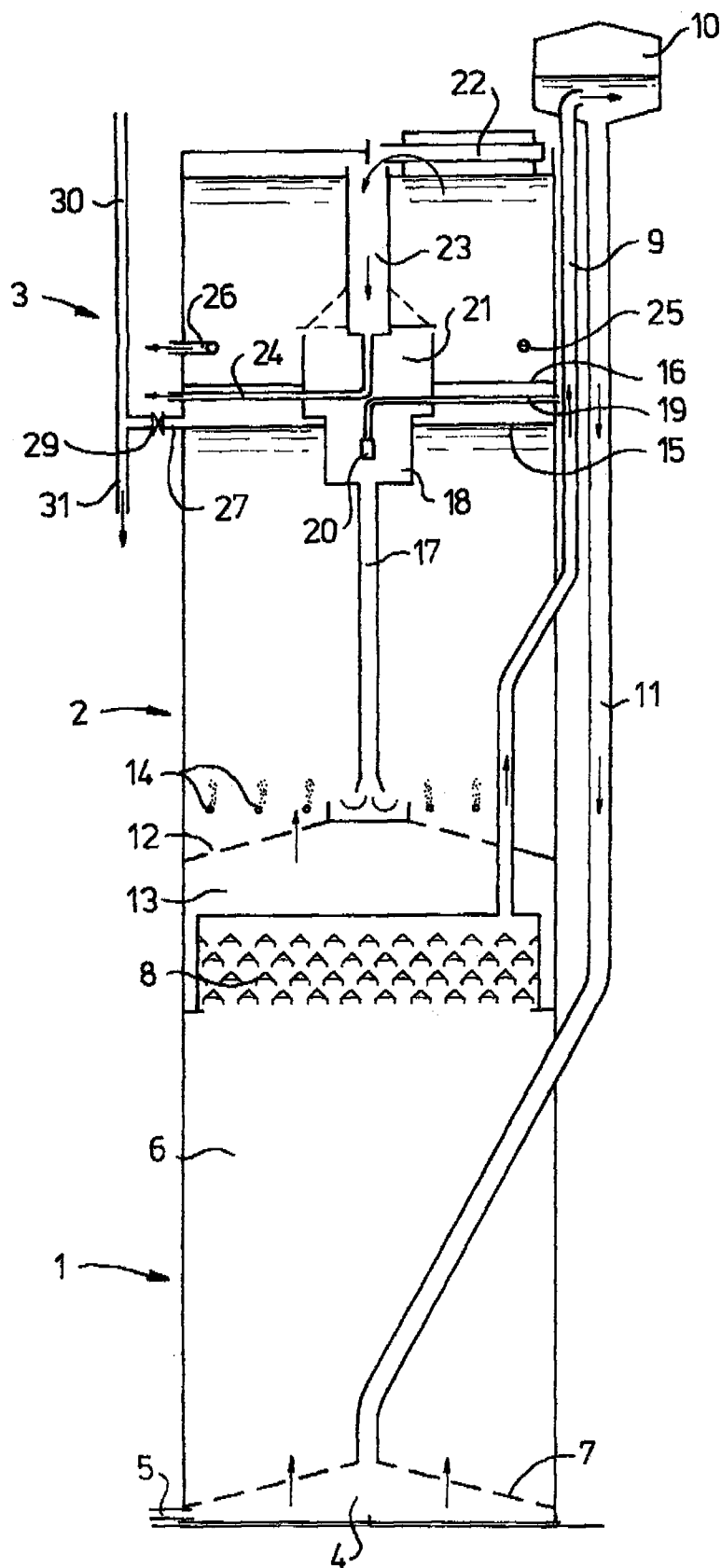
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ABSTRACT

For the biological purification of waste water, use is made of a column containing a UASB reactor (1) at the bottom and an aerobic reactor (2) at the top. The two reactors (1; 2) are separated from one another by a partition (12) in which openings are provided to allow the anaerobic effluent through into the aerobic reactor. The partition (12) is situated at some distance above the gas collection means (8) in order to form a buffer zone (13) for anaerobic sludge which has flowed through. Preferably, a floatation apparatus (3) is mounted on the aerobic reactor in order to separate biomass from the purified water.

8 Claims, 1 Drawing Sheet



APPARATUS FOR THE BIOLOGICAL PURIFICATION OF WASTE WATER

This is a continuation of co-pending international application No. PCT/NL97/00592 filed on Oct. 29, 1997, which designated the United States of America.

The invention relates to an apparatus for the biological purification of waste water, comprising:

a first part being an upflow anaerobic sludge blanket (UASB) reactor which has, at the bottom, a mixing section (4), at the top gas collection means (8) for collecting methane gas bubbles, and a fermentation section (6) which is present between the mixing section and gas collection means, which fermentation section is intended for biomass and the water to be purified,

a second part being an aerobic reactor (2) mounted above the UASB-reactor (1), said aerobic reactor comprising means (14) for supplying air and/or oxygen. Such an apparatus is disclosed in International Patent Application WO96/23735.

Aerobic purification requires a relatively large amount of energy for aeration and results in a relatively large amount of solid waste in the form of surplus. However, the quality of the treated water is satisfactory. Anaerobic purification requires little or no energy and the amount of excess sludge is negligible. On the other hand, the quality of the treated water is generally unsatisfactory. If anaerobic and aerobic treatments are combined, the advantages of both methods are utilized, while the disadvantages are reduced. In the anaerobic part, the majority of the chemically oxidizable material (for example, 75%) is converted into methane gas the energy consumption and the sludge growth being low. The residual contamination is converted into sludge-type biomass and carbonic acid gas in the aerobic section. The savings are especially appreciable in the case of somewhat larger projects. In the case of small installations, the combination of anaerobic and aerobic purification is less attractive because the savings do not offset the additional investment for an aerobic purification and because there is often insufficient space. Mounting the anaerobic reactor and the aerobic reactor above one another, preferably in one tank, makes the combination of anaerobic and aerobic purification profitable even for smaller projects.

A possible drawback of the design disclosed in the abovementioned international patent application is that the anaerobic and the aerobic biomasses may mix with one another at the position of the transition from the one reactor to the other. As the result of the fact that the flow in the aerobic reactor may be fairly turbulent, the anaerobic biomass cannot sink back into the anaerobic reactor, which adversely affects the purification efficiency.

The object of the invention is to avoid this drawback and, for this purpose, the method mentioned in the introduction is characterized by a third part being a buffer zone for anaerobic sludge which has flowed upwards through the gas collection means, said buffer zone being confined at the top by a partition provided with openings and at the lower side by said gas collection means, said means for supplying air and/or oxygen being mounted above said buffer zone.

The partition ensures, inter alia, that the anaerobic sludge does not end up in the aerobic reactor and the aerobic sludge cannot sink into the anaerobic reactor. The aerobic effluent can flow into the aerobic reactor via the openings in the partition. In the calm buffer zone, any anaerobic sludge which has got in can be collected so that it can sink back into the anaerobic reactor chamber.

It is pointed out that the JP-A-61274798 (abstract) discloses an apparatus for treating organic waste water com-

prising a vessel having an anaerobic reactor in the lower part and an aerobic reactor in the upper part. Between both reactors a partition is situated to which pressurized air is supplied to inject air bubbles into the aerobic reactor. There is no buffer zone formed between the partition and gas collection means. Consequently the problem of avoiding anaerobic sludge from flowing into the aerobic reactor is not solved. Further the anaerobic reactor is not an UASB-reactor.

In addition, DE-A-4411825 discloses an apparatus for purification of waste water having an anaerobic section in the lower part and an aerobic section in the upper part. The organic substances are flocculated by an iron salt and the flocks and sludge of the aerobic part are introduced into the anaerobic part. There is no combination of a partition and a buffer zone to avoid anaerobic sludge from flowing into the aerobic section and aerobic sludge from flowing into the anaerobic section; on the contrary. Further U.S. Pat. No. 5,147,547 relates to an oxidation and biological reduction reactor for liquid to be treated by upward circulation and recirculation. A vessel is filled by a lower layer of lower density than the liquid to be treated and an upper layer of higher density than the liquid to be treated. A partition is situated between said lower and upper layers. The partition is provided with pintles as a central tube. This reactor does not give any indication to solve the problem of the solution on which the present invention is directed.

It is pointed out that the operation of the UASB reactor can be improved in a manner known per se by recirculating some of the effluent with the aid of the biogas acting as an internal pump (gas lift). In addition, some of the aerobic effluent can be recirculated via the anaerobic reactor in order to bring about denitrification.

In order to separate the aerobic biomass from the purified liquid, sludge separation means, for example a floatation apparatus, are preferably mounted on the aerobic reactor.

An efficient embodiment of the aerobic section comprises a central riser for feeding water up out of the aerobic reactor into a mixing chamber into which there debouches a pipe for supplying gas-bubble-rich recirculation water (white water). In addition, the mixing chamber mentioned may debouch at the top into a contact chamber in which water originating from the aerobic reactor, the gas-bubble-rich water and the water present in the floatation apparatus can mix with one another.

To remove the aerobic sludge separated, there may be provided, above the usual liquid level in the floatation apparatus, a floating layer skimmer which feeds the sludge which has collected on the liquid to a central sludge tank which is connected to a sludge recirculation pipe.

A drainage pipe having an expansion valve for the removal of foam and air can be provided at the top of the aerobic tank underneath the bottom of the floatation apparatus.

Water can be entrained with the gas from the anaerobic reactor by means of a gas-lift action. In order to separate said water from the gas and, at the same time, to promote the recirculation, the gas removal means of the anaerobic reactor can be connected, via a riser, to a gas chamber which is connected in turn via a downer (downcomer) to the mixing chamber just above the bottom of the apparatus.

Said mixing chamber just above the bottom of the apparatus is separated from the anaerobic reactor by a partition having openings.

Another oxygen-containing gas can also be fed into the aerobic reactor instead of air.

The invention will now be explained in greater detail by reference to the FIGURE which shows a diagrammatic reproduction of the apparatus according to the invention.

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The apparatus shown is intended to purify waste water biologically and comprises an anaerobic reactor 1 of the UASB type, an aerobic reactor 2 and a floatation chamber 3. Said units are situated in a single, relatively high column (for example, 10 to 25 meters high). Said column is preferably a single tank.

The lowermost section—the UASB reactor 1—is provided at the bottom with a mixing chamber 4 into which the influent pipe 5 debouches. Said mixing chamber is separated from the actual anaerobic fermentation chamber 6 by a partition 7 having flow-through openings. Facilities known per se may be present in the mixing chamber 4 in order to mix the influent, for example tangentially debouching inlet pipes.

In the UASB reactor, contaminants are converted into methane. Provided in the uppermost section of the UASB reactor are gas collection hoods in which the methane formed in the chamber 6 is collected and fed via a riser 9 to a gas chamber 10. Water entrained with the gas collects in the chamber 10 and is fed back via a downcomer 11 to the mixing chamber 4.

The UASB reactor 1 is separated from the aerobic reactor 2 by a partition 12 having openings. Situated between the gas hoods 8 and the partition 12 is a buffer space 13 in which anaerobic sludge which has passed through the hoods 8 can collect so that it can sink back into the anaerobic reactor 1. The buffer space 13 is calm.

Situated above the partition 12 are means 14 for feeding air and/or oxygen into the aerobic reactor. In said reactor, contaminants are converted into essentially carbonic acid and biomass by means of aerobic bacteria. The liquid level in the reactor 2 is indicated by 15 and the closed partition between the aerobic reactor 2 and the floatation chamber 3 is indicated by 16.

The purified water which becomes superfluous as a result of feeding effluent from the UASB reactor leaves the aerobic reactor via the central pipe 17 and ends up in a mixing chamber 18 into which water with air dissolved into it can be fed via a pipe 19. At the end of the pipe 19 there is an expansion valve 20. Air bubbles which give the water a white colour are produced by the expansion.

The mixing chamber is followed by a contact chamber 21 in which the white water mixes with the water in the floatation chamber 3, as a result of which flocs are formed which are driven upwards by the air bubbles. A floating layer of biomass forms on the water in the floatation chamber.

By means of a floating layer skimmer 22, the biomass is fed into a central sludge tank 23 in which it is removed from the floatation chamber 3 via the pipe 24. The biomass can be fed back to the aerobic reactor 2. The effluent from the aerobic treatment leaves the floatation chamber 3 via the annular pipe 25 and the drainage pipe 26 and can be discharged into the sewer or the surface water free of sludge and solid matter. The excess biomass can be drained at set times to a sludge storage apparatus.

Situated at the position of the liquid level 15 in the aerobic reactor 2 is an outlet 27 for air together with any foam which debouches via the expansion valve 29 into a pipe 30 for removing air and a pipe 31 for removing foam.

Because the complex treatment (anaerobic, aerobic, floatation) takes place in a column having a relatively great height (10–25 meters), little floor space is occupied. In addition, a number of components are not needed which would indeed be needed in the case of a separate

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construction, such as drainage gutters, covering materials and ventilation facilities.

It goes without saying that all kinds of modifications and additional facilities are possible. For example, some of the aerobic effluent could be recirculated via the UASB reactor in order to bring about denitrification. The aeration could then be different from that described. Instead of air, pure oxygen can also be used.

What is claimed is:

1. Apparatus for the biological purification of waste water, comprising:

a first part being an upflow anaerobic sludge blanket (UASB) reactor which has, at the bottom, a mixing section (4), at the top gas collection means (8) for collecting methane gas bubbles, and a fermentation section (6) which is present between the mixing section and gas collection means, which fermentation section is intended for biomass and the water to be purified,

a second part being an aerobic reactor (2) mounted above the UASB-reactor (1), said aerobic reactor comprising means (14) for supplying air and/or oxygen, characterized by

a third part being a buffer zone (13) for anaerobic sludge which has flowed upwards through the gas collection means, said buffer zone being confined at the top by a partition (12) provided with openings and at the lower side by said gas collection means (8), said means (14) for supplying air and/or oxygen being mounted above said buffer zone (13).

2. Apparatus according to claim 1, characterized in that sludge separation means, for example a floatation apparatus (3), are mounted on the aerobic reactor (2) in order to separate biomass from the purified water.

3. Apparatus according to claim 1, characterized in that a central riser (17) is situated in the aerobic reactor (2) which is intended to feed water up out of the aerobic reactor (2) into a mixing section (18) into which there debouches a pipe (19) for supplying gas-bubble-rich water (white water).

4. Apparatus according to claim 3, characterized in that the mixing section (18) mentioned debouches at the top into a contact chamber (21) in which water originating from the aerobic reactor, the gas-bubble-rich water and the water present in the floatation apparatus mix with one another.

5. Apparatus according to claim 1 inclusive, characterized in that there is provided, above the usual liquid level in the floatation apparatus, a floating layer skimmer (22) which feeds the sludge which has collected on the liquid to a central sludge tank (23) which is connected to a sludge drainage pipe (24).

6. Apparatus according to claim 2, characterized in that, a drainage pipe (28) having a reducing valve (29) for the removal of air and foam is provided at the top of the aerobic reactor (2) underneath the bottom (19) of the floatation apparatus (3).

