

HOLLOW FIBRE MEMBRANE MODULE

Field of the Invention

[0001] The present invention generally relates to filtration technologies, and more particularly to a hollow fiber membrane module with integrated cleaning system for cleaning the fiber membrane surfaces during the filtration.

Background of the Invention

[0002] Polymeric hollow fiber membranes have elongated central lumens so that they are useful in filtration, one of its broad applications. Filtration separates mixed components in either liquids or gases according to the sizes and/or charges of the components. Thus, polymeric hollow fiber membranes have been extensively used as a liquid/solid separation mean in material purification and wastewater treatment. For example, in the wastewater treatment, wastewater is passed through either the bore or shell sides of multiple microporous hollow fiber membranes. Some components (e.g., water) diffuse through the microporous walls of such fiber membranes into the shell or bore sides of the hollow fiber membranes, forming a permeate, while other components are selectively rejected by such microporous walls and therefore form a retentate. The porosity of such hollow fiber membranes determines the specific compositions of the permeate and retentate.

[0003] Hollow fiber membrane module usually comprises a plurality of hollow fiber membranes for filtration. The filtration can be performed by external pressure mode where suspension liquid such as wastewater can be pressured on the external side of hollow fiber wall to leave the solid on the external surface of the hollow fiber membrane and to get filtered liquid from the inner channel, or by internal pressure mode where the suspension liquid can be pressured from inner surface through the hollow fiber membrane wall to leave the solid on the inner wall of the hollow fibers and to get filtered liquid from outside of the hollow fibers.

[0004] Many types of hollow fiber membrane modules are described, such as a cylinder (e.g., U.S. Pat. 6,331,248) and curtain (e.g., U.S. Pat. 5,922,201). Some

membrane modules can be made without frame (e.g., U.S. Pat. 5,248,424) or immersing type (e.g., U.S. Pat. 6,630,069). No matter of the configurations of different hollow fiber membrane modules, solid retentates will deposit upon the outer surface for external pressure mode filtration or the inner surface for internal pressure mode filtration. The deposition will severely affect the filtration efficiency. Therefore, In order to keep the filtration process going, the filtered deposits on the membrane surface need to be removed time to time by mechanical, hydraulic or acoustic force. If the force is too strong it may sometimes cause damage of fibers. If the force is too weak it may cause incomplete removal of the deposits. One commonly used method for cleaning the hollow fiber membranes is to reverse the flow so that the particles trapped within the membrane and the deposits upon the surfaces can be removed. Obviously, this is not very efficient way for cleaning the modules because the filtration has to be halted and clean liquid has to be used. Another commonly used method for cleaning the hollow fiber deposits is to use flushing gas.

[0005] Attempts have been made to incorporate certain cleaning means into the hollow fiber membrane modules. U.S. Pat. 5,783,083 discloses a gas-scrubbed vertical cylindrical skein of fibers that has their opposed terminal portions held in headers unconfined in a modular shell, and aerated with a cleaning gas supplied by a gas-distribution means which produces a mass of bubbles serving the function of a scrub-brush for the outer surfaces of the fibers. However, the gas distribution means complicate the making of the module, and it is hard to optimize the conditions of gas distribution for different membranes and suspension liquids.

[0006] WO 2004/024304 A2 discloses a system and method for cleaning hollow fiber membranes. The method includes the application of a first pressure to the inner surface of the hollow fiber membrane and a second pressure to the outer surface of the hollow fiber membranes. The differentials between these two pressures will determine the flow directions across the fiber membranes. Quick flips of the flow directions will reduce the deposits on the surfaces. However, its basic principle is still using the reverses of flow directions to reduce the deposits.

[0007] Mostly, both ends of hollow fibers are fixed or potted in a resin bed so that the inner channel of fibers is separated from outside of fibers. However, it makes fiber hard to wave due to the restraining from the potted resin. In some prior arts, the

hollow fiber membrane modules have only one end of hollow fibers embedded in sealing compound and leave the other end free. For example, U.S. Pat. 6,890,436 discloses a hollow fiber membrane module with one end of the fibers free within the filtration chamber. It further discloses that the fibers can be cleaned by reversed gas flushing.

[0008] It is evident that there is an imperative need for a hollow fiber membrane module that integrates a self-cleaning means so as to improve the filtration efficiency and reduce the manufacture cost.

