

Membrane Bioreactor with Micro Stainless Steel Wire Mesh Filtration Module for Wastewater Treatment

Field of the Invention

The present invention relates to membrane bioreactor wastewater treatment technology, in particular to membrane bioreactor with novel micro stainless steel wire mesh filtration modules, to replace conventional organic and inorganic membrane modules as the core filtration elements.

Background

Membrane Bioreactor (MBR) integrates the advanced membrane separation and biological wastewater treatment technology (*T. Stephenson, S. Judd, B. Jefferson and K. Brindle, Membrane Bioreactors for Wastewater Treatment, IWA Publishing: London, 2000.*). Due to the filtration process from membrane, the microorganism and sludge are kept in the bioreactor, the wastewater retention time and sludge retention time are separated completely and a higher concentration of sludge (MLSS) is achieved, resulting in smaller footprint, higher quality for effluent and reduced sludge formation.

Currently, microfiltration membrane (MF) or ultrafiltration (UF) membrane with the pore sizes ranged from 0.01 to 0.4 μm are common for most submerged MBR process (*X. Huang, B. Cao, X. H. Wen and H. C. Wei, State-of-the-art of membrane bioreactors research and application in China [J]; Acta Scientiae Circumstantiae, 2008, 28(3), 416-432.*); the commercial materials for the membranes are polymeric materials, such as polyethylene, polypropylene and polysulfone, inorganic materials such as ceramic membrane, etc (*M. H. Al-Malack and G. K. Anderson, Use of crossflow microfiltration in wastewater treatment [J]; Water Research, 1997, 31(12), 3064-3072.*). Nevertheless, because of easy fouling, low flux rate and high cost, the application of MBR is limited. Many attempts have been employed to reduce the membrane fouling, increase the flux rate and control the cost.

Non-woven fabric materials was studied as solid-liquid separation media in a MBR process, which demonstrated a lower filtration resistance than a microporous membrane, though the fluxes are still at the order of 20-40 $\text{L}/\text{m}^2\cdot\text{h}$. (*G. T. Seo, B. H. Moon, T. S. Lee, T. J. Lim and I. S. Kim, Non-woven fabric separation activated sludge*

reactor for domestic wastewater reclamation[J]; *Water Science and Technology*, 2002, 47(1), 133-138.)

Research was also conducted on the use of some low-cost materials as substitutes for the microporous membrane in MBR applications. Those low-cost materials include nylon, Dacron and metal meshes with a pore size in the order of 10^2 μm and the filtration is achieved via the formation of a biomembrane on the meshes. [(a) Y. Kiso, Y.-J. Jung, T. Ichinari, M. Park, T. Kitao, K. Nishimura and K.-S. Min, *Wastewater treatment performance of a filtration bio-reactor equipped with a mesh as a filter material [J]*, *Water Research*, 2000, 34(17), 4143-4150; (b) F. Bin, H. Xia, X. H. Wen and Y. Yan, *Filtration capability of the bio-dynamic membrane [J]*, *Environmental Science*, 2003, 24(1), 91-97.]. During operation of this kind so-called dynamic membrane bioreactor, a sludge layer or a bio-membrane formed on the mesh surface was dynamic, and solid-liquid separation process was achieved. However, due to the big pore size of the meshes, the quality of the effluent was not stable. Particularly at the initial stage of each filtration cycle, high concentration of suspended solids was observed in the effluent when the dynamic bio-membrane started to grow and was not mature yet.

The less stable performance from dynamic membrane bioreactor was overcome when nylon mesh with the pore size at the order of 10^1 μm (20-30 μm) was used for filtration medium. In addition, high flux rates of up to 150 $\text{L}/\text{m}^2\cdot\text{h}$ were also achieved. (W. Fuchs, C. Resch, M. Kernstock, M. Mayer, P. Schoeberl and R. Braun, *Influence of operational conditions on the performance of a mesh filter activated sludge process [J]*, *Water Research*, 2005, 39(5), 803-810.)

In this invention, a novel filtration module based on micro stainless steel mesh with the pore size at the order of 10^0 - 10^1 μm (1-10 μm) was used for MBR wastewater treatment. In this filtration set-up, an automatically-controlled suction and back-washing system were also connected to the module so that effluent of high quality was induced out of the reactor and the mesh membrane was cleaned to maintain high flux rate.

Detailed Description of the Invention

In order to overcome the problems inherited from conventional MBR, such as fouling, low flux rate, high energy consumption, short life time, heavy work load on maintenance, high cost, etc., this invention has proposed the use of micro metal wire mesh, especially the micro stainless steel wire mesh, as the core filtration element for the MBR, resulting in a new generation of solid-liquid separation technique in the wastewater treatment process. This new technique fills the gap between conventional MBR and dynamic MBR in terms of the pore sizes for the filtration media. The pore sizes for the membranes used for conventional MBR are at the order of $10^{-1}\mu\text{m}$, and the pore sizes for the meshes used for dynamic MBR are at the order of $10^1\mu\text{m}$ [Z. J. Pang, *Dynamic membrane and its new application in wastewater treatment [J], Water Purification Technology*, 2008, 27(6), 5-7,23 .). In this invention, the stainless steel wire meshes with the pore sizes at the order of 10^0 to $10^1\mu\text{m}$ are employed to fabricate the filtration modules, representing the third option of filtration method in the MBR wastewater treatment technology. The advantages are described as followings:

1) With the fine filtration from the stainless steel wire mesh of the pore size in the range of 1-10 μm , most of the solids in the wastewater can be filtered off. If the modules are immersed into conventional activated sludge process tank, the effluent with comparable quality as that from the sand filter can be obtained. An effluent with better quality can also be obtained if the MLSS in the bioreactor is increased.