7. Apparatus according to claim 1, characterized in that the gas removal means (8) of the UASB reactor (2) are connected, via a riser (9), to a gas chamber (10) which is connected in turn via a downer (downcomer) (11) to the mixing chamber (4) just above the bottom of the apparatus.

8. Apparatus according to claim 7, characterized in that the mixing section (4) mentioned just above the bottom of the apparatus is separated from the UASB reactor (1) by a partition (7) having openings.

* * * * *

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(12) EUROPEAN PATENT APPLICATION

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(22) Date of filing: 18.07.85

(30) Priority: 24.07.84 NL 8402337 (43) Date of publication of application: 05.02.86 Bulletin 86/6 (84) Designated Contracting States: AT BE CH DE FR GB IT LI LU NL SE	(71) Applicant: Paques B.V. T. de Boerstraat 11 NL-8561 DT Balk(NL) (72) Inventor: Vellings, Sjoerd Hubertus Jozef De Terp 1 NL-8731 AX Wommels(NL) (74) Representative: van der Beek, George Frans, Ir. et al, Nederlandsch Octrooibureau P.O. Box 29720 NL-2502 LS The Hague(NL)
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(64) Anaerobic purification equipment for waste water.

(57) A considerable portion of the gas developed by fermentation in an anaerobic purification equipment for waste water, together with buoyant sludge, is collected by at least one additional collecting system (5), before it may reach the upper part of the reactor. This additional collecting system is fitted at a distance below the collecting system (6) fitted as usual just below the level of one or more overflow gutters (3; 23) for purified water. The additional collecting system (5) has a hydraulic link with one or more rising pipes (7, 7', 27, 32, 31) for raising the liquid sludge mixture by gas lift action. The rising pipes discharge into a separation device (8) from which one or more downpipes (9; 29) for returning separated liquid and sludge extend to the lower section of the reactor chamber. As a result of the tranquility at the top and the turbulence near the bottom, a substantial increase of the load capacity of the equipment can be obtained.

Anaerobic purification equipment for waste water.

The invention relates to an anaerobic purification equipment for waste water comprising a container with a reactor chamber for fermentation, means for introducing influent into the reactor chamber, at least one overflow gutter for collecting
5 purified water by overflow, and, fitted below the level of the overflow gutter, a collecting system for collecting and removing gas from the liquid.

First subjecting waste water which contains organic material to a process in which the organic material is broken down
10 into substances soluble in water, in particular fatty acids and then treating the water pretreated in this manner under anaerobic conditions by contact with granular sludge which contains methane-producing microorganisms, methane being produced which is separated from the liquid which still contains sludge, is known. The treated
15 water (effluent) is removed via overflows. For the anaerobic fermentation the theoretical residence time of the liquid in the reactor is determined by the hydraulic flow in conjunction with the total capacity of the equipment including the settling chamber. The optimum residence time of the liquid in the reactor is determined,
20 provided there is sufficient sludge present, among others by the COD concentration of the waste water. It has been found that with a residence time of several hours a purification of as much as 90 % can be reached. The extent to which such a purification efficiency can be maintained over a long period also depends on the sludge
25 retention. In particular, care must be taken to ensure that on average no more sludge is rinsed out of the reactor than can be formed in a certain period of time. If a high hydraulic flow is used with a low COD concentration in the influent, there is a considerable risk that the internal settler will not be capable of
30 preventing a large amount of sludge being flushed out. A factor which is of importance in this connection is the hydraulic surface loading of the settler.

Because there is a difference in density between the settled sludge mass in the settling chamber and the mixture of
35 sludge particles, waste water and small gas bubbles in a reactor, the settled mass is partially stirred up. As a result of the

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turbulence produced by this in the uppermost part of the reactor an excessive quantity of sludge will be flushed out of the reactor. To this must be added the fact that so much methane has penetrated into a portion of the sludge grains that the grains have become lighter
5 than the ambient liquid. This limits the load capacity of the reactor to a considerable extent.

From Dutch Patent Application 82.01293 it is known that the "gas-lifting recirculation" of the settled mass can be controlled by creating an overpressure in the gas-collecting
10 chamber. According to this publication the overpressure required for this is at most 30 % of the static pressure in the reactor. This measure therefore prevents a portion of the settled mass being removed with the overflow as a result of uncontrolled gas evolution. A disadvantage of this method is that as a result of the
15 implementation of this type of method, installations are required which withstand pressure, and this entails a considerable increase in the cost price.

The invention aims to overcome the disadvantages described above and to create a reactor of the type mentioned in the
20 introduction in which a good control of the gas-lifting effect can be achieved without overpressure being produced in the reactor.

According to the invention for this purpose at least one additional collecting system for collecting gas and buoyant sludge is fitted at a distance below the first-named collecting system.
25 which additional system has a hydraulic link with at least one rising pipe for raising the liquid sludge mixture by gas lift action, said rising pipe discharging into a separation device for separating gas and liquid.

In view of the fact that gas and buoyant sludge are
30 trapped at a considerable distance below the liquid level and are conveyed further via the said rising pipe or rising pipes, an essentially turbulence-free flow can occur in the uppermost section of the reactor. This increases the load capacity. At the top clean effluent is obtained.

35 It is of importance that the buoyant sludge which is carried along with the gas to the rising pipe or rising pipes is separated and returned to the reactor. While a quiet, eddy-free flow is required at the top of the reactor, good mixture of sludge and

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fluid will be required at the bottom of the reactor. For this purpose the heavy sludge has to be fluidised.

In a preferred embodiment according to the invention this fluidisation can be achieved in the bottom section of the reactor
5 with the aid of the energy from the gas lifting in the rising pipe or rising pipes described provided that from said separation chamber at least one downpipe for returning separated liquid and sludge extends to the bottom section of the reactor chamber.

The gas will have to be freed from the entrained foam. For
10 this purpose use can be made of a defoamer for separating gas and foam, which defoamer is connected to a separation device and has an outlet connection for separated liquid to the said downpipe.

It is preferable that the first-named collecting system is also connected to the said separation device.

15 The additional collecting system will have to collect the gas and the buoyant sludge as completely as possible and will have to carry it off to the rising pipe or rising pipes without the rising liquid being excessively accelerated by constriction of the cross-section. In particular, such an acceleration would per se
20 cause disturbance in the uppermost section of the reactor. According to the invention this is catered for by the fact that at least the said additional collecting system has a number of hoods arranged in layers, the hoods in each layer having a certain offset in relation to the hoods of a subsequent layer and that the cross-sectional area
25 occupied by the hoods in one layer is at most 55 % of the total cross-sectional area.

Within a relatively large reactor container the various pipes can be accommodated in a space-saving manner if within the container there is a number of said rising pipes which alternate
30 with pipes provided by said collecting systems for conveying the purified liquid to an overflow gutter and with at least one downpipe, the various pipes being hexagonal and adjoining each other in a honeycomb pattern.

The invention will now be explained in more detail by
35 reference to the figures in which two exemplary embodiments are shown more or less diagrammatically.

Figure 1 shows a vertical section of the first embodiment.

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Figure 2 shows on a larger scale a detail of the collecting system, of this embodiment, for collecting gas and buoyant sludge.

Figure 3 shows a plan view of the collecting system according to Figure 2.

Figure 4 shows a vertical section of a second embodiment.

Figure 5 shows a horizontal section along the line V-V in Figure 4.

The anaerobic purification equipment shown in Figures 1 - 3 comprises a tall container 1 into the bottom end of which there discharges an inlet 2 for influent. Near the upper rim of the container effluent gutters 3 are fitted which are connected to a drain pipe 4. Within the container two collecting systems 5 and 6 for gas and buoyant sludge are fitted, each consisting of hoods fitted at four levels 5a, b, c, d and 6a, b, c, d respectively which to some extent slope in the direction of a central rising pipe 7.

During operation fermentation takes place particularly in the bottom section of the reactor under anaerobic conditions as a result of contact between sludge grains and substances soluble in water such as fatty acids, methane being formed. A portion of the sludge grains absorb so much methane that they become lighter than the ambient fluid. In order to achieve a quiet, turbulence-free flow in the uppermost part of the reactor and to ensure that virtually no sludge is carried off with the effluent, there is fitted at a level, which is at a substantial distance below the overflow gutters 3, a collecting system which guides the gas and the buoyant sludge into the rising pipe 7. In the pipe 7 the gas and sludge collected by the system 5 end up in a constricted section of pipe 7' which is fitted inside the unconstricted section of pipe 7. The collecting system 6 guides the collected gas and possibly some foam into the unconstricted section of pipe 7. Both the sections 7 and 7' discharge into a separation chamber 8 where liquid and gas are separated from each other. Liquid gathers at the bottom of the separation chamber 8 and flows via a downpipe 9 to the bottom section of the reactor. A pipe 12 extends between the separation chamber 8 and a defoamer 11 in which sludge and liquid are separated from gas. Liquid with sludge is guided to the downpipe 9 through pipe 10.

As a result of the fact that the gas has been removed from

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it, the liquid column in the pipe 9 is heavier than the ambient liquid in the reactor 1. This means that a fairly powerful downward flow is produced in the downpipe 9 which stirs up the relatively heavy sludge at the bottom of the reactor. In addition, separated
5 sludge is returned to the bottom section of the reactor. In a simple way the effect is therefore achieved that tranquility prevails at the top of the reactor and heavy sludge and influent at the bottom of the reactor are thoroughly mixed by turbulence.

The construction of the collecting systems 5 and 6 is such
10 that accelerations of the flow by constrictions of the cross-section are to a large extent limited. Figures 2 and 3 show that in each of the layers 5a, 5b, 5c and 5d two gas hoods are fitted, the two gas hoods in each level occupying less than half the cross-sectional area. The hoods of successive layer overlap each other and the hoods
15 of the four layers together cover the whole cross-sectional area. The cross-sectional area of the reactor occupied by the hoods of a single layer should not be more than 55 % of the total cross-section and preferably less (for example, less than 50 %). The outlines of the various hoods are indicated in Figure 3 by the reference figure
20 of the layer concerned.

It is possible to combine a number of embodiments according to figures 1, 2 and 3 into a big reactor container.

Figures 4 and 5 show a second embodiment in which the reactor has a much larger cross-sectional area and is filled with a
25 large number of hexagonal pipes. The reactor container is indicated by 21, the influent inlet by 22, annular effluent gutters by 23 and the main drain for effluent by 24. The gutters 23 and the main drain 24 are connected to each other by pipes 25.

Within the container there are arranged approximately
30 fifteen hexagonal reactor pipes 26, three combined hexagonal rising pipes 27, and a central hexagonal pipe 28. In this last-named is mounted a downpipe 29 which, in contrast to the hexagonal pipes 26, 27 and 28, extends almost to the bottom of the reactor 21. The pipes 26, 27 and 28 are arranged in a honeycomb pattern.

35 In each of the reactor pipes 26 there are gas-collecting systems 5, 6 at two levels. These have the same construction and position in relation to each other as described in connection with Figures 1, 2 and 3. The gas-collecting systems 5 at the relatively

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low level guide the collected gas and buoyant sludge to a rising pipe 7 which narrows connection pipe 30. One or more connection pipes 30 are connected to a combined rising pipe 27. In the combined rising pipe 27 there is accommodated a pipe 31 of considerably smaller cross-section which is joined to the pipe 27 by an adaptor 32. Each of the three pipes 31 discharges at its upper rim into a separation chamber 33, the three chambers 33 being connected via connecting pipes 34 to a defoamer 35 and connected via connecting pipes 36 to a funnel 37 into which the central downpipe 29 debouches. The defoamer has a gas outlet 38 and a liquid drain 39.

Also pipe 28 has a gas collecting system 40 collecting gas bubbles and guiding gas to a rising pipe. Pipe 28 is closed above system 40.

The gas-collecting systems 6 are located in each of the reactor pipes 26 immediately below the annular overflow gutters 24 for effluent. These systems collect the residual gas and foam and guide them to a rising pipe 7 which debouches into a gas-liquid separator 41. The fluid separated in the latter is conveyed via pipes 42 and a combined chamber 33 to the downpipe 29. The gas obtained is combined with the gas from the defoamer 35.

In this reactor, which is more complicated compared with Figures 1, 2 and 3, the effect is also achieved that gas and buoyant sludge are removed from the reactor pipes 26 at a relatively low level via the collecting systems 5 and the pipes 27, 32, 21 so that in the uppermost part of the reactor pipes 26 tranquility prevails and effluent containing virtually no sludge can flow into the gutters 23. In addition, the heavy sludge at the bottom of the reactor will be stirred up by the relatively heavy liquid which flows downwards from the combined funnel 37 through the downpipe 29. The mixing of influent and sludge is considerably improved as a result. The excess and even dangerous kinetic potential energy of the gas in the uppermost regions of the reactor is used to bring about the necessary mixing and fluidisation in the bottom regions.

Within the scope of the invention various modifications are possible. The embodiments drawn and described are only examples. All the embodiments have in common that a significant portion of the gas evolved during the fermentation and the buoyant sludge are collected before they can reach the uppermost section of the reactor

and that the liquid propelled up in this process by the gas-lifting action is separated from gas and the potential energy of the relatively heavy liquid column is used via a recirculating flow to obtain the stirring necessary for a thorough mixing and fluidisation at the bottom of the reactor. Power present at the top of the reactor is taken to the bottom. The load capacity of the reactor is considerably increased as a result of the tranquility at the top and the turbulence at the bottom. The special construction of the overlapping gas hoods off-set in layers results in a good collection of gas and buoyant sludge without noticeable accelerations of the liquid.

C L A I M S

1. Anaerobic purification equipment for waste water comprising a container with a reactor chamber for fermentation, means for introducing influent into the reactor chamber, at least one overflow gutter for collecting purified water by overflow, and,
5 fitted below the level of the overflow gutter, a collecting system for collecting and removing gas from the liquid, characterised in that at least one additional collecting system (5) for collecting gas and buoyant sludge is fitted at a distance below the first-named collecting system (6), which additional system (5) has a hydraulic
10 link with at least one rising pipe (7, 7', 27, 32, 31) for raising the liquid-sludge mixture by gas lift action, said rising pipe discharging into a separation device (8; 33) for separating gas and liquid.

2. Anaerobic purification equipment according to claim 1,
15 characterised in that from said separation device (8; 33) at least one downpipe (9; 29) for returning separated liquid and sludge extends to the bottom section of the reactor chamber.

3. Anaerobic purification equipment according to claim 2,
20 characterised in that a defoamer (11; 35) for separating gas and foam is connected to the separation device (8; 33), which defoamer has an outlet connection for separated liquid to the said downpipe (9; 29).