Summary of the Invention

[0009] Therefore, one of the objectives of the present invention is to provide a hollow fiber membrane module with an integrated self-cleaning system. The hollow fiber membrane module of the present invention has improved the filtration efficiency and reduced the manufacture cost.

[0010] In one aspect of the present invention, there is provided a hollow fiber membrane module for external pressure mode filtrations. In one embodiment, the hollow fiber membrane module comprises a container in which the filtration is performed, wherein the container has fluid communication means for introduction of suspension liquids into the container and removal of retentates and permeates from the container; at least one fiber bundle, wherein each fiber bundle comprises a plurality of hollow fiber membranes with first ends and second ends; wherein the first ends of the hollow fiber membranes are potted in a solid bed that in turn is fixed in a mold and sealed by sealers so as to form a collection chamber and a filtration chamber within the container; and wherein the second ends of the hollow fiber membranes are closed by a sealer and disposed within the filtration chamber; and at least one flushing pipe with a plurality of flushing holes for introducing the suspension liquid into the filtration chamber to cause the unrestrained fiber membranes having a seaweed-like movement so as to self-clean the surfaces of the hollow fiber membranes.

[0011] In another embodiment of the hollow fiber membrane module, the fluid communication means comprises at least one suspension inlet for the suspension liquid to be introduced into the filtration chamber, at least one filtered liquid outlet for the permeates to be removed from the collection chamber, and at least one discharge outlet for the

retentates to be removed from the filtration chamber. In another embodiment of the hollow fiber membrane module, the container comprises a top and a bottom, wherein the top and bottom form the container and the two parts can be assembled and disassembled easily.

[0012] In yet another embodiment of the hollow fiber membrane module, the hollow fiber membrane is with pore size from 0.002 to 2 μ m, fiber diameter 0.2-2mm and porosity between 50% and 90% by volume. In a further embodiment of the hollow fiber membrane module, the hollow fiber membrane is made from various flexible polymers selected from the group consisting of polyvinylidene fluoride (PVDF), cellulose, polyacrylonitrile (PAN), polysulfone (PS), polyethersulfone (PES), polypropylene (PP), polyvinyl chloride(PVC), polyamides and polyimides.

[0013] In yet still another embodiment of the hollow fiber membrane module, the solid bed is made of resin such as epoxy, polyurethane, polyester, and the mold is made of engineering plastic such as ABS, polycarbonate, PVC, PP, PMMA, PE. In yet further embodiment of the hollow fiber membrane module, the sealers for sealing the solid bed and mold and the second ends are selected from the group consisting of epoxy, polyurethane, polyester, PAN, PVDF, PP, PVC, PS, PES, Cellulose, polyamides and polyimides.

[0014] In yet another embodiment of the hollow fiber membrane module, the flushing pipe is made of materials selected from the group consisting of ABS, PVC, PMMA, polyester, polycarbonate, PP, copper, steel, aluminum and stainless steel. In a further embodiment of the hollow fiber membrane module, the at least one flushing pipe is merged with the suspension inlet at one end. In another further embodiment of the hollow fiber membrane module, the at least one flushing pipe is separated from the suspension inlet.

[0015] In another aspect of the present invention, there is provided a method for filtrating a suspension liquid with the hollow fiber membrane module of the present invention. The method comprises the steps of introducing the suspension liquid via the suspension inlet into the filtration chamber, causing the hollow fiber membranes to have seaweed-like movements by the flushing pipe, and collecting permeates from the collection chamber and removing the retentates from the filtration chamber; whereby the hollow fiber membranes are self-cleaned during the filtration process so that the filtration process can be prolonged and maintained with high efficiency.

[0016] In yet another aspect, the present invention provides a hollow fiber membrane filtration system. In one embodiment, the hollow fiber membrane filtration system comprises a suspension liquid holding means, wherein the suspension liquid holding means has fluid communication means for introduction of the suspension liquids into and removal of retentates and permeates from the suspension liquid holding means; at least one fiber bundle, wherein each fiber bundle comprises a plurality of hollow fiber membranes with first ends and second ends; wherein the first ends of the hollow fiber membranes are open and potted together, thereby the permeates from the interior of the hollow fiber membranes pass through the open ends; and wherein the second ends of the hollow fiber membranes are closed by a sealer and disposed within the suspension liquid holding means for filtration; at least one permeates collection means for collecting the permeates from the interior of the hollow fiber membranes; wherein the at least one permeates collection means has means for allowing the permeates to flow outside; and wherein the at least one fiber bundle is disposed sealedly between the suspension liquid holding means and the at least one permeates collection means so that there is no liquid communication between the holding means and the collection means for proper filtration; and at least one flushing pipe with a plurality of flushing holes for introducing the suspension liquid into the suspension liquid holding means to cause the unrestrained fiber membranes having a seaweed-like movement so as to self-clean the surfaces of the hollow fiber membranes.

