

METHOD FOR FILTERING A LIQUID, AND FILTER DEVICE

[0001] The invention relates to a method for filtering a liquid in a membrane filter immersed into the liquid, wherein the membrane filter includes membranes. In
5 order to clean the membranes, gas is introduced into the membrane filter from below in successive pulses using a gas introduction device by filling a gas volume which is arranged below the surface of the liquid and is defined at a bottom by a level of the liquid is initially filled with the gas, wherein the gas simultaneously displaces the liquid from a top downward and out of a gas lifting channel until a
10 level of the liquid drops below an inlet cross-section of a gas outflow channel, and the gas then flows downward out of the gas volume, through the gas lifting channel, a deflection portion adjoining the gas lifting channel at a bottom of the gas lifting channel, upwards through the inlet cross-section and through the gas outflow channel adjoining the inlet cross-section at a top of the gas inlet cross-section from
15 above, and then to a surface of the liquid.

[0002] The invention also relates to a filter device, comprising a membrane filter for filtering a liquid through membranes and a gas introduction device arranged below the membranes, a downward open gas collection cavity that is defined by an upper wall and a lower wall, a gas inlet for introducing the gas into
20 the gas collection cavity, a gas lifting channel for lifting gas out of the gas collection cavity and emptying the gas collection cavity, wherein the gas lifting channel includes a gas lifting inlet at a top of the gas collection cavity, a deflection

portion arranged at a bottom of the gas lifting channel and an inlet cross-section arranged at a top of the deflection portion, wherein a gas outflow channel adjoins at a top of the gas outflow channel.

[0003] A generic method and a generic gas introduction device are known from
5 US 2015/026 5973 A1, CN 104084049 A and CN 105854619 A.

[0004] The known methods and the known gas introduction devices are configured for introducing gas into membrane filters that can be found e.g; in membrane bioreactors (MBR). The gas introduction device is positioned below the membrane filters and supplied with an essentially constant air volume flow which
10 then flows out of the gas introduction device in pulses.

[0005] In order to prevent a plugging of the membranes by filtered substances, air is introduced from below into the membrane filters on a path towards a surface of the liquid, the gas flows through the membrane filters installed on top of the gas introduction device. The shear force of the two-phase flow made from air and
15 liquid to be filtered flushes the membranes.

[0006] The pulsed exit of the liquid generates higher shear forces than continuous gas introduction while simultaneously preventing a channeling of the air, this means the rising air bubbles always have to be formed anew and thus always find new paths through the membrane filter.

20 **[0007]** A gas introduction device that is constantly supplied with air and that lets out the air in pulses is also designated as a geyser.

[0008] A gas volume that is built up in the gas collection cavity is pulled through the gas lifting channel connected to the inlet cross section when gas flows out of the gas introduction device through the principle of communicating pipes so that the gas collection cavity is substantially emptied.

5 **[0009]** During emptying of the gas collection cavity, the outflowing gas volume flow suctions liquid through the compensation inlet and transports the liquid through the outflow channel according to the air lift pump effect. This the advantage that the gas volume flow subsides more quickly after emptying the gas collection cavity so that the gas introduction device can be operated with a higher
10 gas flow.

[0010] In the known methods and filter devices the air flows from the geyser (gas introduction device) initially into a laterally open portion so that a large portion of the liquid displaced by the air is laterally displaced from the module and can thus not be used for flushing the membranes. Furthermore, depending on the size of
15 the air pulse a portion of the air escapes at a bottom of the module out of the module in a lateral direction and rises adjacent to the membrane filter, unused this means without a flushing effect upon the membranes.

[0011] In the background of the invention WO 2016/064466 A (Koch Membrane Systems), US 2009/0194477 A1 (Asahi Kasai), US 10,179,311 B2
20 (Sumitomo Electric), CN104519984B B (Samsung Cheil Industries), KR20190002717 A (Mitsubishi Chemical) und WO 2011/028341 A1 (Zenon Technology Partnership) disclose gas introduction devices that do not include a

compensation inlet and that are therefore only operable with a rather low gas volume feed in a pulsating manner. Also in these filter devices air flows during exit from the geyser into a laterally open area.