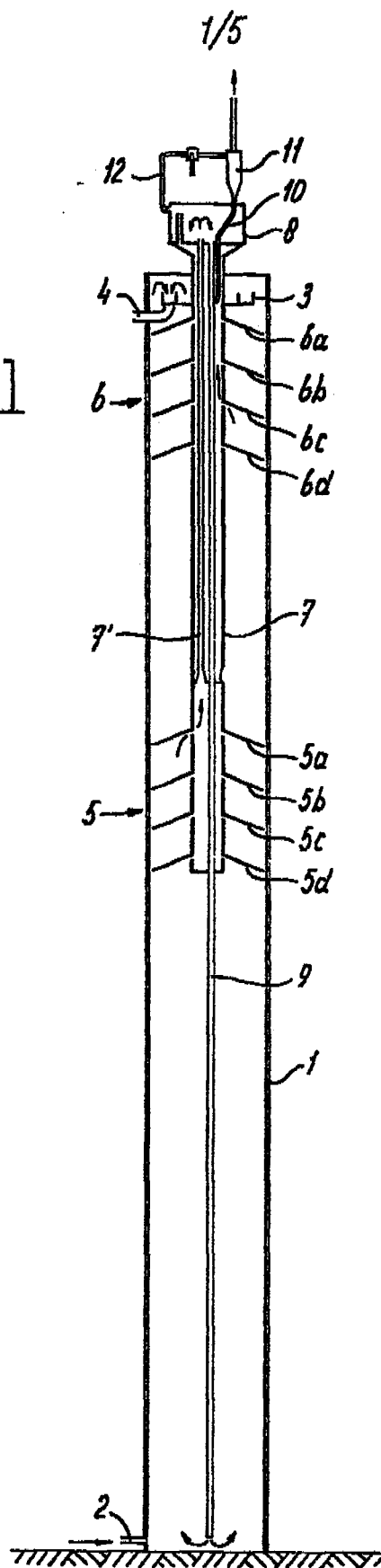
4. Anaerobic purification equipment according to claim 2 or 3, characterised in that the first-named collecting system (6) is
25 also linked to the said separation device (8; 33).

5. Anaerobic purification equipment according to one of the preceding claims, characterised in that at least the said additional collecting system (5) has a number of hoods arranged in layers, the hoods in each layer having a certain offset in relation
30 to the hoods of a subsequent layer and the cross-section occupied by the hoods in a layer being at most 55 % of the total cross-sectional area.

6. Anaerobic purification equipment according to one of the preceding claims, characterised in that within the container (1)
35 there are a number of combined rising pipes (27), which alternate with the pipes (26) provided by the said collecting systems (5, 6),

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fig-1

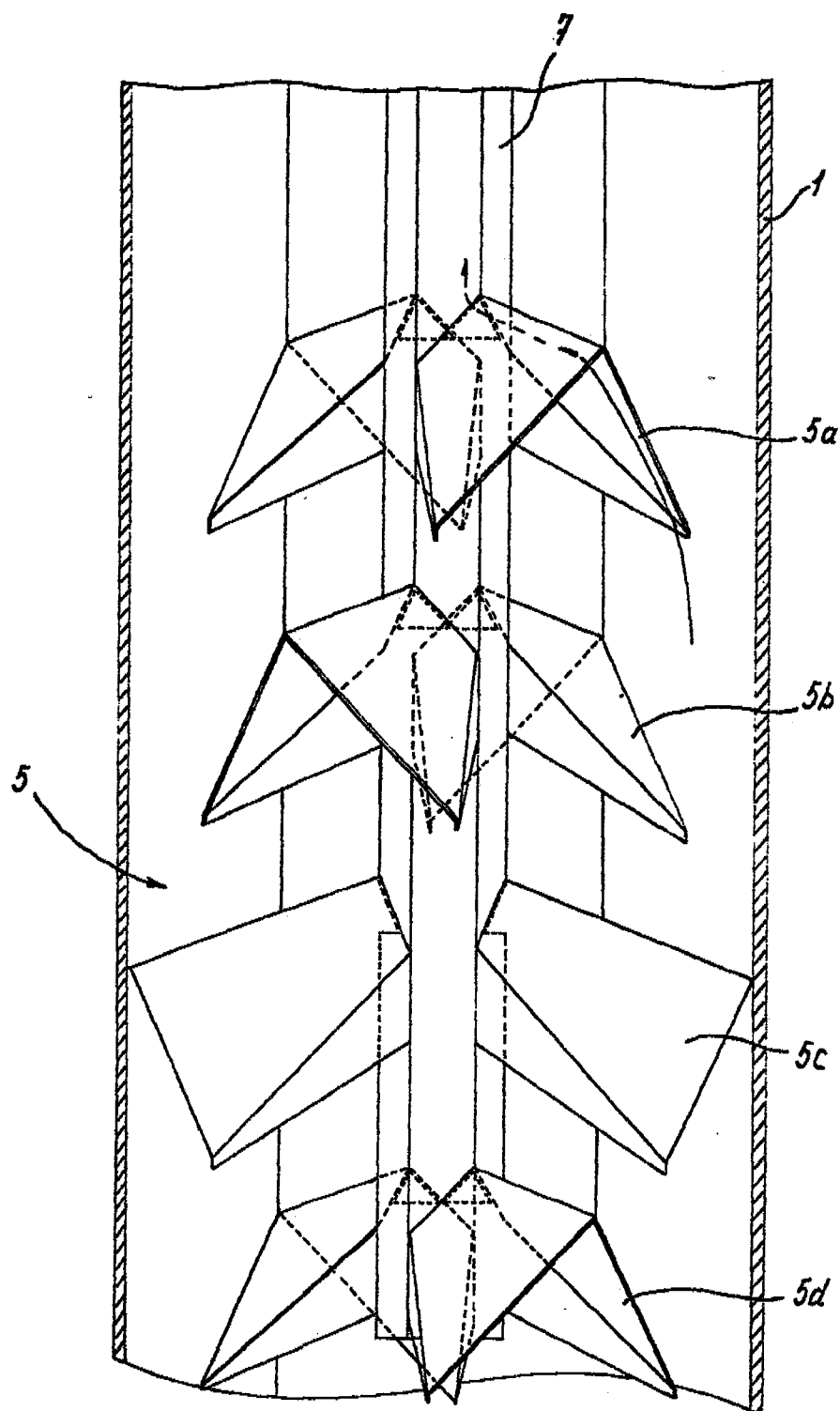


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fig-2



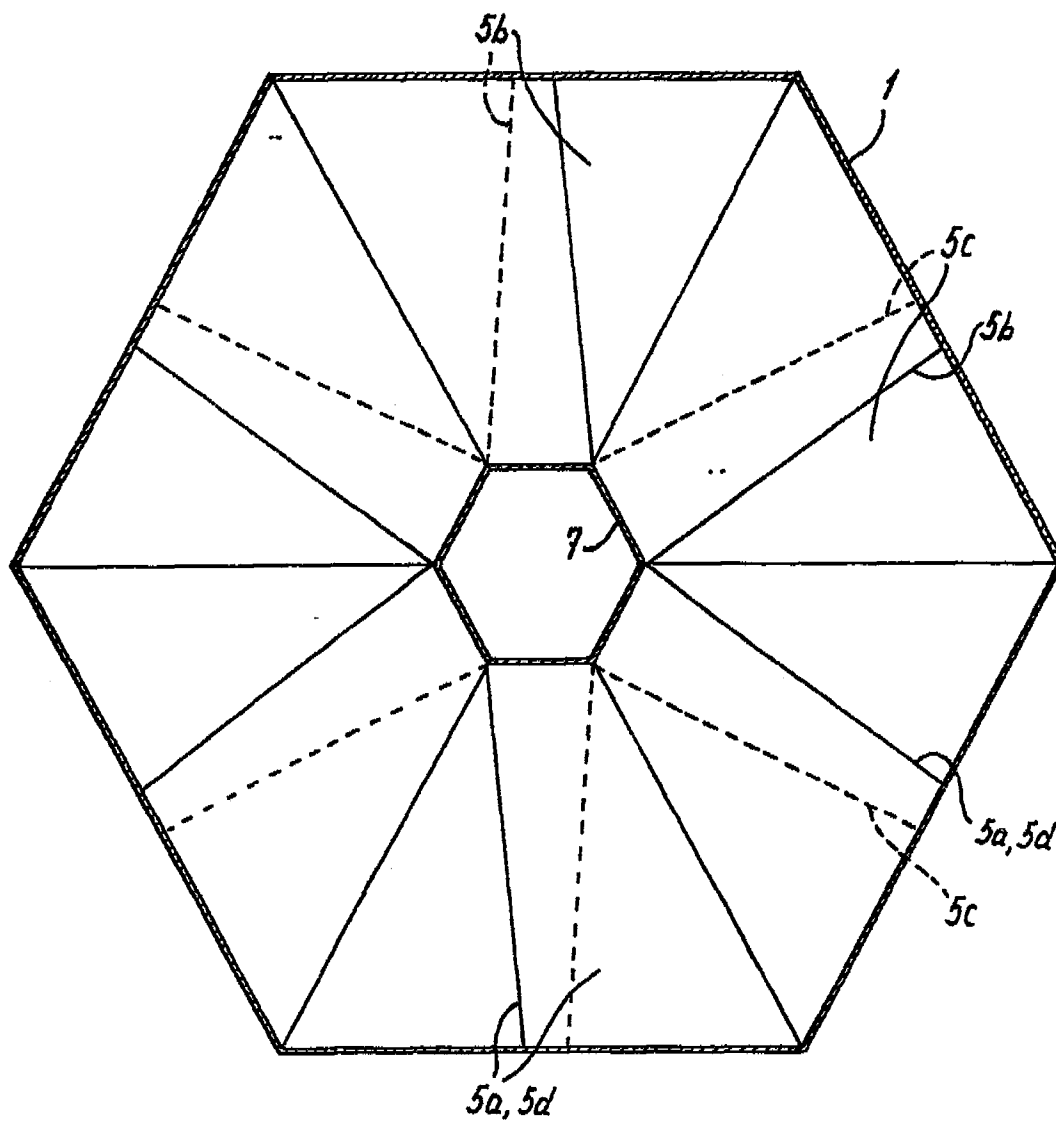
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fig - 3



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fig-4

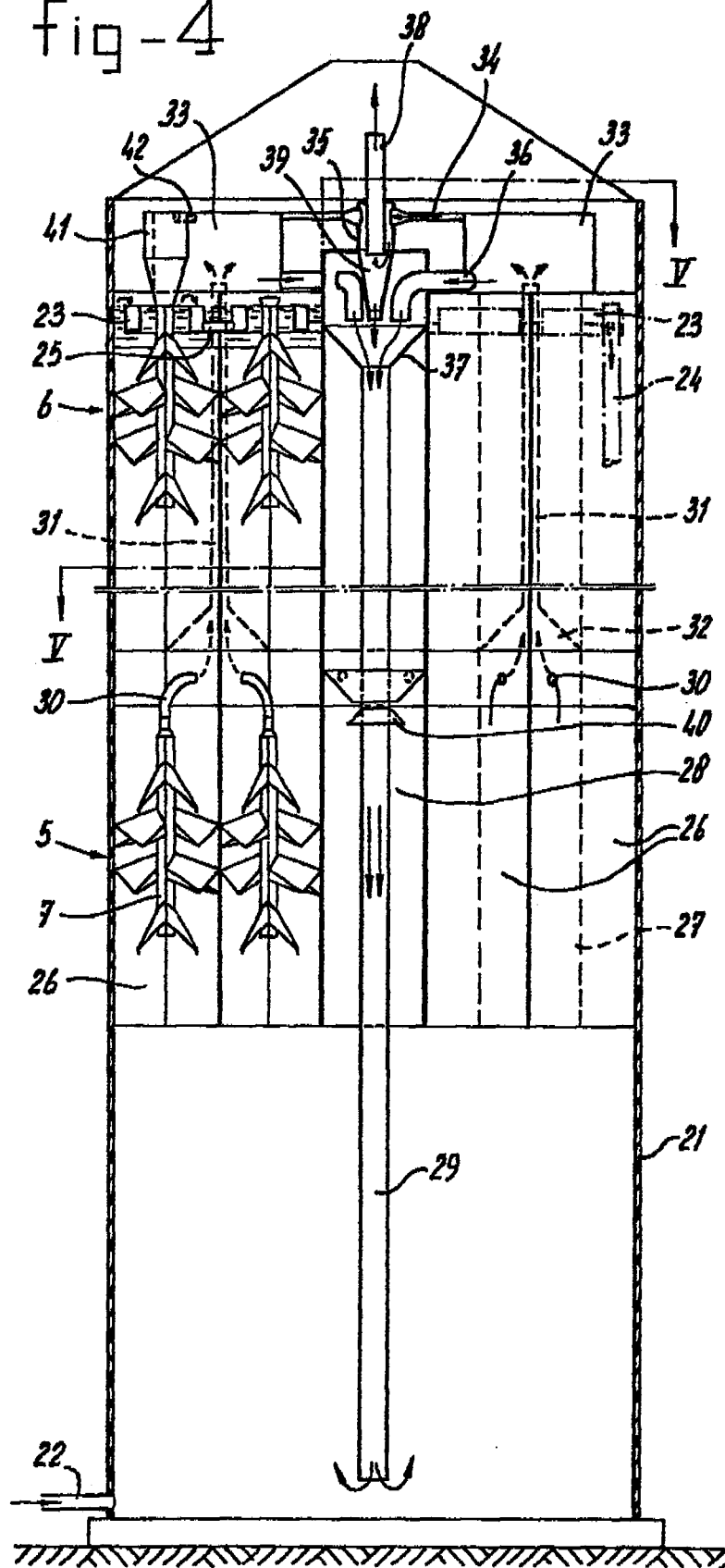
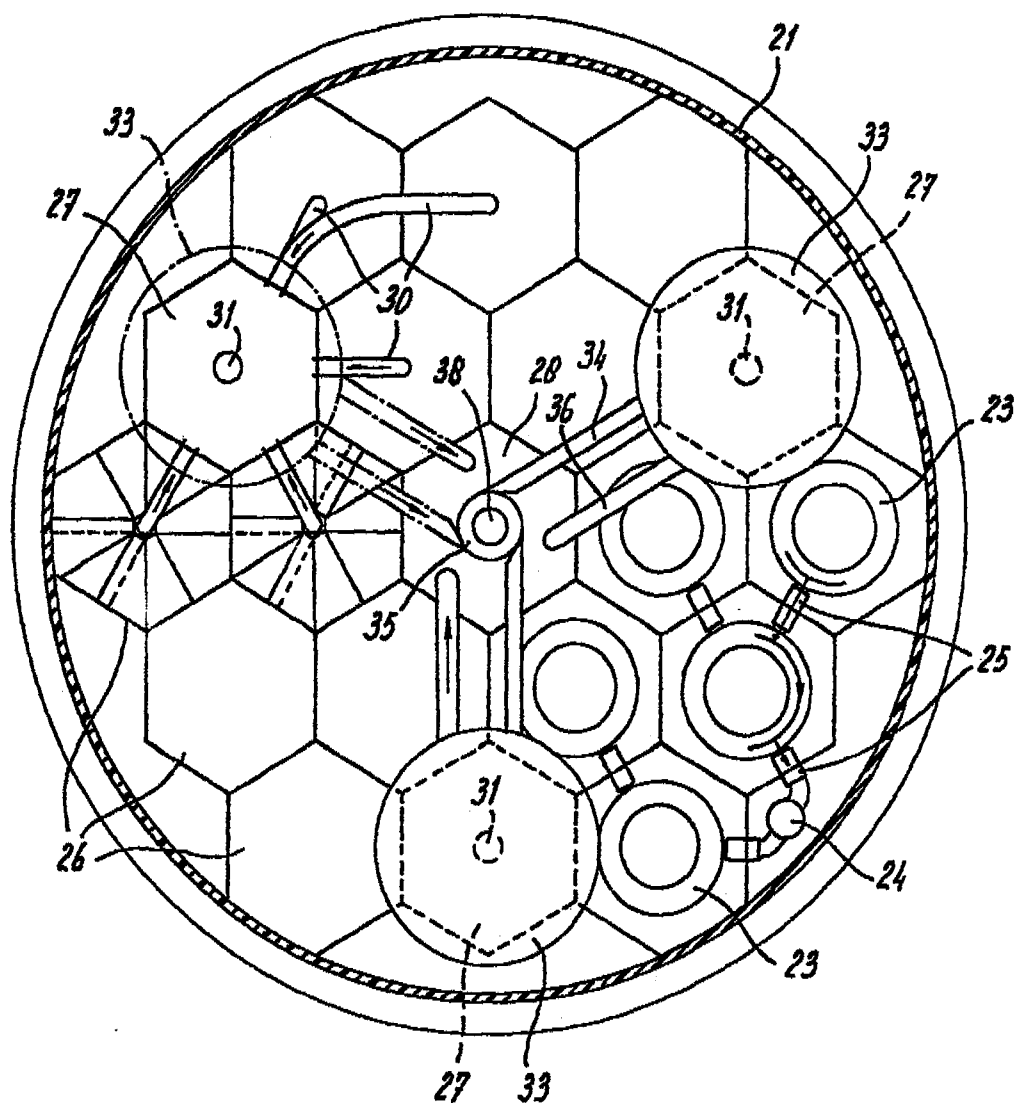


fig-5





European Patent
Office

EUROPEAN SEARCH REPORT

Application number
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EP 85 20 1216