[0017] In another embodiment of the hollow fiber membrane filtration system, the fluid communication means comprises at least one suspension inlet for the suspension liquid to be introduced into the filtration chamber; and at least one discharge outlet for the retentates to be removed from the filtration chamber.

[0018] In yet another embodiment of the hollow fiber membrane filtration system, wherein the hollow fiber membrane is with pore size from 0.002 to 2 μ m, fiber diameter 0.2-2mm and porosity between 50% and 90% by volume. In a further embodiment of the hollow fiber membrane filtration system, the hollow fiber membrane is made from various flexible polymers selected from the group consisting of polyvinylidene fluoride (PVDF), cellulose, polyacrylonitrile (PAN), polysulfone (PS), polyethersulfone (PES), polypropylene (PP), polyvinyl chloride(PVC), polyamides and polyimides.

[0019] In yet still another embodiment of the hollow fiber membrane filtration system, the first ends of the hollow fiber membranes are potted by materials selected from the group consisting of epoxy, polyurethane, polyester. In a further embodiment of the hollow fiber membrane filtration system, the fiber bundles are sealed from the suspension liquid holding means and the permeates collection means by materials selected from the group consisting of epoxy, polyurethane, polyester, PAN, PVDF, PP, PVC, PS, PES, Cellulose, polyamides and polyimides.

[0020] In yet still another embodiment of the hollow fiber membrane filtration system, the flushing pipe is made of materials selected from the group consisting of ABS, PVC, PMMA, polyester, polycarbonate, PP, copper, steel, aluminum and stainless steel. In a further embodiment of the hollow fiber membrane filtration system, the at least one flushing pipe is merged with the suspension inlet at one end. In yet further embodiment of the hollow fiber membrane filtration system, the at least one flushing pipe is separated from the suspension inlet.

[0021] The objectives and advantages of the invention will become apparent from the following detailed description of preferred embodiments thereof in connection with the accompanying drawings.

Brief Description of the Drawings

[0022] Preferred embodiments according to the present invention will now be described with reference to the Figures, in which like reference numerals denote like elements.

[0023] Fig 1 shows an illustratively schematic diagram of the hollow fiber membrane module in accordance with one embodiment of the present invention.

Detailed Description of the Invention

[0024] The present invention may be understood more readily by reference to the following detailed description of certain embodiments of the invention.

[0025] Throughout this application, where publications are referenced, the disclosures of these publications are hereby incorporated by reference, in their entireties,

into this application in order to more fully describe the state of art to which this invention pertains.

[0026] While the present invention will be described in reference to the accompanying drawings, the specifics and details are provided for the sole purpose of illustrating the principles of the present invention. It is to be appreciated that the present invention may be practiced without employing the specifics and details. Furthermore, certain variations of the specifics and details in the practice are permissible without deviation from the principles of the present invention.

[0027] In one aspect, the present invention provides a hollow fiber membrane module that can be used for external pressure mode filtrations. Briefly, the hollow fiber membrane module comprises at least one fiber bundle of a plurality of hollow fiber membranes, where each hollow fiber membrane has its one end embedded in a resin pot and another end unrestrained so that the filtered solids on the external surface of the fibers can be self-cleaned by waves caused by suspension liquid flow.

[0028] Now referring to FIG 1, there is provided an illustratively schematic diagram of the hollow fiber membrane module with three fiber bundles. It is to be appreciated that the number of fiber bundles within one module and the number of hollow fiber membranes within each fiber bundle are not limitation of the present invention. Instead, the numbers of fiber bundles and hollow fiber membranes can be varied according to one's specific applications. The distance between two bundles is not restricted; it is preferably larger than 10mm. Fiber and pipe distance has no restriction. Fiber length is at least 80mm, preferably 200 to 3000mm. Pipe length may be the same or shorter than the fiber length. Number of holes is not restricted; it is preferable that the total surface area of the holes is less than the cross section area of the pipe. Distribution of the holes is not restricted; it is suitable as long as the distribution can cause fiber movement. In addition, the number and location of inlets and outlets are not restricted; they can be determined by a user's specific applications.