5 **OBJECT**

[0012] Thus, it is an object of the invention to improve a purging effect of air that is being introduced.

SOLUTION

10 **[0013]** Improving upon the known method it is proposed according to the invention that a housing laterally envelops the membranes and directly adjoins the gas introduction device on top.

[0014] Thus, it is an advantage of this configuration of the membrane filter that gas introduced into the membrane filter cannot exit the membrane filter due to the
15 housing adjoining the gas introduction device without gaps and then laterally enveloping the membranes so that the gas is effectively used to flush the membranes.

[0015] Thus, it is an advantage that also the liquid displaced by the air cannot laterally escape from the membrane filter which increases the acceleration of the
20 liquid column. The bubble forming from the introduced gas in the housing and initially rising in cohesion accelerates the liquid column arranged there above so that it also flows with a high velocity past the membranes and that it dislodges

accretions from the membranes due to shear forces generated. The cleaning effect of the introduced air is improved through both effects approximately by an order of magnitude and energy to be used for cleaning is reduced accordingly.

[0016] Advantageously a blocking flow of the liquid runs through a
5 compensation inlet below the gas lifter inlet to the inlet cross section and is then pulled along by the gas until the liquid fills the deflection portion and thus closes the inlet cross section for the gas.

[0017] According to the method according to the invention the level in the liquid in the gas introduction device rises again during the emptying of the gas
10 volume, wherein the gas volume is displaced by the liquid flowing in from below. Thus, the suction effect of the gas rising into the flow out channel causes a blocking flow of the liquid to be pulled through the compensation inlet and to flow to the inlet cross section. This blocking flow of the liquid is pulled along by the gas so that the liquid fills the deflection portion and thus fills the inlet cross section and
15 therefore closes like a valve for the gas.

[0018] Thus, the method according to the invention assures that the flow out of the gas is interrupted at a point in time when the gas volume is substantially emptied even under a high gas volume flow feed and the gas volume can be filled again. Thus, a pulsating of the gas is also secured at a high gas volume flow feed.

20 **[0019]** Advantageously gas only flows through the gas outflow channel in a method according to the invention after the level has dropped below the inlet cross section until the level rises above the compensation inlet and only then the blocking

flow runs through the compensation inlet to the inlet cross section. The geyser then also pulls along liquid shortly before emptying even when there are greater air flows so that stopping the geyser is assured and refilling can commence.

[0020] This means that the compensation inlet is in gas communication at the beginning of the gas flow through the outlet channel, this means the compensation inlet is within the gas filled gas collection cavity when performing the method according to the invention. This assures that emptying the gas volume starts reliably even at the extremely low gas volume flows since no liquid flow impedes the gas suction effect and thus the emptying of the gas volume by lifting the gas.

10 **[0021]** The geyser then commences emptying even at a very small air flow.

[0022] Thus, the method according to the invention has the advantage that substantially constant gas volume feed can be varied in a very wide range and is then introduced into the membrane filter with a stable pulsing. Thus, the pulsing gas volume flow through the membrane filter can be adapted in an energy saving manner to the respective filtration performance over a wide range of filtration performance variations.

[0023] This means the method according to the invention allows operating the membrane filter at a variable filtration performance also with a variable gas volume flow feed in a reliable and pulsing manner in order to implement an effective flushing of the membranes at low energy consumption.

20 **[0024]** Improving upon the known filtering device it is proposed according to the invention that a housing laterally envelops the membranes and directly adjoins

the gas introduction device on top. The filtering device according to the invention facilitates performing the method according to the invention and is characterized by the advantages described supra.

[0025] Advantageously the filtering device according to the invention includes
5 a gas introduction device including a compensation inlet below the gas lifter inlet wherein the compensation inlet is flowable up the inlet cross section. Further advantageously the compensation inlet is arranged at a level of the inlet cross section or above. Thus, the compensation inlet is arranged below the upper wall and above or at the same level of the inlet cross section. Thus, the compensation
10 inlet is in gas communication when the gas collection cavity is filled and the compensation inlet is in liquid communication when the gas collection cavity is empty. This has the advantages described supra for the start and stop process of the geyser process of pulsating emptying and filling the gas collection cavity.