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 4)
A	AT-B- 361 015 (W. WEYMELKA) * Page 2, lines 19-45; page 3, lines 11-16, 26-33 *	1, 2, 5	C 02 F 3/28
A	DE-A-1 584 857 (ANLAGENBAU-GESELLSCHAFT) * Page 5, paragraph 2; figure 1 *	6	
A	US-A-3 812 029 (MOBIL OIL) * Column 3, lines 71, 72; figures 1, reference 28 *	3	
A	DE-A-3 232 530 (W. SCHRAUFSTETTER) * Pages 24-25; figure 1 *	6	
			TECHNICAL FIELDS SEARCHED (Int. Cl. 4)
			C 02 F C 12 M
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 25-10-1985	Examiner TEPLY J.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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Courier Press, Leamington Spa, England.

EP 0 170 332 B1

Description

The invention relates to an anaerobic purification equipment for waste water comprising a container with a reactor chamber for fermentation, means for introducing influent into the reactor chamber, at least one overflow gutter for collecting purified water by overflow, and fitted below the level of the overflow gutter, a collecting system for collecting and removing gas from the liquid.

First subjecting waste water which contains organic material to a process in which the organic material is broken down into substances soluble in water, in particular fatty acids and then treating the water pretreated in this manner under anaerobic conditions by contact with granular sludge which contains methane-producing microorganisms, methane being produced which is separated from the liquid which still contains sludge, is known. The treated water (effluent) is removed via overflows. For the anaerobic fermentation the theoretical residence time of the liquid in the reactor is determined by the hydraulic flow in conjunction with the total capacity of the equipment including the settling chamber. The optimum residence time of the liquid in the reactor is determined, provided there is sufficient sludge present, among others by the COD concentration of the waste water. It has been found that with a residence time of several hours a purification of as much as 90% can be reached. The extent to which such a purification efficiency can be maintained over a long period also depends on the sludge retention. In particular, care must be taken to ensure that on average no more sludge is rinsed out of the reactor than can be formed in a certain period of time. If a high hydraulic flow is used with a low COD concentration in the influent, there is a considerable risk that the internal settler will not be capable of preventing a large amount of sludge being flushed out. A factor which is of importance in this connection is the hydraulic surface loading of the settler.

Because there is a difference in density between the settled sludge mass in the settling chamber and the mixture of sludge particles, waste water and small gas bubbles in a reactor, the settled mass is partially stirred up. As a result of the turbulence produced by this in the uppermost part of the reactor an excessive quantity of sludge will be flushed out of the reactor. To this must be added the fact that so much methane has penetrated into a portion of the sludge grains that the grains have become lighter than the ambient liquid. This limits the load capacity of the reactor to a considerable extent.

From Dutch Patent Application 82.01293 it is known that the "gas-lifting recirculation" of the settled mass can be controlled by creating an overpressure in the gas-collecting chamber. According to this publication the overpressure required for this is at most 30% of the static pressure in the reactor. This measure therefore

prevents a portion of the settled mass being removed with the overflow as a result of uncontrolled gas evolution. A disadvantage of this method is that as a result of the implementation of this type of method, installations are required which withstand pressure, and this entails a considerable increase in the cost price.

The invention aims to overcome the disadvantages described above and to create a reactor of the type mentioned in the introduction in which a good control of the gas-lifting effect can be achieved without overpressure being produced in the reactor.

According to the invention for this purpose at least one additional collecting system for collecting gas and buoyant sludge is fitted at a distance below the first-named collecting system which additional system has a hydraulic link with at least one rising pipe for raising the liquid sludge mixture by gas lift action, said rising pipe discharging into a separation device for separating gas and liquid.

In view of the fact that gas and buoyant sludge are trapped at a considerable distance below the liquid level and are conveyed further via the said rising pipe or rising pipes, an essentially turbulence-free flow can occur in the uppermost section of the reactor. This increases the load capacity. At the top clean effluent is obtained.

It is of importance that the buoyant sludge which is carried along with the gas to the rising pipe or rising pipes is separated and returned to the reactor. While a quiet, eddy-free flow is required at the top of the reactor, good mixture of sludge and fluid will be required at the bottom of the reactor. For this purpose the heavy sludge has to be fluidised.

In a preferred embodiment according to the invention this fluidisation can be achieved in the bottom section of the reactor with the aid of the energy from the gas lifting in the rising pipe or rising pipes described provided that from said separation chamber at least one downpipe for returning separated liquid and sludge extends to the bottom section of the reactor chamber.

The gas will have to be freed from the entrained foam. For this purpose use can be made of a defoamer for separating gas and foam, which defoamer is connected to a separation device and has an outlet connection for separated liquid to the said downpipe.

It is preferable that the first-named collecting system is also connected to the said separation device.

The additional collecting system will have to collect the gas and the buoyant sludge as completely as possible and will have to carry it off to the rising pipe or rising pipes without the rising liquid being excessively accelerated by constriction of the cross-section. In particular, such an acceleration would per se cause disturbance in the uppermost section of the reactor. According to the invention this is catered for by the fact that at least the said additional collecting system has a number of hoods arranged in layers, the hoods in

each layer having a certain offset in relation to the hoods of a subsequent layer and that the cross-sectional area occupied by the hoods in one layer is at most 55% of the total cross-sectional area.

Within a relatively large reactor container the various pipes can be accommodated in a space-saving manner if within the container there is a number of said rising pipes which alternate with pipes provided by said collecting systems for conveying the purified liquid to an overflow gutter and with at least one downpipe, the various pipes being hexagonal and adjoining each other in a honeycomb pattern.

The invention will now be explained in more detail by reference to the figures in which two exemplary embodiments are shown more or less diagrammatically.

Figure 1 shows a vertical section of the first embodiment.

Figure 2 shows on a larger scale a detail of the collecting system, of this embodiment, for collecting gas and buoyant sludge.

Figure 3 shows a plan view of the collecting system according to Figure 2.

Figure 4 shows a vertical section of a second embodiment.

Figure 5 shows a horizontal section along the line V—V in Figure 4.

The anaerobic purification equipment shown in Figures 1—3 comprises a tall container 1 into the bottom end of which there discharges an inlet 2 for influent. Near the upper rim of the container effluent gutters 3 are fitted which are connected to a drain pipe 4. Within the container two collecting systems 5 and 6 for gas and buoyant sludge are fitted, each consisting of hoods fitted at four levels 5a, b, c, d and 6a, b, c, d respectively which to some extent slope in the direction of a central rising pipe 7.

During operation fermentation takes place particularly in the bottom section of the reactor under anaerobic conditions as a result of contact between sludge grains and substances soluble in water such as fatty acids, methane being formed. A portion of the sludge grains absorb so much methane that they become lighter than the ambient fluid. In order to achieve a quiet, turbulence-free flow in the uppermost part of the reactor and to ensure that virtually no sludge is carried off with the effluent, there is fitted at a level, which is at a substantial distance below the overflow gutters 3, a collecting system which guides the gas and the buoyant sludge into the rising pipe 7. In the pipe 7 the gas and sludge collected by the system 5 end up in a constricted section of pipe 7' which is fitted inside the unconstricted section of pipe 7. The collecting system 6 guides the collected gas and possibly some foam into the unconstricted section of pipe 7. Both the sections 7 and 7' discharge into a separation chamber 8 where liquid and gas are separated from each other. Liquid gathers at the bottom of the separation chamber 8 and flows via a downpipe 9 to the bottom section of the reactor. A pipe 12 extends between the separation

chamber 8 and a defoamer 11 in which sludge and liquid are separated from gas. Liquid with sludge is guided to the downpipe 9 through pipe 10.

As a result of the fact that the gas has been removed from it, the liquid column in the pipe 9 is heavier than the ambient liquid in the reactor 1. This means that a fairly powerful downward flow is produced in the downpipe 9 which stirs up the relatively heavy sludge at the bottom of the reactor. In addition, separated sludge is returned to the bottom section of the reactor. In a simple way the effect is therefore achieved that tranquility prevails at the top of the reactor and heavy sludge and influent at the bottom of the reactor are thoroughly mixed by turbulence.

The construction of the collecting systems 5 and 6 is such that accelerations of the flow by constrictions of the cross-section are to a large extent limited. Figures 2 and 3 show that in each of the layers 5a, 5b, 5c and 5d two gas hoods are fitted, the two gas hoods in each level occupying less than half the cross-sectional area. The hoods of successive layer overlap each other and the hoods of the four layers together cover the whole cross-sectional area. The cross-sectional area of the reactor occupied by the hoods of a single layer should not be more than 55% of the total cross-section and preferably less (for example, less than 50%). The outlines of the various hoods are indicated in Figure 3 by the reference figure of the layer concerned.

It is possible to combine a number of embodiments according to figures 1, 2 and 3 into a big reactor container.

Figures 4 and 5 show a second embodiment in which the reactor has a much larger cross-sectional area and is filled with a large number of hexagonal pipes. The reactor container is indicated by 21, the influent inlet by 22, annular effluent gutters by 23 and the main drain for effluent by 24. The gutters 23 and the main drain 24 are connected to each other by pipes 25.

Within the container there are arranged approximately fifteen hexagonal reactor pipes 26, three combined hexagonal rising pipes 27, and a central hexagonal pipe 28. In this last-named is mounted a downpipe 29 which, in contrast to the hexagonal pipes 26, 27 and 28, extends almost to the bottom of the reactor 21. The pipes 26, 27 and 28 are arranged in a honeycomb pattern.

In each of the reactor pipes 26 there are gas-collecting systems 5, 6 at two levels. These have the same construction and position in relation to each other as described in connection with Figures 1, 2 and 3. The gas-collecting systems 5 at the relatively low level guide the collected gas and buoyant sludge to a rising pipe 7 which narrows connection pipe 30. One or more connection pipes 30 are connected to a combined rising pipe 27. In the combined rising pipe 27 there is accommodated a pipe 31 of considerably smaller cross-section which is joined to the pipe 27 by an adaptor 32. Each of the three pipes 31 discharges at its upper rim into a separation chamber 33, the

three chambers 33 being connected via connecting pipes 34 to a defoamer 35 and connected via connecting pipes 36 to a funnel 37 into which the central downpipe 29 debouches. The defoamer has a gas outlet 38 and a liquid drain 39.

Also pipe 28 has a gas collecting system 40 collecting gas bubbles and guiding gas to a rising pipe. Pipe 28 is closed above system 40.

The gas-collecting systems 6 are located in each of the reactor pipes 26 immediately below the annular overflow gutters 24 for effluent. These systems collect the residual gas and foam and guide them to a rising pipe 7 which debouches into a gas-liquid separator 41. The fluid separated in the latter is conveyed via pipes 42 and a combined chamber 33 to the downpipe 29. The gas obtained is combined with the gas from the defoamer 35.

In this reactor, which is more complicated compared with Figures 1, 2 and 3, the effect is also achieved that gas and buoyant sludge are removed from the reactor pipes 26 at a relatively low level via the collecting systems 5 and the pipes 27, 32, 21 so that in the uppermost part of the reactor pipes 26 tranquillity prevails and effluent containing virtually no sludge can flow into the gutters 23. In addition, the heavy sludge at the bottom of the reactor will be stirred up by the relatively heavy liquid which flows downwards from the combined funnel 37 through the downpipe 29. The mixing of influent and sludge is considerably improved as a result. The excess and even dangerous kinetic potential energy of the gas in the uppermost regions of the reactor is used to bring about the necessary mixing and fluidisation in the bottom regions.

Within the scope of the invention various modifications are possible. The embodiments drawn and described are only examples. All the embodiments have in common that a significant portion of the gas evolved during the fermentation and the buoyant sludge are collected before they can reach the uppermost section of the reactor and that the liquid propelled up in this process by the gas-lifting action is separated from gas and the potential energy of the relatively heavy liquid column is used via a recirculating flow to obtain the stirring necessary for a thorough mixing and fluidisation at the bottom of the reactor. Power present at the top of the reactor is taken to the bottom. The load capacity of the reactor is considerably increased as a result of the tranquillity at the top and the turbulence at the bottom. The special construction of the overlapping gas hoods off-set in layers results in a good collection of gas and buoyant sludge without noticeable accelerations of the liquid.

Claims

1. Anaerobic purification equipment for waste water comprising a container with a reactor chamber for fermentation, means for introducing influent into the reactor chamber, at least one overflow gutter for collecting purified water by overflow, and, fitted below the level of the over-

flow gutter, a collecting system for collecting and removing gas from the liquid, characterised in that at least one additional collecting system (5) for collecting gas and buoyant sludge is fitted at a distance below the first-named collecting system (6), which additional system (5) has a hydraulic link with at least one rising pipe (7, 7', 27, 32, 31) for raising the liquid-sludge mixture by gas lift action, said rising pipe discharging into a separation device (8; 33) for separating gas and liquid.

2. Anaerobic purification equipment according to claim 1, characterised in that from said separation device (8; 33) at least one downpipe (9; 29) for returning separated liquid and sludge extends to the bottom section of the reactor chamber.