[0029] The hollow fiber membrane module as shown in Fig 1 comprises a bottom container 4 in which the filtered liquid is collected. The container 4 has at least one suspension inlet 1 and at least one filtered liquid outlet 2. Another top container 8 in which suspension liquid such as water, solutions or other fluids to be filtered is stored. The container 8 has at least one discharge outlet 14. The at least one suspension inlet 1

provides means for suspension liquid to flow into the collection chamber 3. The at least one filtered liquid outlet 2 provides means for clean or filtered liquid to come out the filtration chamber. The at least one discharge outlet 14 provides means for retentates to be removed from the filtration chamber.

[0030] The hollow fiber membrane module further comprises at least one fiber bundle, wherein each fiber bundle comprises a plurality of hollow fibers 9. The hollow fibers 9 have first ends and second ends, wherein the first ends of the hollow fibers are potted in a solid bed 7 such as a resin. It is to be appreciated that the designation of first and second is for the convenience of description only. The solid bed 7 is fixed in a mold 5 and sealed by sealers 6 so as to form a collection chamber 3 and a filtration chamber 13 within the container 1, where the collection chamber 3 and the filtration chamber 13 are separated with limited communications discussed hereinafter. The first ends of the hollow fibers 9 that are potted in the solid bed 7 are open to the collection chamber 3 as magnified in FIG 1. The second ends of the hollow fibers 9 are closed by a sealer 12 as magnified in FIG 1. The sealed second ends are disposed within the filtration chamber. The two chambers may be formed by the mold that provides adaptors for the fiber bundle. A sealer 15 can be used to seal collection chamber. It is preferred that the whole or at least part of the fiber should be potted in filtration chamber. In addition, the top and bottom parts of the container may be easily assembled and disassembled. It is to be appreciated that in application of the present invention, the collection chamber is essential but the filtration chamber can be part of water tank or reservoir.

[0031] The hollow fiber membrane module further comprises at least one flushing pipe 11 with a plurality of flushing holes 10. It is to be appreciated that one of the at least one fiber bundles may have more than one flushing pipe. The number of the flushing pipes is not a limitation for the present invention. The flushing pipe 11 can merge with the suspension inlet 1 at one end and penetrate the solid bed 7 as shown in FIG 1 so that the flushing pipe 11 functions both as channel for passing the suspension liquid from the external source to the filtration chamber and as a flushing source to cause the fibers with unrestrained second ends to have seaweed movements within the filtration chamber so as to self-clean the fiber surfaces. In another embodiment, the flushing pipe 11 may be a separate component from the suspension inlet so that the suspension inlet can function as a channel for the introduction of suspension liquid into the filtration chamber and the

flushing pipe can function as a flushing source. In this manner, different pressures may be applied to the suspension inlet and the flushing pipe.

[0032] In another aspect of the present invention, there is provided a method for liquid filtration using a hollow fiber membrane module with self-cleaning mechanisms as shown in Fig 1. In one embodiment, suspension liquid such as water, solutions or other fluids flows through the suspension inlet **1**, passes the flushing pipe **11** and comes out from the flushing holes **10** into the filtration chamber **13**. The filtration pressure drop can be caused by liquid height or produced when outlet **14** is partially closed or by suction from outlet **2**. Clean liquid penetrates the hollow fibers **9** into the collection chamber **3** and then goes through the clean or filtered liquid outlet **2**. During the filtration the discharge outlet **14** can be opened to form cross flow filtration mode in order to remove cakes on the external side of the hollow fiber.

[0033] In the present invention, the hollow fiber membranes can be made from various flexible polymers such as polyvinylidene fluoride (PVDF), cellulose, polyacrylonitrile (PAN), polysulfone (PS), polyethersulfone (PES), polypropylene (PP), polyvinyl chloride (PVC), polyamides and polyimides. In addition, the hollow fiber membrane is with pore size from 0.002 to 2 μ m, fiber diameter 0.2-2mm and porosity between 50% and 90% by volume.