[0026] In a simple embodiment of the filter device according to the invention,
15 the compensation inlet leads into the gas lifting channel. Since the liquid is introduced in this embodiment directly into the strong downward running gas volume flow in the gas lifting channel, the pull along effect from the gas is comparatively strong which limits an increase of the gas volume flow feed. This effect can be counteracted by enlarging the compensation inlet which leads to a
20 limitation of the gas volume flow feed in downward direction since the gas volume above the compensation inlet is then not pulled empty.

[0027] In another embodiment of the filter device according to the invention a compensation channel adjoins the compensation inlet in a direction towards the deflection portion. Through the compensation channel the position of the compensation inlet and the location of introducing the liquid blocking flow into the exiting gas flow are decoupled which leads to an increase of the variation of the gas volume flow feed.

[0028] In an advantageous embodiment of the filter device the compensation channel leads into the deflection portion parallel to the gas lifting channel. Thus, a location of introduction of the blocking liquid flow is displaced downward as far as possible. This has the advantage that the liquid is fed separately from the gas volume flow exactly to the location where the liquid shall create the blocking effect for the gas which assures a stop of the exiting gas flow also at higher gas volume flow feeds.

[0029] The gas volume flow feed can be increased even further while reliably maintaining pulsation using an alternative embodiment of the filter device according to the invention, by making a cross section of the compensation inlet larger than a minimum cross section of the compensation channel when connecting the compensation channel and the gas lifting channel in parallel with one another to the deflection portion. This increases the blocking flow of the liquid and a quicker and thus more reliable closing of the inlet cross section for the gas is also provided for a higher gas volume flow feed.

[0030] Thus, the membrane filter can also be configured with different types of membranes like e.g; hollow filter membranes, plate membranes, cushion membranes or hollow fiber membranes connected to form curtains. The membranes are advantageously from the field of ultra or micro filtration membranes with a pore size between 0.02 μm and 1 μm . However, also other membranes from the field of nanofiltration or low pressure reverse osmosis can be used.

[0031] Since the liquid volume within the membrane filter has to be replaced while flushing the membranes with the gas in order to prevent a concentration of the substances in the filter that were previously retained by the membranes the gas introduction device includes a liquid flow channel that vertically penetrates the gas collection cavity in order to let liquid flow into a bottom of the membrane filter.

[0032] In an advantageous embodiment of the filter device according to the invention the housing of the membrane filter is configured as a tube. The tube can have a circular, rectangular, or any other cross section. The advantage of the tube is economical fabrication e.g. by extrusion.

[0033] In order to distribute air in an optimum manner that is introduced from the gas introduction device into the membrane filter an embodiment of the filter device according to the invention includes a gas distributor below the membranes, wherein the flow out channel leads into the gas distributor.

[0034] In the filter device according to the invention the flow channels are partially or completely formed by walls of a housing of the gas introduction device.

The flow channels include the flow out channel, the compensation channel and the deflection portion.

EMBODIMENTS

5 **[0035]** The invention is subsequently described in more detail based on an advantageous embodiments with reference to drawing figures, wherein

[0036] FIGs 1a-i illustrate process steps of a method according to the invention showing a gas introduction device according to the invention in sectional views; and

10 **[0037]** FIG. 2 illustrates a filter device according to the invention.

[0038] The drawing figures are not to scale. All details of the subsequently described methods or gas filtering devices are identical with the embodiments of the filtering devices according to the invention described supra.

15 **[0039]** FIG. 1a shows the process steps of a first method according to the invention for introducing a gas 1 into a liquid 2 using a first gas introduction device 3 according to the invention illustrated sectional views.