3. Anaerobic purification equipment according to claim 2, characterised in that a defoamer (11; 35) for separating gas and foam is connected to the separation device (8; 33), which defoamer has an outlet connection for separated liquid to the said downpipe (9; 29).

4. Anaerobic purification equipment according to claim 2 or 3, characterised in that the first-named collecting system (6) is also linked to the said separation device (8; 33).

5. Anaerobic purification equipment according to one of the preceding claims, characterised in that at least the said additional collecting system (5) has a number of hoods arranged in layers, the hoods in each layer having a certain offset in relation to the hoods of a subsequent layer and the cross-section occupied by the hoods in a layer being at most 55% of the total cross-sectional area.

6. Anaerobic purification equipment according to one of the preceding claims, characterised in that within the container (1) there are a number of combined rising pipes (27), which alternate with the pipes (26) provided by the said collecting systems (5, 6), for conveying purified liquid to an overflow gutter (23) and with at least one pipe (28) for a down flow, the various pipes (26, 27, 28) being hexagonal and adjoining each other in a honeycomb pattern.

Patentansprüche

1. Anaerobe Reinigungseinrichtung für Abwasser, mit einem Behälter mit einer Reaktionskammer für die Gärung, mit einem Zulauf für die Einspeisung des Einlaufgutes in die Reaktionskammer, mit zumindest einer Überlaufrinne, zum Auffangen gereinigten Wassers im Überlauf, und mit einem unterhalb der Ebene der Überlaufrinne angeordneten Sammelsystem zur Sammlung und Abführung von Gas aus der Flüssigkeit, dadurch gekennzeichnet, daß zumindest ein zusätzliches Sammelsystem (5) zur Sammlung von Gas und schwimmfähigem Schlamm im Abstand unterhalb von dem erstgenannten Sammelsystem (6) angeordnet ist und in Strömungsverbindung steht mit zumindest einer Steigleitung (7, 7', 27, 32, 31), um die flüssige Schlammischung durch eine Art Gasheber anzuheben, wobei die genannte Steigleitung in eine Gas und Flüssigkeit

voneinander trennende Trenneinrichtung (8; 33) mündet.

2. Reinigungseinrichtung nach Anspruch 1, dadurch gekennzeichnet, daß sich von der genannten Trenneinrichtung (8; 33) zum Boden der Reaktionskammer zumindest ein Fallrohr (9; 29) erstreckt für die Rückführung der getrennten Phasen Flüssigkeit und Schlamm.

3. Reinigungseinrichtung nach Anspruch 2, dadurch gekennzeichnet, daß an die Trenneinrichtung (8; 33) eine Antischaumeinrichtung (11; 35) zur Trennung von Gas und Schaum angeschlossen ist, und daß diese Antischaumeinrichtung für die abgetrennte Flüssigkeit eine Auslaßverbindung mit dem genannten Fallrohr (9; 29) aufweist.

4. Reinigungseinrichtung nach Anspruch 2 oder 3, dadurch gekennzeichnet, daß das erstgenannte Sammelsystem (6) auch an die genannte Trenneinrichtung (8; 33) angeschlossen ist.

5. Reinigungseinrichtung nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß zumindest das genannte zusätzliche Sammelsystem (5) mehrere etagenförmig übereinander angeordnete Hauben aufweist, wobei die Hauben jeder Etage gegenüber den Hauben einer folgenden Etage umfangsversetzt sind, und wobei der von den Hauben einer Etage abgedeckte Querschnitt maximal 55% des gesamten Querschnittsbereiches umfaßt.

6. Reinigungseinrichtung nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß im Behälter (1) mehrere zusammengefaßte Steigleitungen (27) vorgesehen sind, die mit Leitungen (26) alternieren, die mit den genannten Sammel-systemen (5, 6) ausgestattet sind, um gereinigte Flüssigkeit zu einer Überlaufrinne (23) zu leiten, und mit zumindest einer Leitung (28) für einen Abfluß, wobei die verschiedenen Leitungen (26, 27, 28) sechseckig sind und aneinander angrenzen entsprechend einem Bienenwabenmuster.

Revendications

1. Equipement d'épuration anaérobie d'eau résiduaire, comprenant une enceinte à chambre de réaction destinée à la fermentation, des moyens pour introduire l'affluent dans la chambre de réaction, au moins une gouttière de trop-plein pour recueillir l'eau épurée par trop-plein, et, fixé au-dessous du niveau de la gouttière de

trop-plein, un système collecteur pour recueillir et éliminer les gaz du liquide, caractérisé en ce qu'au moins un système collecteur additionnel (5) pour recueillir les gaz et les boues flottantes est fixé à une certaine distance au-dessous du système collecteur (6) premièrement mentionné, lequel système additionnel (5) comporte une liaison hydraulique avec au moins un tuyau de montée (7, 7', 27, 32, 31) pour élever le mélange de liquide et de boue par effet d'aspiration, ledit tuyau de montée débouchant dans un dispositif de séparation (8; 33) pour séparer le gaz et le liquide.

2. Equipement d'épuration anaérobie selon la revendication 1, caractérisé en ce qu'au moins un tuyau de descente (9; 29) destiné à ramener le liquide et la boue séparés s'étend jusqu'à la section inférieure de la chambre de réaction.

3. Equipement d'épuration anaérobie selon la revendication 2, caractérisé en ce qu'un démousseur (11; 35) destiné à séparer le gaz et la mousse est relié au dispositif de séparation (8; 33), lequel démousseur présente une connexion de sortie destinée à renvoyer le liquide séparé audit tuyau de descente (9; 29).

4. Equipement d'épuration anaérobie selon la revendication 2 ou 3, caractérisé en ce que le système collecteur (6) premièrement mentionné est également relié audit dispositif de séparation (8; 33).

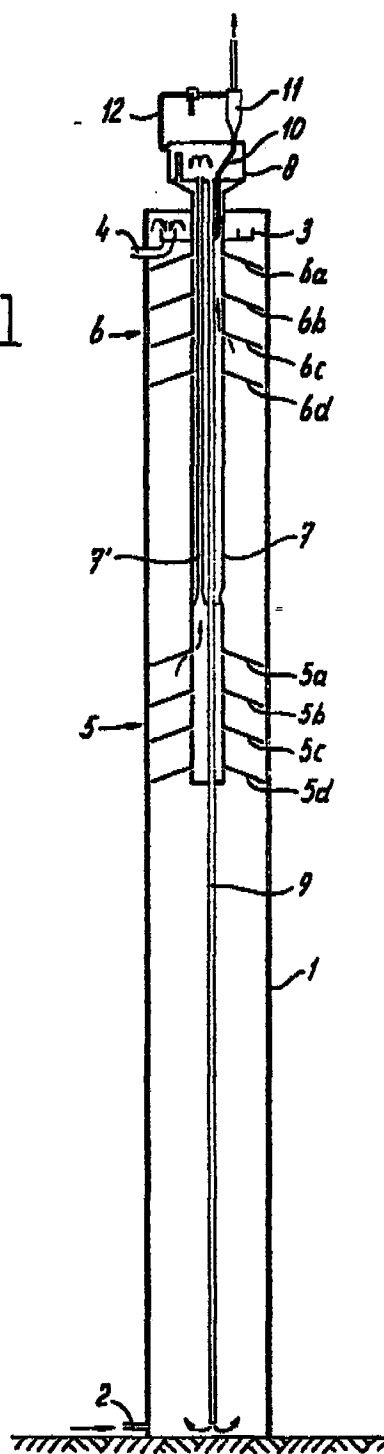
5. Equipement d'épuration anaérobie selon l'une quelconque des revendications précédentes, caractérisé en ce que ledit système collecteur additionnel (5) au moins comprend un certain nombre de capots disposés en couches, les capots de chaque couche présentant un certain décalage par rapport aux capots d'une couche subséquente, et la section transversale occupée par les capots d'une couche étant au maximum de 55% de l'aire de surface totale.

6. Equipement d'épuration anaérobie selon l'une quelconque des revendications précédentes, caractérisé en ce qu'un certain nombre de tuyaux de montée combinés (27) sont prévus dans l'enceinte (1), qui alternent avec les tuyaux (26) appartenant auxdits systèmes collecteurs (5, 6) en vue d'acheminer le liquide épuré vers une gouttière de trop-plein (23) et avec au moins un tuyau (28) pour un courant descendant, les divers tuyaux (26, 27, 28) étant hexagonaux et voisins les uns des autres en formant un ensemble en nid d'abeilles.

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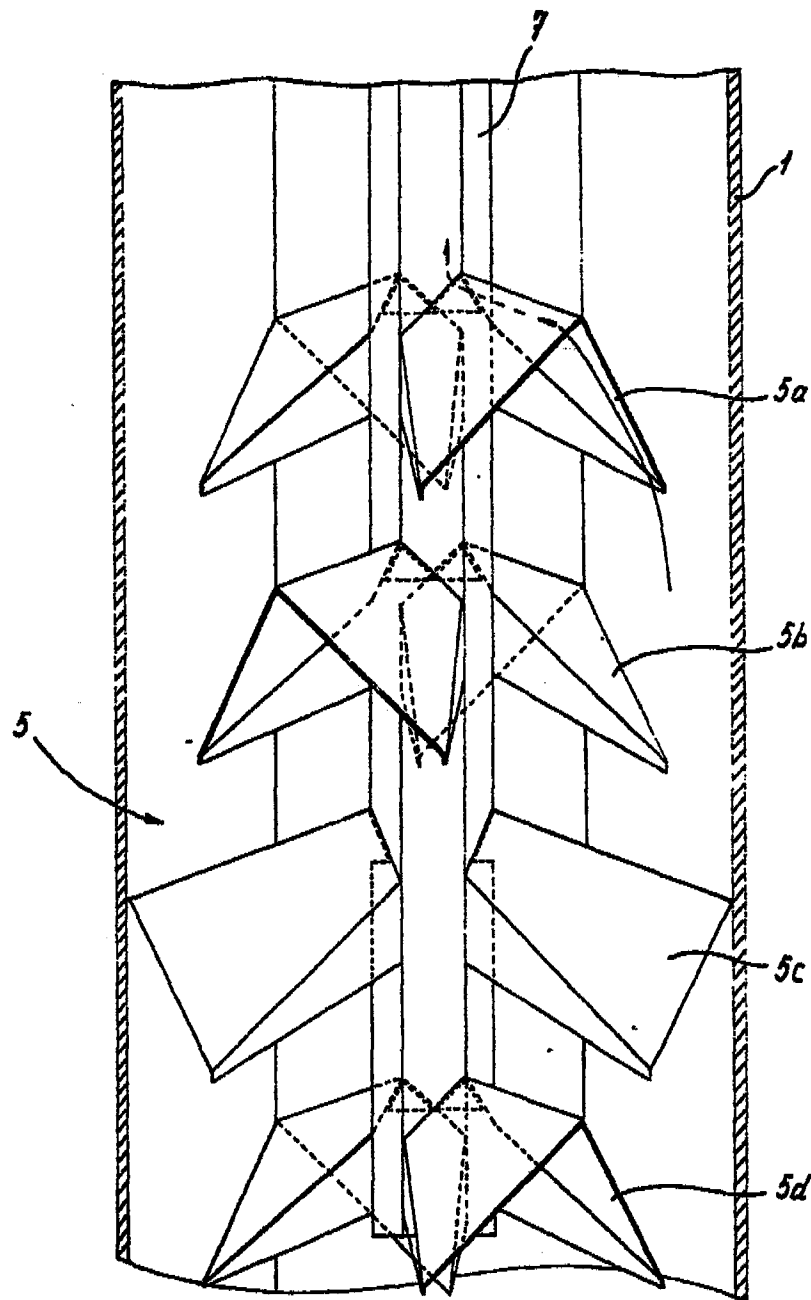
fig-1



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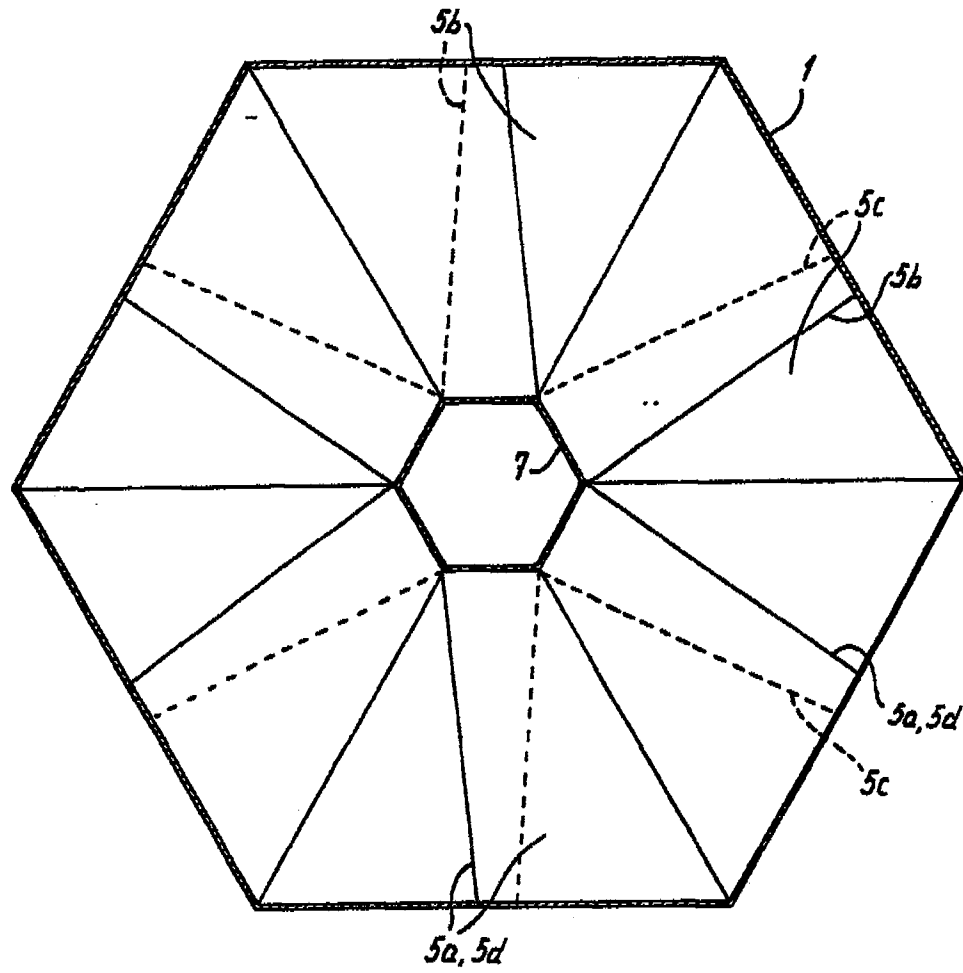
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fig-2