[0034] The fixed ends of hollow fibers are open to the collection chamber and the free ends are sealed to separate from external side of hollow fibers. The sealing material and method are critical to prevent leakage of suspension liquid from the filtration chamber into the fibers and then to the collection chamber. The polymer used to seal the free end should have strong adhesion to the hollow fibers. The polymer can be, not restricted to, epoxy, polyurethane, polyester, PAN, PVDF, PP, PVC, PS, PES, Cellulose, polyamides and polyimides. The hollow fibers are dipped in a liquid with sealing polymer and separated from each other. After the sealing polymer is cured the hollow fibers can be used in the module.

[0035] In one embodiment, the flushing pipe can be made from common plastic piping materials such as ABS, PVC, PMMA, polyester, polycarbonate and PP or metals such as copper, steel, aluminium and stainless steel. The holes are drilled on the side of the pipe. The diameter of the holes are from 0.5 to 10mm.

[0036] The following examples are provided for the sole purpose of illustrating the principles of the present invention. It by no means limits the scope of the present invention.

[0037] Example 1

[0038] A bundle of 3500 pieces PVDF hollow fiber membrane with outer diameter 1.0mm, inner diameter 0.6mm, length 300mm, average pore size 0.2um and porosity 80% was put in a module as shown in Fig. 1. One end of the fibers was fixed in a PVC mould with epoxy resin. The other end of fibers was dipped in an epoxy resin. The fibers were physically separated each other during the curing process of the epoxy resin with a filler (silica gel powder). A central ABS flushing pipe with inner diameter 20mm and 80 holes with diameter 2mm is assembled as suspension liquid inlet. After solidification of the epoxy resin a solid seal was formed in the free end of the hollow fiber. The fibers could be waved freely. The whole module was put in a PVC collection chamber and a filtration chamber. The module was attached in a water supply pipe. The initial flux of the module is 1200L/hr.

[0039] While the present invention has been described with reference to particular embodiments, it will be understood that the embodiments are illustrative and that the invention scope is not so limited. Alternative embodiments of the present invention will become apparent to those having ordinary skill in the art to which the present invention pertains. Such alternate embodiments are considered to be encompassed within the spirit and scope of the present invention. Accordingly, the scope of the present invention is described by the appended claims and is supported by the foregoing description.

CLAIMS

What is claimed is:

1. A hollow fiber membrane module for external pressure mode filtrations, comprising:

a container in which the filtration is performed, wherein the container has fluid communication means for introduction of suspension liquids into the container and removal of retentates and permeates from the container;

at least one fiber bundle, wherein each fiber bundle comprises a plurality of hollow fiber membranes with first ends and second ends; wherein the first ends of the hollow fiber membranes are potted in a solid bed that in turn is fixed in a mold and sealed by sealers so as to form a collection chamber and a filtration chamber within the container; and wherein the second ends of the hollow fiber membranes are closed by a sealer and disposed within the filtration chamber; and

at least one flushing pipe with a plurality of flushing holes for introducing the suspension liquid into the filtration chamber to cause the unrestrained fiber membranes having a seaweed-like movement so as to self-clean the surfaces of the hollow fiber membranes.

2. The hollow fiber membrane module of claim 1, wherein the fluid communication means comprises:

at least one suspension inlet for the suspension liquid to be introduced into the filtration chamber;

at least one filtered liquid outlet for the permeates to be removed from the collection chamber; and

at least one discharge outlet for the retentates to be removed from the filtration chamber.

3. The hollow fiber membrane module of claim 1, wherein the container comprises a top and a bottom, wherein the top and bottom form the container and the two parts can be assembled and disassembled easily.