[0040] The gas introduction device 3 includes a gas volume 6 that is arranged below a surface 4 of the liquid 2 and defined in downward direction by a level 5 of
20 the liquid 2. The gas volume 6 is arranged in a gas collection cavity 7 that is defined by an upper wall 8 and a side wall 9. Through a gas inlet 10 installed below the gas collection cavity 7 and separate from the gas collection cavity 7 gas 1 is introduced

into the gas collection cavity 7 and thus fills the gas volume 6 so that the level 5 of the liquid 2 goes down. Thus, the liquid 2 that is in the gas collection cavity 7 is displaced at this point in time successively by inflowing gas 1 in downward direction and replaced by the gas 1.

- 5 **[0041]** The gas introduction device 3 according to the invention includes a deflection portion 11 which includes an inlet cross section 12 on top wherein a gas outflow channel 13 joins the inlet cross section on top. A gas lifting channel 14 and a compensation channel 15 lead into the deflection portion 11. The gas lifting channel 14 includes an open gas lifting inlet 16 in a top of the gas collection cavity
- 10 7 and the compensation channel 15 includes a compensation inlet 17 below the upper wall 8 in the gas collection cavity 7, wherein the cross section of the compensation inlet 17 is sized larger than the minimum cross section of the compensation channel 15. Furthermore, the gas outlet channel 13 penetrates the upper wall 8.
- 15 **[0042]** FIGs. 1b – 1d show additional filling of the gas collection cavity 7 with the gas 1 and thus an additional filling of the gas volume 6 and an additional lowering of the level 5 of the liquid 2. As illustrated in FIG. 1b, gas 1 moves from above through the gas lifting inlet 16 into the gas lifting channel 14 when filling the gas volume 6 so that the gas lifting channel 14 is filled with the gas 1 top down.
- 20 **[0043]** In FIG. 1c the level 5 has dropped below the compensation inlet 17 and gas 1 moves from above into the compensation channel 15. During the method

steps shown in FIGs. 1a – 1c, the gas flow out channel 13 remains filled with fluid 2, this means no gas flows out of the gas introduction device 3.

[0044] In FIG. 1d, the level 5 of the liquid 2 has dropped below the inlet cross section 12. From this moment the gas 1 flows out of the gas volume 6 through the gas lifting channel 14 and the compensation channel 15 in downward direction to the deflection portion 11 and thereafter through the inlet cross section 12 and the subsequent gas flow out channel 13 to the surface 4.

[0045] FIG. 1e shows how the gas volume 6 in the gas collection cavity 7 is reduced by the outflowing gas 1. Thus, gas 1 flowing out of the gas collection cavity 7 is successively replaced by liquid 2 that flows in from below so that the level 5 of the liquid 2 rises again.

[0046] The gas 1 flowing out through the gas flow out channel 13 generates a vacuum in the gas flow out channel 13 and in the adjoining gas lifting channel 14 and in the compensation channel 15. Since the gas lifting inlet 16 as well as the compensation inlet 17 are arranged at this point in time in the gas volume 6 filled with the gas 1 in the gas collection cavity 7, initially only the gas 1 flows through the gas outlet channel 13 induced by the suction created.

[0047] FIG. 1f shows the moment in time when the level 5 of the liquid 2 reaches the compensation inlet 17. Up to this point in time, only gas 1 has flowed through the gas outlet channel 13.

[0048] FIG. 1g shows how the compensation inlet 17 is flooded with fluid 2 during a further increase of the level 5 due to the gas flowing out through the gas lifting channel 14.

[0049] FIG. 1h shows how a blocking flow 18 of the liquid 2 is pulled through the compensation inlet 17 through the suction effect of the gas 1 flowing out of the gas flow out channel 13 so that the blocking flow 18 of the liquid 2 flows through the compensation channel 15 to the inlet cross section 12 and is pulled along by the outflowing gas 1 until the blocking flow 18 of the liquid 2 fills the deflection portion 11 in FIG. 1i and closes the inlet cross section 12 for the gas 1 like a valve.