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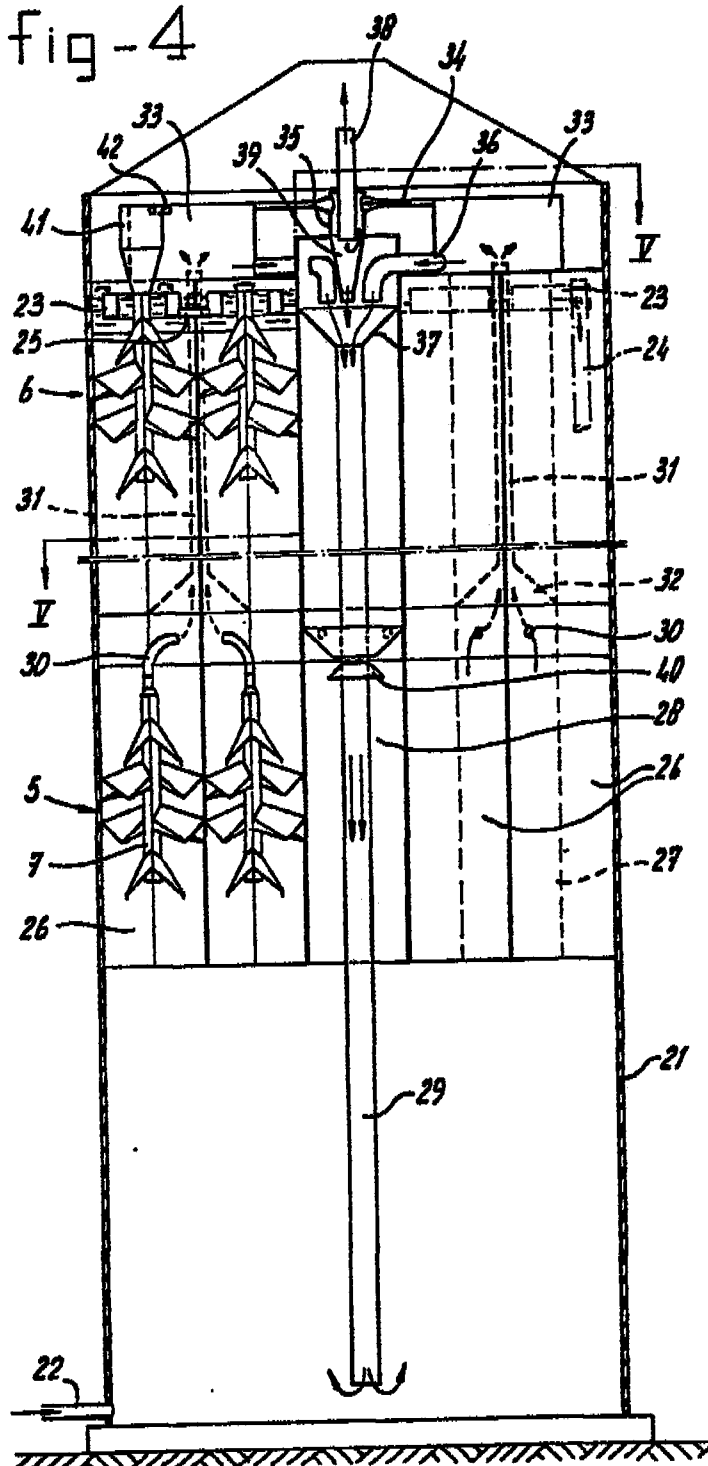
fig - 3



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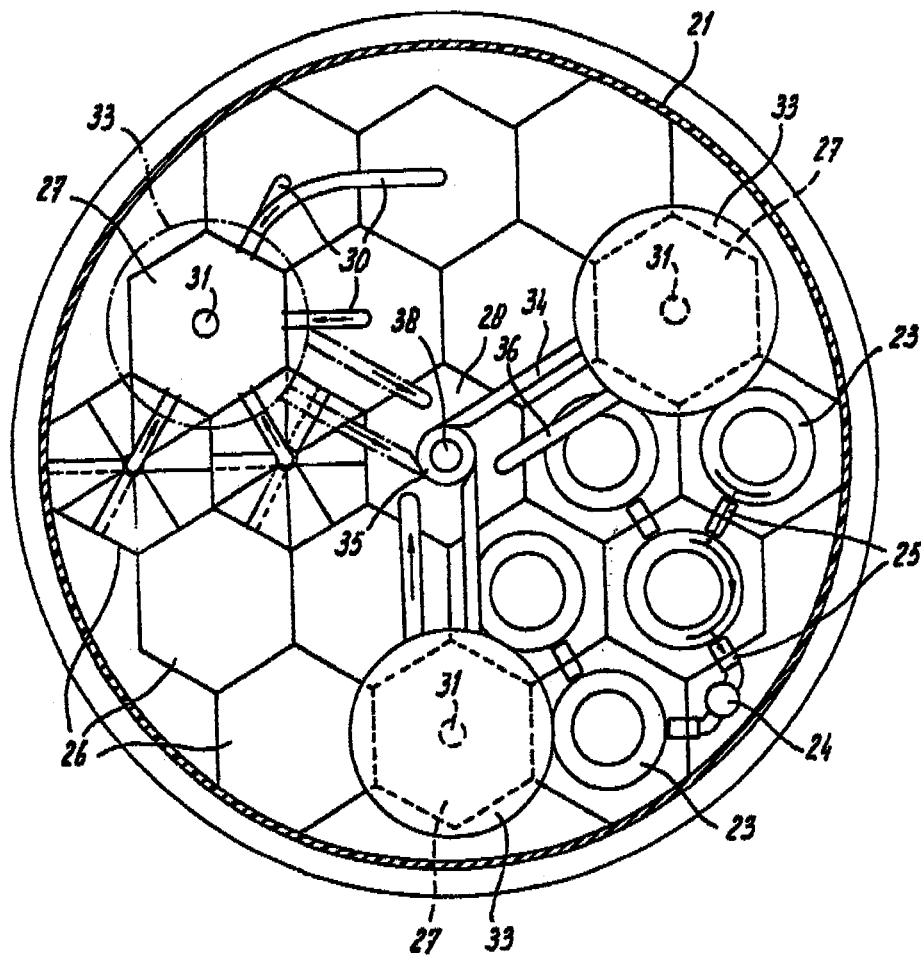
fig-4



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fig-5



BIOLOGICAL TREATMENT PROCESS

FIELD OF INVENTION

[0001] This invention relates to anaerobic and anaerobic-aerobic processes conducted in stacked sections, and particularly concerned with mixing, separation and collection of digestion gases, generation of methane-rich digestion gases, and solid-liquid separation in stacked reactors.

PRIOR ART

[0002] A stacked two-stage anaerobic reactor for treatment of liquid wastewater have been disclosed by Vellinga in U.S. Pat. No. 4,609,460, stacked anaerobic-aerobic reactors for treatment of liquid wastewater and for considerably viscous wastewater sludges have been disclosed by Khudenko in U.S. Pat. Nos. 5,514,277 and 5,616,241, and by Habets et.al. in U.S. Pat. Nos. 5,972,219 and 6,063,273. The described methods and apparatus address passive mixing of liquid wastewater by digestion gases and separation of the treated liquid from the sludge due to gravity in fluidized beds with granular sludge and in quiescent settling devices as commonly used for liquid wastewater. Khudenko also teaches how to produce digestion gas substantially free from hydrogen sulfide. Passive mixing in fluidized beds are described by Khudenko in U.S. Pat. No. 4,472,358, by Vellinga in U.S. Pat. No. 4,609,460, and by Habets in U.S. Pat. No. 6,03,273. Passive mixing of viscous sludges is described in by Khudenko in U.S. Pat. No. 4,472,358 and by Edwards in U.S. Pat. No. 5,441,634. Active mixing in fluidized beds by recycling effluent with pumps is well known. The problems of such recycling are as follows: it is very difficult to produce uniform or other predetermined distribution of flows with multiple suction ports and a single pump or a single header and several pumps, use of multiple pumps is complex, it is difficult to select pumps with very low head as needed for most mixing applications because such pumps are not made, pipelines are large and require many turns, many control valves are required, electrical part for the system of many pumps becomes complex, sludge flocks and granules break up in pumps and pipelines with multiple turns. Active mixing with various submersible propeller mixers is also known. Propeller mixers have problems similar to those of pumps. One active system of airlift-mixers for fluidized beds is described by Khudenko in U.S. Pat. No. 6,048,459 and for fluidized beds and viscous sludges in a co-pending patent application. A method of providing pH and alkalinity control with an additional benefit of generating methane-rich digestion gas virtually free from hydrogen sulfide is described by Khudenko in U.S. Pat. No. 5,798,043. None of these technologies provides for collection of treated methane-rich digestion gas under pressure, an option that would greatly improve conditions for utilization of this gas instead of flaring it. Collection of the digestion gas can be further improved if the reactors are made taller. Above-ground reactors, or conventional at least partially in-ground reactors are usually limited in height by about 25 meters, and sometimes somewhat taller.

[0003] U.S. Pat. Nos. 4,217,211, 4,251,361, 4,253,949, 4,287,070, 4,374,027, 4,466,928, 4,477,393, 5,503,748, 5,650,070, 5,651,892, 5,645,726, 5,660,724, 6,214,228 B1, Re. 30,944 describe a variety of aerobic and otherwise aerated treatment systems making use of airlift-aerators for the combined purposes of aerating and mixing. These sys-

tems have an advantage of a very deep reactor of up to 150-200 meters deep. Such system can be very economical for conducting thermophilic processes, which present great advantages in both the process rate and the degree of treatment. The use of combined anaerobic-aerobic systems, especially with sludges of both anaerobic and aerobic steps being at least partially mixed further significantly improves the performance.

[0004] Accordingly, the main objective of the present invention is to provide a stacked anaerobic-aerobic process with active controllable mixing of either fluidized beds or viscous sludges in reactors.

[0005] Another objective of the present invention is to generate and collect under pressure a methane-rich clean digestion gas.

[0006] Another objective of the present invention is to provide a simple and economical way of separating solids and liquid in treatment processes, while increasing a quality of the effluent and improving the biological processes in reactors.

[0007] Yet another objective of the present invention is to increase the biological process rate and degree of treatment.

[0008] Other objectives will become apparent from the ensuing description of the invention.

SUMMARY OF INVENTION

[0009] This is a method of biological treatment of wastewater with biomass. Wastewater and biomass form mixed liquor. Preferably, a tall reactor is used, for example, predominantly in-ground deep shaft reactor, or above ground column type reactors of a substantial height, much greater than conventional 3-4.5 m. The reactor has a closed or open top, a bottom, and an essentially horizontal partition between the top and the bottom. Depending on the technological (treatment related) and structural requirements, the partition can be flat, conical, pyramidal, or curvilinear, convex or concave, or of other shape. The main process steps comprise (a) at least one anaerobic treatment step conducted between the bottom and the partition, a digestion gas comprising methane and carbon dioxide is formed in the anaerobic treatment, (b) a step of mixing said mixed liquor in said anaerobic step by at least one controllable gaslift with a gas other than the digestion gas. At least one step of treatment of wastewater can be conducted between the partition and top of said reactor. The organic loaded waste can be water, wastewater, wastewater sludge, hazardous waste, manure, guano, industrial waste, agricultural waste, polluted soils, contents of polluted ponds and lagoons, and combinations thereof. These mixing steps are very effective not only for treatment of wastewater with dilute biomass but also for treatment of thicker sludges or wastewater with high content of biomass. This method is also more convenient than mixing with digestion gases: there is no corrosion of equipment by digestion gas impurities, no gas leak and fire problems. Unlike with other mixing systems, critical equipment (everything but the submerged pipes) can be open to the atmosphere and is easy to operate, repair, and replace.

[0010] The controllable gaslift lifts the mixed liquor from at least one location between the bottom and the partition to the uppermost point of said controllable gaslift and returns said mixed liquor in said anaerobic treatment step. The

lifting and returning constitute a lifting-returning operation step effecting said mixing. Usually, the most convenient uppermost point of the gaslift is above the top of the reactor. However, this point can be at any elevation from the intake or discharge level of the gaslift, whichever is higher, to the top of the reactor. The lifting-returning operation step can include a nonreversible flow in airlift pipes, reversible flow, when the same pipe is used, first, to lift liquid and then to return it back, continuous flow meaning a constant flow rate all the time, discontinuous flow, a flow through a riser-downcomer pipe, a flow through a system of stacked contracting-expanding zones, for example stacked cones forming a virtual pipe which is a nonconfined hydraulic stream within the liquid volume, periodic flow, for example on/off flow or stepwise changing flow, and combinations thereof. Gas other than the digestion gas can be an oxidizing gas, oxygen, air, oxides of nitrogen, nitrogen, and combinations thereof. The oxidizing gas provides oxidizing reactions in the mixed liquor, whereby the mixed liquor is heated. The oxidizing reactions can be biological reactions, abiotic reactions, and combinations thereof.

[0011] Stripping carbon dioxide from the mixed liquor in the anaerobic treatment step can also be provided. Stripping carbon dioxide can be done by gas stripping, oxygen stripping, air stripping, nitrogen stripping, steam stripping, vacuum-stripping, vacuum-vapor-stripping, vacuum-vapor-stripping with steam recompression and condensation, vacuum-vapor-stripping with steam recompression and condensation with preheating the influent, vacuum-vapor-stripping with steam recompression and condensation with heating the contents of said reactor, heat degassing, and combinations thereof.

[0012] The method also provides steps of vaporization of wastewater from the mixed liquor with production of a low pressure steam. This steam is condensed and becomes the treated effluent. The vaporization method can be vaporization by preheating the mixed liquor, vaporization by vacuuming the mixed liquor, vaporization by vacuuming the mixed liquor with steam recompression and condensation, vaporization by vacuuming the mixed liquor with steam recompression and condensation and preheating the influent, vaporization by vacuuming the mixed liquor with steam recompression and condensation and preheating the mixed liquor, and combinations thereof.

[0013] The method also provides steps of feeding reagents, for example, recuperable alkaline species, recuperable oxidation-reduction species, alkalies, acids, nutrients, micronutrients, probiotics, and combinations thereof. Recuperable alkaline species help to control pH and alkalinity by creating a carbonate-bicarbonate buffer which is maintained by stripping biologically produced carbon dioxide. Calcium and iron ions are most practicable species. The bulk of these metals is in form of insoluble carbonates or hydroxides at the stage of solid-liquid separation. Recuperable oxidation-reduction species mediate oxidation-reduction of the original organics in the wastewater, intermediate products and the sludge. Iron ions are most practicable oxidation reduction species. They cycle between ferric and ferrous ions, ferric ions are made of ferrous by oxidation with oxygen, nitrates and nitrites, some halogenated organics, and some other species. The bulk of these ions is in form of insoluble hydroxides at the stage of solid-liquid separation. Maintaining elevated alkalinity also produces very low

carbon dioxide concentration in the anaerobic mixed liquor. Accordingly, very high methane content of the harvested digestion gas can be obtained.