4. The hollow fiber membrane module of claim 1, wherein the hollow fiber membrane is with pore size from 0.002 to 2 μ m, fiber diameter 0.2-2mm and porosity between 50% and 90% by volume.
5. The hollow fiber membrane module of claim 1, wherein the hollow fiber membrane is made from various flexible polymers selected from the group consisting of polyvinylidene fluoride (PVDF), cellulose, polyacrylonitrile (PAN), polysulfone (PS), polyethersulfone (PES), polypropylene (PP), polyvinyl chloride(PVC), polyamides and polyimides.
6. The hollow fiber membrane module of claim 1, wherein the solid bed is made of resin such as epoxy, polyurethane, polyester, and the mold is made of engineering plastic such as ABS, polycarbonate, PVC, PP, PMMA, PE.
7. The hollow fiber membrane module of claim 1, wherein the sealers for sealing the solid bed and mold and the second ends are selected from the group consisting of epoxy, polyurethane, polyester, PAN, PVDF, PP, PVC, PS, PES, Cellulose, polyamides and polyimides.
8. The hollow fiber membrane module of claim 1, wherein the flushing pipe is made of materials selected from the group consisting of ABS, PVC, PMMA, polyester, polycarbonate, PP, copper, steel, aluminum and stainless steel.
9. The hollow fiber membrane module of claim 1, wherein the at least one flushing pipe is merged with the suspension inlet at one end.
10. The hollow fiber membrane module of claim 1, wherein the at least one flushing pipe is separated from the suspension inlet.
11. A method for filtrating a suspension liquid by filtration pressure drop caused by liquid height or produced when discharge outlet for the retentates is partially closed or

generated by suction from outlet, with the hollow fiber membrane module of claim 1, comprising the steps of:

introducing the suspension liquid via the suspension inlet into the filtration chamber;

causing the hollow fiber membranes to have seaweed-like movements by the flushing pipe; and

collecting permeates from the collection chamber and removing the retentates from the filtration chamber;

whereby the hollow fiber membranes are self-cleaned during the filtration process so that the filtration process can be prolonged and maintained with high efficiency.

12. A hollow fiber membrane filtration system, comprising:

a suspension liquid holding means, wherein the suspension liquid holding means has fluid communication means for introduction of the suspension liquids into and removal of retentates and permeates from the suspension liquid holding means;

at least one fiber bundle, wherein each fiber bundle comprises a plurality of hollow fiber membranes with first ends and second ends; wherein the first ends of the hollow fiber membranes are open and potted together, thereby the permeates from the interior of the hollow fiber membranes pass through the open ends; and wherein the second ends of the hollow fiber membranes are closed by a sealer and disposed within the suspension liquid holding means for filtration;

at least one permeates collection means for collecting the permeates from the interior of the hollow fiber membranes; wherein the at least one permeates collection means has means for allowing the permeates to flow outside; and wherein the at least one fiber bundle is disposed sealedly between the suspension liquid holding means and the at least one permeates collection means so that there is no liquid communication between the holding means and the collection means for proper filtration; and

at least one flushing pipe with a plurality of flushing holes for introducing the suspension liquid into the suspension liquid holding means to cause the unrestrained fiber membranes having a seaweed-like movement so as to self-clean the surfaces of the hollow fiber membranes.

13. The hollow fiber membrane filtration system of claim 12, wherein the fluid communication means comprises:

at least one suspension inlet for the suspension liquid to be introduced into the filtration chamber; and

at least one discharge outlet for the retentates to be removed from the filtration chamber.

14. The hollow fiber membrane filtration system of claim 12, wherein the hollow fiber membrane is with pore size from 0.002 to 2 μ m, fiber diameter 0.2-2mm and porosity between 50% and 90% by volume.

15. The hollow fiber membrane filtration system of claim 12, wherein the hollow fiber membrane is made from various flexible polymers selected from the group consisting of polyvinylidene fluoride (PVDF), cellulose, polyacrylonitrile (PAN), polysulfone (PS), polyethersulfone (PES), polypropylene (PP), polyvinyl chloride(PVC), polyamides and polyimides.

16. The hollow fiber membrane filtration system of claim 12, wherein the first ends of the hollow fiber membranes are potted by materials selected from the group consisting of epoxy, polyurethane, polyester.

17. The hollow fiber membrane filtration system of claim 12, wherein the fiber bundles are sealed from the suspension liquid holding means and the permeates collection means by materials selected from the group consisting of epoxy, polyurethane, polyester, PAN, PVDF, PP, PVC, PS, PES, Cellulose, polyamides and polyimides.

18. The hollow fiber membrane filtration system of claim 12, wherein the flushing pipe is made of materials selected from the group consisting of ABS, PVC, PMMA, polyester, polycarbonate, PP, copper, steel, aluminum and stainless steel.

19. The hollow fiber membrane filtration system of claim 12, wherein the at least one flushing pipe is merged with the suspension inlet at one end.

20. The hollow fiber membrane filtration system of claim 12, wherein the at least one flushing pipe is separated from the suspension inlet.