[0050] FIG. 2 illustrates a sectional view of a gas introduction device 63 according to the invention which is mounted below a membrane filter 64. The gas introduction device 63 has a gas collection cavity 65 that is laterally defined by a lateral wall 66 configured as a rectangular tube with 20 cm lateral width. The gas collection cavity 65 is open in a downward direction with a gas inlet 67 arranged there under and configured to fill the gas collection cavity 65 with a gas during operations. A gas lifting inlet 69 leads into the gas collection cavity 65 on top below an upper wall 68 wherein a gas lifting channel 70 adjoins the gas lifting inlet 69. The gas lifting channel 70 leads at a bottom into a deflection portion 71 which is adjoined by an inlet cross section 72 on top. The deflection portion 71 runs through a lateral wall 66 at a bottom. A gas outlet channel 73 is connected to the inlet cross section 72 on top. Additionally, the gas introduction device 63 includes a compensation channel 74 that is arranged within the side wall 66. The

compensation channel 74 includes a compensation inlet 75 at a top of the gas collection cavity 65 and leads into the deflection portion 71 at a bottom.

[0051] The membrane filter 64 includes membranes 76 configured as hollow fiber membranes 77 which are cast into a base element 78 at a bottom. The base element 78 includes a permeate collection cavity 79 wherein the hollow fiber membranes 77 are connected with an open lumen side to the permeate collection cavity in order to extract a filtrate out of the lumen of the hollow fiber membranes 77. The hollow fiber membranes 77 are individually closed on top and are laterally enveloped by a housing 80 which is configured as a rectangular tube 81 with identical cross-sectional dimensions as the lateral wall 66 and that adjoins the lateral wall 66 on top. Below the base element 78 the membrane filter 64 includes a gas distributor 82 wherein the gas flow out channel 73 leads into the gas distributor 82. The gas introduction device 63 includes a liquid flow channel 83 that vertically penetrates the gas collection cavity 65 and the upper wall 68 in order to let a liquid flow into the bottom of the membrane filter 63. The combination of gas introduction device 63 and membrane filter 64 jointly forms a filtering device 84.

REFERENCE NUMERALS AND DESIGNATIONS

	[0052]	1	gas
	[0053]	2	liquid
	[0054]	3	gas introduction device
5	[0055]	4	surface
	[0056]	5	level
	[0057]	6	gas volume
	[0058]	7	gas collection cavity
	[0059]	8	upper wall
10	[0060]	9	side wall
	[0061]	10	gas inlet
	[0062]	11	deflection portion
	[0063]	12	inlet cross section
	[0064]	13	gas flow out channel
15	[0065]	14	gas lifting channel
	[0066]	15	compensation channel
	[0067]	16	gas lifting inlet
	[0068]	17	compensation inlet
	[0069]	18	blocking flow
20	[0070]	63	gas introduction device
	[0071]	64	membrane filter
	[0072]	65	gas collection cavity

	[0073]	66	side wall
	[0074]	67	gas inlet
	[0075]	68	upper wall
	[0076]	69	gas lifting inlet
5	[0077]	70	gas lifting channel
	[0078]	71	deflection portion
	[0079]	72	inlet cross section
	[0080]	73	gas outlet channel
	[0081]	74	compensation channel
10	[0082]	75	compensation inlet
	[0083]	76	membrane
	[0084]	77	hollow filter membrane
	[0085]	78	base element
	[0086]	79	permeate collection cavity
15	[0087]	80	housing
	[0088]	81	tube
	[0089]	82	gas distributor
	[0090]	83	liquid flow channel
	[0091]	84	filter device

20

PATENT CLAIMS

1. A method for filtering a liquid (2) in a membrane filter (64) immersed in the liquid (2) and including membranes (76), the method comprising:

introducing a gas (1) through a gas introduction device (63) into a base of the membrane filter (64) in successive pulses so that the membranes (76) are cleaned wherein the gas introduction device (3, 63) includes a liquid flow channel (83) which vertically penetrates a gas collection space (7, 65) and admits the liquid (2) into a bottom of membrane filter (64); and initially