[0014] The method also provides for transferring the mixed liquor between anaerobic and other process steps. Additionally, the partition can be a flow-through means capable of collecting the digestion gas and passing through the mixed liquor, or at least partially clarified water. The step of treatment of said wastewater conducted between the partition and the top of the reactor can be an aerobic treatment, an aerobic treatment with aeration by air, an aerobic treatment with aeration by oxygen, an aerobic treatment with nitrification, an aerobic treatment with denitrification, an aerobic treatment with phosphorus removal, an anoxic treatment, a treatment with iron as an intermediate oxidation-reduction specie, an anaerobic hydrolysis treatment, an anaerobic acetogenic treatment, an anaerobic acidogenic treatment, an anaerobic sulfate reduction treatment, an anaerobic methanogenic treatment, and combinations thereof.

[0015] This is also a method of biological treatment of wastewater with biomass, where wastewater and biomass form mixed liquor. Tall reactors are preferably used. The reactor has a top, a bottom, and an essentially horizontal partition between said top and said bottom. The main process steps comprise (a) at least one anaerobic treatment step conducted between said bottom and said partition, a digestion gas comprising methane and carbon dioxide is formed in such anaerobic treatment, (c) at least one step of treatment of wastewater conducted between the partition and the top of the reactor, and (d) collecting digestion gas under the partition, whereby the collected gas is pressurized. The accumulation and the release of the gas from under the partition are controlled such a way that the gas volume under the partition changes between preset maximum and minimum values. This simple task can be performed by a variety of ways well familiar to skilled in art. This process modification can also include step of stripping carbon dioxide from the mixed liquor in the anaerobic treatment step. Stripping can be coupled with maintaining high alkalinity. As previously described, a methane-rich digestion gas results. Collecting methane-rich digestion gas under pressure can reduce the gasholder requirements by an order of magnitude, while doubling or tripling the heat value of the gas. Moreover, this gas is also free from hydrogen sulfide. Accordingly, the gas quality and the convenience of the gas storage greatly increase, thus making the gas utilization (instead of flaring) a very attractive option.

[0016] This is further a method of biological treatment of wastewater with biomass, where wastewater and the biomass form mixed liquor, in a tall reactor, said reactor having a top, a bottom, and an essentially horizontal partition between the top and the bottom, comprising (a) at least one anaerobic treatment step conducted between the bottom and the partition, a digestion gas comprising methane and carbon dioxide is formed in the anaerobic treatment, (c) at least one step of treatment conducted between the partition and the top of the reactor, and (e) at least one step of vaporization-separation of liquid from solids in said mixed liquor, whereby the separated liquid constitutes the treated effluent. The step of vaporization can be vaporization by preheating the mixed liquor, vaporization by bioheating the mixed liquor, vaporization by vacuuming the mixed liquor, vapor-

ization by vacuuming the mixed liquor with steam recompression and condensation, vaporization by vacuuming the mixed liquor with steam recompression and condensation and preheating the influent, vaporization by vacuuming the mixed liquor with steam recompression and condensation and preheating the mixed liquor, and combinations thereof. The bioheating is provided by oxidizing the organics and the biomass with an oxidizer such as oxygen of air, oxygen, iron as intermediate oxidation-reduction specie, and combinations thereof. The method further provides a step of vacuum evacuation of digestion gases from mixed liquor simultaneously with step (e). The of vacuum evacuation of gases can be chemical vacuum evacuation, steam recompression vacuum evacuation, and combinations thereof. Chemical evacuation involves absorption with chemical reaction, for example, absorption of carbon dioxide into an alkaline solution. Steam recompression is a process used mainly in water distillation. It involves a vacuum-compressor (a blower) which pumps water vapors through with a vacuum at the suction side and some pressure at the discharge side. In the present case, the vacuum compressor will pull in under vacuum both, the water vapors and the gases. On the discharge side, water vapor is condensed while gases are separated from water and evacuated for utilization or discharge.

[0017] The method taught in this application can be carried out in a reactor selected from the group of deep shaft reactors, tall above-ground reactors, multi-cell reactors, and combinations thereof. Deep shaft reactors can be as deep as 150-200 m, above ground tanks are from at least 5 to 25 m and possibly taller. Multi-cell tanks are a considerably large footprint reservoirs divided into smaller cells to take advantage of the hydraulics of tall tanks. Either both, the bottom and the top sections or only bottom, or only top sections of multi-cell tank can be divided into cells. Top and bottom cells may also have different dimensions.

DRAWINGS

[0018] FIG. 1 is a stacked reactor with anaerobic stage at the bottom and aerated stage at the top, the reactor is provided with passive and active mixing means and with a pressurized digestion gas collection.

[0019] FIG. 2 is an alternative embodiment of FIG. 1 having multiple active gaslift means.

[0020] FIG. 3 is a bottom section of anaerobic reactor showing a passive means for sludge or fluidized bed mixing and active means in form of a pipe-gaslift with complete absorption of the driving gas.

[0021] FIGS. 4 and 5 are details of the improved passive mixing system.

[0022] FIG. 6 is a bottom section of anaerobic reactor showing a passive means for sludge or fluidized bed mixing and active means in form of a nonconfined gaslift with complete absorption of the driving gas.

[0023] FIG. 7 is a system with a first anaerobic stage and an aerated stage stacked on top of the second anaerobic stage.

[0024] FIG. 8 is a stacked reactor with passive and active mixing means, pressurized gas collection, and a vaporiza-

tion-steam-recompression-heat utilization system for separating effluent from the mixed liquor in the reactor.

[0025] FIG. 9 is an alternative embodiment of that shown in FIG. 8

DETAILED DESCRIPTION OF EMBODIMENTS

[0026] Referring now to FIG. 1, there is shown a reactor 1 having a bottom 100, a top 101, and a partition 66 defining the bottom anaerobic section comprising zones 51a and 51b, 56, and 52 respectively for reaction, at least partial sludge separation, and gas collection. A mixing cone 6 is a passive mixing means. Pipelines 60 and 61 with air (or oxygen, or another nondigestion gas) supply lines 23a and 23b connected to an elevated vessel 71 are the active mixing means. Optionally, vessel 71 is provided with an air line 10 and distributors (not shown) for stripping carbon dioxide. Also optionally, an influent line 8 and lines for feeding reagents 80 (for example, for lime) and 81 (for example, for iron) are connected to vessel 71. Alternatively, lines 8, 80, and 81 can be connected to the anaerobic process stage, or to the aerated process stage. A calming box 69 is provided at the lower end of pipeline 61, and flow directors 70 are provided around the lower end of pipeline 60. The gas collection section 52 is provided with a line 11 for gas evacuation. A flow passage 65 across the partition 66 with a flow calmer is provided. A central pipe 59 and an air (or oxygen) line 23f are provided in the upper aerated stage 53a. The upper stage also has a circular clarifier 55 with an effluent collection flume 54, sludge return airlifts 58, and an effluent line 9. Optionally, means for conveying anaerobic mixed liquor to the aerated stage and for feeding mixed liquor from the aerated stage to the anaerobic stage can also be provided. These mixed liquor transfer means are not shown in FIG. 1.

[0027] The embodiment of FIG. 1 is operated as follows. The influent via line 8 is fed in vessel 71 and ultimately, via line 60 or 61 in the anaerobic process stage wherein it undergoes anaerobic transformations resulting in organics conversion to water, carbon dioxide, methane, and lesser quantities of ammonia and hydrogen sulfide. The process is intensified by mixing. Mixing is naturally provided by the digestion gas, however, the quantity of gas per unit volume of the reactor diminishes with increased degree of treatment, and additional mixing is required. Mixing can be partially intensified by using a cone 6 which produces circulations as shown in FIG. 1 and as described in the U.S. Pat. No. 4,472,358 which is made a part of this application by inclusion. Lacking a generic term, the term cone is used here in a broad sense. Actually, it can be a pyramid, or a pair of oppositely inclined baffles forming a contracting cross section in the direction of the flow, or other shape producing effect of flow contraction and circulation around baffles. Such cones may not provide sufficient mixing, especially at low gas production rates. Accordingly, active mixing means should be used. A simple version of such means is as follows: air is fed via line 23a in pipeline 61 and lifts liquid from the calming box 69 and ultimately from the top of fluidized bed or from the upper part of the viscous sludge in the vessel 71. From vessel 71 thus lifted liquid descends via pipe 60 to the reactor bottom 100, strikes the bottom, and the flow directors 70 and flows upwardly. If the cone 6 is present, the flow forms the rotational patterns as shown by arrows. Alternative patterns of mixing streams can be produced by skilled in arts, for example, a rotational bottom

flow as in the U.S. Pat. No. 5,338,447, or other, preferably nonuniform flows. The digestion gas accumulates in the liquid and separates into bubbles, which flow up and become collected in section 56 from where the gas is evacuated via line 11. Unlike in other systems, digestion gas is evacuated under substantial pressure thus saving on the compression equipment and storage volumes. This is an important unexpected benefit. Another unexpected benefit is in the use of air in the active airlift which produces stripping of carbon dioxide and thus greatly improves pH and alkalinity control in the system. This effect is further improved by stripping carbon dioxide by air (or oxygen) fed via line 10 in vessel 71. The stripping process is additionally improved by providing recuperable alkaline species, calcium and iron, as described in the U.S. Pat. No. 5,798,043 which is made a part of the present invention by inclusion. It may be important to strip carbon dioxide from largely bicarbonate solution by forming carbonates of calcium provided with lime or otherwise. When calcium carbonate is formed, it is precipitated in the biomass. When this biomass is returned in the anaerobic stage, thus precipitated carbonate reacts with carbon dioxide and makes bicarbonates. Accordingly, pH in the reactor is not significantly reduced and carbon dioxide gas is not released from the solution. Hence, only methane-rich gas is released. It is important that the total amount of the carbonate alkalinity and the rate of recycle of this alkalinity are sufficient to substantially exclude free carbon dioxide formation. Another benefit is in bioheating of the wastewater or sludge due to oxidation by oxygen of air or better by oxygen in the airlift line 61 and in the stripping step conducted in vessel 71. Such heating increases the process rate. The aerated section is operated as usual aeration tank with aerators or with airlift-aerators. Aerated stage can be either a conventional activated sludge process, or process with nitrification, or a microaeration process, or any other process with various levels of oxidation-reduction potentials. Moreover, even methanogenic bacteria can be provided in the aerated stage, these bacteria producing methane. Airlift-aerators are shown in FIG. 1. As described in prior art, airlift-aerators have a partially aerated downcomer and aerated riser. In case of using oxygen instead of air, virtually all oxygen can be absorbed and consumed in the process thus reducing the quantity of off gases and heat loss with off gases and improving the heating efficiency of the process overall. The absorption of gases can be further increased by providing iron ions in the reactor. In aerated stage, iron in ferrous form is oxidized to ferric ions by oxygen and thus increases oxygen absorption via chemisorption mechanism, with ferric ions oxidizing organics and sludge in the system. Ferric and ferrous ions also participate in oxidation-reduction removal of ammonia and nitrates and nitrites with the formation of nitrogen. The beneficial effects of iron ions are described in U.S. Pat. No. 5,919,367 which is made a part of this application by inclusion. For many waste the present invention may increase the total methane content in the digestion gas from about 50% to 95%, and the collected gas pressure may be several atmospheres, for example, 3 ata. At such conditions, the volume of the required gas storage may be reduced almost by a factor of six. This is a very tangible benefit for many industries and municipalities.

[0028] Alternative operations of the active airlift system may include using only line 60 in a reciprocal regime: when vessel 71 is filled via line 60, air in line 23b is shut off and flow goes from the vessel 71 to the reactor bottom. Another

alternative can be when one or both airlifts can be operated periodically, both airlifts can be operated in a reciprocal flow regime, line 60 can be a riser and line 61 can be a downcomer, lines 60 and 61 can be alternating in the riser-downcoming regimes. Such mixing in multiple points with very variable operating regimes is virtually impossible with pumps and submersible mixers. Additionally, airlifts have no moving parts, easy to service (only air solenoids beyond the reactor volume), and are unlikely to break down, if well made. Even best pumps and especially submersible mixers periodically break down, require extraction from the system for service and repair.

[0029] Referring now to FIG. 2, there is shown a modified version of the reactor of FIG. 1. The common parts of these reactors will not be described. FIG. 2 shows alternative feed locations 8a and 8b for the influent directed in the aerated stage and in the anaerobic stage respectively. The reactor 1 has a curvilinear bottom 100, there are no mixing cones in the anaerobic section and there is no airlift aerators in the aerated stage. The anaerobic stage is provided with multiple gaslifts 60, 61, 62, 63, and 64 having intakes at various elevations and terminating in the vessel 71. These gaslifts can be operated periodically, for example, gaslift 60 can periodically lift some well digested methanogen-rich sludge from the reactor bottom, this sludge can be fed down any of the remaining airlifts and mixed with the sludge volume being digested. In such a case, the bottom part of the reactor will serve as a sludge conditioner as described in U.S. Pat. No. 5,514,277. This patent is made a part of the present application by inclusion. The contents of any vertical segment between intakes of the gaslifts of the anaerobic stage can be mixed with any other segment or recycled from the bottom up or in opposite direction within any segment. Gaslifts may be provided with a variable flow of air so that at a lower air feed the gaslift stays in a neutral position, which means it does not lift any noticeable quantity of liquid and does not let any noticeable quantity to flow down. At maximum air feed, the gaslift lifts the liquid in the vessel 71. When air is not fed, the gaslift becomes a downcomer. Additionally, the vessel 71 can be split into more than one compartment. More than one gaslift originating at a given elevation in the reactor can be provided. Such arrangements of active mixing can be very convenient and effective in anaerobic deep shaft reactors or deeper anaerobic reactors. The use of air and/or oxygen will provide the benefits already discussed in the FIG. 1. The aerated stage can be operated as previously described with the airlift-aerator or as a more conventional aerated stage.

[0030] Referring now to FIGS. 3, 4, and 5 there is shown an anaerobic stage of the reactor 1 from the bottom 100 to the partition 66. The upper stage is not shown. It can be the same as in FIGS. 1 and 2, or it can be such as shown later in FIGS. 7 or 8. Other variants are also well known to skilled in arts. FIGS. 3, 4, and 5 show a combination of a passive and an active mixing means comprising multiple stacked cones 6 secured to a central pipe 2 by gussets 12. There are openings 14 between the upper end of the cone in sectors 16 and the central pipe, and openings 15 in the central pipe within sectors 17. Sectors 16 and 17 are separated by gussets 12. A working gaslift gas is fed in the central pipe via line 23. In operation, digestion gases are formed in the entire volume of the anaerobic stage and form floating bubbles. Bubbles are collected under the cones and produce rotational mixing pattern around cones through openings 14 as shown

by arrows. A portion of the gases in sections 17 is directed through openings 15 into the central pipe and serve as a gaslift gas. All these gases eventually are collected in the gas section 52 and evacuated via line 11. The working gas fed via line 23, preferably methane, or possibly oxygen, creates a controllable gaslift effect in the central pipe. As already described, oxygen in very deep tanks can be dissolved virtually completely. Accordingly, the gas collected in section 52 will not contain oxygen.

[0031] Referring now to FIG. 6, there is shown an anaerobic stage of the reactor 1 from the bottom 100 to the partition 66. FIG. 6 differs from FIG. 3 by the absence of the central pipe in the mixing arrangement. Instead the cones 6 and the connecting gussets 21 form a cage with a central passage into which a working gas is provided via line 23. Hydraulically, the non-confined central passage plays the same role as the central pipe 2 in FIGS. 3, 4, and 5. The operation of the embodiments of FIGS. 6 and FIGS. 3, 4, and 5 are similar.

[0032] Referring now to FIG. 7, there is shown a reactor 1 having a bottom 100, a top 101, and a partition 66, the partition divides the reactor into stacked lower and upper stages. The lower stage of the present embodiment has like elements marked with like numerals already described in previous Figures. Note, the airlift vessel in FIG. 7 is marked as 71a. The portion of the upper level circumscribed by the partition 66, top 101, outer wall of the reactor 1, and a vertical circular partition 103 accommodates a first anaerobic stage 102. Partition 103 delimits the aerated stage within the upper level. This partition can be level with the horizontal partition 66, or, as shown in FIG. 7, it may form a recess in the partition 66, or skilled in art may choose other configurations, for example, the entire upper stage may be the first anaerobic stage, or the anaerobic stage may be inscribed into aerated stage. Alternatively, the upper level stage can be an equalization basin or can include an equalization basin. The first anaerobic stage is equipped with gaslifts 105 supplied with the working gas, air or oxygen, via lines 23g. These gaslifts lift mixed liquor from the stage 102 into a separate lift vessel 71b, carbon dioxide is partially stripped from the mixed liquor, preferably by air, and returned via the same airlifts back into the first anaerobic stage. Stripping means are not shown in FIG. 8. Gas accumulating at the top of stage 102, mainly carbon dioxide, is released via line 107, preferably in the vessel 71a where it is scrubbed and re-stripped from the mixed liquor. A portion of the flow lifted to the vessel 71b is transferred via passage 106 into vessel 71a and further into the lower anaerobic stage, which in this embodiment is the second anaerobic stage. The effluent from the second anaerobic stage is transferred to the aerated stage via passages 65. The aerated stage can be similar to those already described. The biological transformations in the first anaerobic stage are preferably limited to hydrolysis and acidification of wastes without or with negligible methane production. The second stage can be a methanogenic stage. In general, these two stages can be operated as a two-stage anaerobic process or as a two-phase anaerobic process. The system of FIG. 7 can be provided with any known means for solid-liquid separation, including those shown herein in other Figures.

[0033] Referring now to FIG. 8, there is shown a biological reactor 1 having a lower portion from the bottom 100 to the partition 66 occupied by an anaerobic stage, and an

upper part from the partition 66 to the top 101 used for aerated process stage 53. The anaerobic process stage of FIG. 8 is similar to that of FIG. 1 and the like parts having like numbers will not be described again. FIG. 8 shows a further development of mixing arrangement at the bottom, comprising flow directors 70 and the bottom fill 72 for improved circulation of the fluidized bed or of a viscous sludges. In the upper part of the anaerobic stage, conical baffles 68 and 90 and a water collection through 67 form a gravity separator (settler, or clarifier) for solid-liquid separation. Additional downcomers 73 from the elevated vessel 71 to the vicinity of the anaerobic clarifier are provided for bringing carbonates for neutralization of carbon dioxide in the upper portion of the anaerobic reactor thus eliminating gassing and floatation of the sludge in the clarifier. The aerated stage can be the same as previously described. A system for separating effluent from the mixed liquor includes a stripper 74 for carbon dioxide connected by line 75 to the aerobic stage 53 and further by line 76 to a vacuum-evaporator vessel 90 connected via line 31 to a vacuum-compressor 32 which further is connected to a heat exchanger 33 having an effluent line 9. A heat exchanger is provided with a gas separation line 41. Alternative arrangements for gas separation are also known to skilled in art. Influent line 8 is also connected to the heat exchanger. Alternatively, a recycle line with a pump for heating the contents of either anaerobic stage or the aerated stage in the heat exchanger 33 can also be provided. A portion of the contents of the vacuum-evaporator vessel 90 can be recycled back in the reactor 1, for example, in aerated stage by pump 78 via line 77. In the stripper 74, carbon dioxide is largely removed from the mixed liquor by, preferably, air stripping, although other gases can also be used. In the vacuum-evaporator vessel 90 a portion of the water is evaporated from the mixed liquor. Vacuum improves evaporation at below-boiling point temperature, for example, at a thermophilic biological range of 45 to 75° C. Other temperature ranges can also be used. Vacuum is created by the vacuum-compressor 32 and the steam condensation in a heat exchanger 33. Recompression of the vapors with the vacuum-compressor insures the evacuation of gases which cannot be condensed in the heat exchanger 33 and provides some additional energy to the steam, thus compensating heat losses in the system. The gases to be evacuated are primarily carbon dioxide and traces of methane, oxygen, nitrogen, and possibly other gases. Steam condensation and dissolution of these gases in the cooled, and even in the chilled, condensate will not be sufficient to evacuate gases and to eliminate the "vacuum breakage" due to the gas build up in the vessel 90. Removal of carbon dioxide and reduction or prevention of its formation in the vessel 90 are improved by providing additional alkalinity. Alkalinity can be in a well soluble form, for example, as sodium hydroxide, or in form of soluble/insoluble compounds such as calcium bicarbonates/carbonates. With biomass present, calcium carbonate precipitates into the biomass.

[0034] Referring now to FIG. 9, there is shown a modification of the embodiment exemplified in FIG. 8 with the principal difference in the arrangement of the vaporization vessel 90, which is disposed above the top of the reactor 1 now. This arrangement also includes a recycle line 35 with pump 36 and sprinklers 37 for improving the steam vaporization and for controlling foam in the vessel 90. A carbon dioxide stripping section 27 communicating with the aerated

stage via openings 28 and 29 and having air supply 40 and the gas exhaust 30 is provided. The airlift effect in section 27 allows to recycle the degassed contents of the combined aerated section-evaporator vessel-and stripping section to be partially recycled via line 38 in the lower anaerobic stage of the reactor 1. The aerated stage is provided with a conical partition to illustrate the possibility of using it for airlift-aerator: the air, or in this case highly preferably oxygen, is fed via line and a distributor 10 in the downcomer space "C" and is circulating through the riser space "B" with a portion of the liquid being split in the vaporization space "A". The use of oxygen is preferred considering the possibility of its virtually complete utilization so that no aeration gases, for example, nitrogen of air, are vacuum-stripped with vapor in the vessel 90. When the system with addition of alkali is used, it is possible to keep the carbonic acid species in the forms of mainly carbonates and bicarbonates with very little free carbon dioxide. This is achieved by stripping carbon dioxide in section 27 in the presence of elevated alkalinity. Accordingly, there is a very low partial pressure of either carbon dioxide or oxygen, or other gas in the vacuum-vaporization vessel 90. Respectively, a small and low-power vacuum-compressor 32 is needed and a small and simple means for separating gases after the steam condensation are required. FIG. 8 also illustrates the possibility of using the vacuum in the upper stage for mixing the lower stage: vacuum "pulls up" the liquid into vessel 90, when vacuum in vessel 90 is temporarily released the pulled-up liquid rushes thorough the riser-downcomer into the bottom 100 thus producing mixing in the anaerobic stage, afterwards, the liquid is pulled up again. Means for releasing vacuum in vessel 90 are trivial and are not shown. The anaerobic stage is also provided with an active airlift operated with a working gas, preferably oxygen, fed via line 23. The anaerobic stage is further provided with passive mixing cones 6 attached to a central pipe 2 with gussets. In this embodiment, the mixing cones are inverted.

I claim:

1. A method of biological treatment of wastewater with biomass, said wastewater and said biomass form mixed liquor, in a tall reactor, said reactor having a top, a bottom, and an essentially horizontal partition between said top and said bottom, comprising (a) at least one anaerobic treatment step conducted between said bottom and said partition, a digestion gas comprising methane and carbon dioxide is formed in said anaerobic treatment, (b) a step of mixing said mixed liquor in said anaerobic step by at least one controllable gaslift with a gas other than said digestion gas, and (c) at least one step of treatment of said wastewater conducted between said partition and said top of said reactor.

2. The method of claim 1, wherein said at least one controllable gaslift lifts said mixed liquor from at least one location between said bottom and said partition to the uppermost point of said controllable gaslift and returns said mixed liquor in said anaerobic treatment step, whereby said lifting and said returning constitute a lifting-returning operation step effecting said mixing.

3. The method of claim 2, wherein said lifting-returning operation step is selected from a group consisting of non-reversible flow, reversible flow, continuous flow, discontinuous flow, flow through a riser-downcomer pipe, flow through a system of stacked contracting-expanding zones, periodic flow, and combinations thereof.

4. The method of claim 1, wherein said gas other than said digestion gas is selected from the group consisting of an oxidizing gas, oxygen, air, oxides of nitrogen, nitrogen, and combinations thereof.

5. The method of claim 4, wherein said oxidizing gas provides oxidizing reactions in said mixed liquor, whereby said mixed liquor is heated, said oxidizing reactions are selected from biological reactions, abiotic reactions, and combinations thereof.

6. The method of claim 1, wherein a step of stripping said carbon dioxide from said mixed liquor in said anaerobic treatment step is provided, said step of stripping carbon dioxide is selected from a group consisting of gas stripping, oxygen stripping, air stripping, nitrogen stripping, steam stripping, vacuum-stripping, vacuum-vapor-stripping, vacuum-vapor-stripping with steam recompression and condensation, vacuum-vapor-stripping with steam recompression and condensation with preheating the influent, vacuum-vapor-stripping with steam recompression and condensation with heating the contents of said reactor, heat degassing, and combinations thereof.

7. The method of claim 1 and further providing steps of vaporization of wastewater from said mixed liquor with low pressure steam production and condensation of said steam.

8. The method of claim 7, wherein said step of vaporization is selected from a group consisting of vaporization by preheating said mixed liquor, vaporization by vacuuming said mixed liquor, vaporization by vacuuming said mixed liquor with steam recompression and condensation, vaporization by vacuuming said mixed liquor with steam recompression and condensation and preheating said influent, vaporization by vacuuming said mixed liquor with steam recompression and condensation and preheating said mixed liquor, and combinations thereof.

9. The method of claim 1 and further providing steps of feeding reagents selected from a group of recuperable alkaline species, recuperable oxidation-reduction species, alkalies, acids, nutrients, micronutrients, probiotics, and combinations thereof.

10. The method of claim 1 and further providing steps of transferring said mixed liquor between said anaerobic and said aerobic process steps.

11. The method of claim 1, wherein said at least one step of treatment of said wastewater conducted between said partition and said top of the reactor is selected from the group consisting of aerobic treatment, aerobic treatment with aeration by air, aerobic treatment with aeration by oxygen, aerobic treatment with nitrification, aerobic treatment with denitrification, aerobic treatment with phosphorus removal, anoxic treatment, treatment with iron as intermediate oxidation-reduction specie, anaerobic hydrolysis treatment, anaerobic acetogenic treatment, anaerobic acidogenic treatment, anaerobic sulfate reduction treatment, anaerobic methanogenic treatment, and combinations thereof.

12. A method of biological treatment of wastewater with biomass, said wastewater and said biomass form mixed liquor, in a tall reactor, said reactor having a top, a bottom, and an essentially horizontal partition between said top and said bottom, comprising (a) at least one anaerobic treatment step conducted between said bottom and said partition, a digestion gas comprising methane and carbon dioxide is formed in said anaerobic treatment, (c) at least one step of treatment of said wastewater conducted between said parti-

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tion and said top of said reactor, and (c) collecting said digestion gas under said partition, whereby said collected gas is pressurized.

13. The method of claim 12, wherein a step of stripping said carbon dioxide from said mixed liquor in said anaerobic treatment step is provided, said step of stripping carbon dioxide is selected from a group consisting of gas stripping, oxygen stripping, air stripping, nitrogen stripping, steam stripping, vacuum-stripping, vacuum-vapor-stripping, vacuum-vapor-stripping with steam recompression and condensation, vacuum-vapor-stripping with steam recompression and condensation with preheating the influent, vacuum-vapor-stripping with steam recompression and condensation with heating the contents of said reactor, heat degassing, and combinations thereof, whereby a methane-rich digestion gas is separated and collected under said partition.

14. A method of biological treatment of wastewater with biomass, said wastewater and said biomass form mixed liquor, in a tall reactor, said reactor having a top, a bottom, and an essentially horizontal partition between said top and said bottom, comprising (a) at least one anaerobic treatment step conducted between said bottom and said partition, a digestion gas comprising methane and carbon dioxide is formed in said anaerobic treatment, (c) at least one step of treatment conducted between said partition and said top of said reactor, and (d) at least one step of vaporization-separation of liquid from solids in said mixed liquor.

15. The method of claim 14, wherein said step of vaporization is selected from a group consisting of vaporization

by preheating said mixed liquor, vaporization by bioheating said mixed liquor, vaporization by vacuuming said mixed liquor, vaporization by vacuuming said mixed liquor with steam recompression and condensation, vaporization by vacuuming said mixed liquor with steam recompression and condensation and preheating said influent, vaporization by vacuuming said mixed liquor with steam recompression and condensation and preheating said mixed liquor, and combinations thereof.

16. The method of claim 15, wherein said bioheating is provided by oxidizing said organics and said biomass with an oxidizer selected from a group consisting of oxygen of air, oxygen, iron as intermediate oxidation-reduction specie, and combinations thereof.

17. The method of claim 15 and further providing a step of vacuum evacuation of said digestion gases from said mixed liquor simultaneously with step (d).

18. The method of claim 16, wherein said step of vacuum evacuation is selected from the group consisting of chemical vacuum evacuation, steam recompression vacuum evacuation, and combinations thereof.

19. The method of claim 1 wherein said reactor is selected from the group of deep shaft reactors, tall above ground reactors, multi-cell reactors, and combinations thereof.

20. The method of claim 1, wherein said partition is a flow-through means capable of collecting said digestion gas and passing through said mixed liquor.

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PATENTE DE INVENCION ☒

MODELO DE UTILIDAD ☐

- ◆ Indicación de que se solicita la concesión de una patente ☒
- ◆ Datos de identificación del solicitante o de la persona que presenta la solicitud ☒
- ◆ Descripción de la invención ☒
- ◆ Dibujos de ser estos pertinentes ☒
- ◆ Comprobante de pago de las tasas establecidas ☒

COMPLETA ☐

INCOMPLETA ☐

DISEÑO INDUSTRIAL ☐

- ◆ Indicación de que se solicita el registro de Diseño Industrial ☐
- ◆ Datos de identificación del solicitante o de la persona que presenta la solicitud ☐
- ◆ Representación gráfica y fotográfica del Diseño Industrial o muestra del material que incorpora el diseño ☐
- ◆ Comprobante de pago de las tasas establecidas ☐

COMPLETA ☐

INCOMPLETA ☐

ESQUEMA DE TRAZADO ☐

- ◆ Indicación de que se solicita el registro de un Esquema de Trazado ☐
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- ◆ Representación gráfica del esquema trazado ☐
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COMPLETA ☐

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Claudia M. Nervo Cortes
Firma Responsable

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