filling a gas volume (6) arranged below a surface (4) of the liquid (2) and defined in a downward direction by a level (5) of the liquid (2) with the gas (1) wherein the gas (1) simultaneously displaces the liquid (2) from a top down from a gas lifting channel (14, 70) until the level (5) drops below an inlet cross section (12, 72) of a gas flow out channel (13, 73); and subsequently

flowing the gas (1) out of the gas volume (6) downward through the gas lifting channel (14, 70), a deflection portion (11, 71) adjoining at a bottom of the gas lifting channel, in upward direction through the inlet cross section (12, 72) and through the gas flow out channel (13, 73) adjoining the inlet cross section (12, 72) at a top and flowing the gas to the surface (4),

characterized in that a housing (80) laterally surrounds the membranes (76) and adjoins the gas introduction device (63) on top.

2. The method according to the preceding claim, characterized in that a blocking flow (18) of the liquid runs through a compensation inlet (17, 75) below a gas

lifting inlet (16, 69) to the inlet cross section (12, 72) and is pulled along by the gas (1) until the liquid (2) fills the deflection portion (11, 71) and thus closes the inlet cross section (12, 72) for the gas (1).

3. The method according to the preceding claim, characterized in that

after the level (5) has dropped below the inlet cross section (12, 72) initially only the gas (1) flows through the gas outflow channel (13, 73) until the level (5) rises above the compensation inlet (17, 75), and

only then does the blocking flow (18) run through the compensation inlet (17, 75) to the inlet cross section (12, 72).

4. A filter device (84), comprising:

a membrane filter (64) for filtering a liquid (2), the membrane filter including membranes (76) and a gas introduction device (3, 63) arranged below the membranes (76), the gas introduction device including

a liquid flow channel (83) which vertically penetrates the gas collection space (7, 65) and admits the liquid (2) into a bottom of membrane filter (64);

a gas collection space (7, 65) which is open at a base and defined by an upper wall (8, 68) and a lateral wall (9, 66),

a gas inlet (10, 67) configured to flow a gas (1) into the gas collection space (7, 65),

a gas lifting channel (70) configured to siphon a gas out of the gas collection space (7,65) and empty the gas collection space (7, 65), the gas lifting channel including a gas lifting inlet (16, 69) at a top in the gas collection space (7, 65),

a deflection portion (11, 71) arranged at a bottom of the gas lifting channel (14, 70), and

an inlet cross section (12, 72) arranged at a top of the deflection portion (11, 71) wherein a gas outflow channel (13, 73) is connected at a top of the inlet cross section (12, 72),

characterized by a housing (80) which laterally surrounds the membranes (76) and which is connected to the gas introduction device (63) at a top of the gas introduction device.

5. The filter device (84) according to the preceding claim, characterized in that a compensation inlet (17, 75) is arranged below the gas lifting inlet (16, 69) and flowable towards the inlet cross section (12, 72).

6. The filter device (84) according to the preceding claim, characterized in that the compensation inlet (17, 75) is arranged at a level of the inlet cross section (12, 72) or above.

7. The filter device (84) according to one of Claims 5 and 6, characterized in that the compensation inlet (17, 75) is formed on the gas lifting channel (14, 70).

8. The filter device (84) according to one of Claims 5 to 7, characterized by a compensation channel (15, 74) which connects to the compensation inlet (17, 75) in a direction towards the deflection area (11, 71).

9. The filter device (84) according to the preceding claim, characterized in that the compensation channel (15, 74) leads into the gas lifting channel (14, 70).

10. The filter device (84) according to one of claims 8 and 9, characterized in that the compensation channel (15, 74) leads parallel to the gas lift channel (14, 70) into the deflection area (11, 71).

11. The filter device (84) according to one of claims 8 to 10, characterized in that a cross section of the compensation inlet (17, 75) is larger than a minimum cross section of the compensation channel (15, 74).

12. The filter device (84) according to one of claims 4 to 11, characterized in that the housing (80) is a continuous tube (81).

13. The filter device (84) according to one of claims 4 to 12, characterized by a gas distributor (82) below the membranes (76) wherein the gas outlet channel (13, 73) leads into the gas distributor.