2) The benefit of this invention over the dynamic MBR is its stable performance because direct filtration by permanent stainless steel wire mesh rather than unstable filtration by self-forming bio-membrane is achieved.

3) The benefits of this invention over conventional MBR include lower installation cost, lower operation cost, lower maintenance cost and longer life time, though some small invisible contaminants still penetrate the mesh.

4) The benefits of this invention over conventional activated sludge process with sand filter include lower installation cost, higher MLSS, better quality for the effluent and more stable performance with comparable operation cost.

5) This invention utilizes the micro metal wire mesh, especially the stainless steel wire mesh, to replace the organic membrane, non-woven cloth, inorganic membrane and other membranes in MBR as the core filtration element. Micro stainless steel wire mesh is woven from 304, 304 L, 316, 316L stainless steel wires. It is acid, alkaline resisting, can endure high temperature with strong abrasion resistance. Types of weaving for the mesh include plain weave, twilled weave, plain Dutch weave, twilled Dutch weave, reverse plain Dutch weave as well as reverse twilled Dutch weave.

Metal mesh openings(pores): 1 to 10 μm

Metal wire diameters: 1 to 10 μm .

6) The metal mesh is easy for fabrication of filters with various shapes, such as flat shape or tube shape. The mesh can be welded, mechanically connected, or glued to the framework, together with main effluent outlets, back-wash tubes and frame connection device, a new type of MBR module for wastewater treatment can be set up. This flexibility to handle metal wire mesh will lead to competitive cost for module fabrication.

7) The new MBR module made of stainless steel wire mesh will have longer life time.

8) Because of the excellent physical property of stainless steel, the new MBR module is easy for cleaning and flux rate restoration. A high back washing pressure can be applied without causing the damage to the mesh. The high flux rate can be easily restored with frequent back-washing, reducing the operational cost from air scouring for conventional MBR. Besides, it is not necessary to take out the MBR frequently for cleaning, reducing the load for maintenance work.

9) The mesh openings (pores) can be from 1 to 10 μm to produce the effluent with excellent quality. With the advancing of modern technology, it is expected that stainless steel mesh with opening size less than 1 μm can be fabricated so that the current organic and inorganic membrane in MBR can be completely replaced and phased out for wastewater treatment.

10) For stable operation, the effluent can be induced by a suction pump with a low suction pressure of 20-25 kPa and the flux rates up to $150 \text{ L/m}^2\cdot\text{h}$ can be achieved. The flux rate is an order higher than that for the conventional MBR modules. If higher flux rate is required, stainless steel mesh with pore size up to $50 \mu\text{m}$ can be employed. The suspended solids in the effluent do not increase significantly.

11) If the effluent is to be recycled or further refined, an ultrafine filtration system or a reverse osmosis system shall be installed. Because the effluent is filtered with micro stainless steel wire mesh, most of the suspended solids are removed, the ultrafine filter or the reverse osmosis filter will have less solids to handle, their life time is extended and the maintenance cost can be reduced too.

Furthermore, the application of this invention provides multiple choices for wastewater treatment approaches. In some places where the effluent is not to be recycled, this invention will treat the wastewater with effluent quality higher than that from conventional activated sludge process equipped with a sand filter, but at a lower initial investment cost and comparable operation cost. It is promising that this invention will replace the conventional activated sludge wastewater treatment process soon. As for conventional MBR, because only effluent of high quality is obtained at higher cost, its application is limited. In the places with abundance water resource, recycle is not necessary; therefore, the production of over qualified effluent with unnecessarily high treatment cost is not welcomed.

However, if this invention is combined with ultrafine filtration or reverse osmosis facility, the effluent of high quality can still be achieved without incurring additional heavy investment and operational cost.

The MBR filtration module for this invention comprises of micro metal wire mesh, especially micro stainless steel wire mesh, effluent outlet, back-washing inlet tubes, frame with sealing edge, connection/assembling device and automatically-controlled suction and back-washing system. In Figure 2, filtration module fabricated from flat sheet micro stainless steel wire mesh is described.

In Figure 3, ten micro filters are bundled together to form a module, each effluent outlet from the filters is connected to the main outlet and each back washing tube is connected to the main back-washing tube.

5 **Figures**

Figure 1 A MBR with micro stainless steel wire mesh filtration module

Figure 2 Single micro stainless steel wire mesh filtration device

Figure 3 Micro stainless steel wire mesh filtration module.

In Figures

- 10 1 — wastewater inlet pump and pipe
- 2 — bioreactor
- 3 — micro stainless steel wire mesh filtration module
- 4 — effluent pressure meter
- 5 — effluent valve
- 15 6 — effluent pump
- 7 — effluent flow meter
- 8 — effluent storage tank
- 9 — back washing pressure meter
- 10 — back washing flow meter
- 20 11 — back washing valve
- 12 — back washing pump
- 13 — air blower
- 14 — air valve
- 15 — air flow meter
- 25 16 — sludge reflux pump
- 17 — aeration system
- 18 — level meter
- 19 — micro stainless steel wire mesh
- 20 — effluent outlet
- 30 21 — back washing inlet tube

- 22 — frame with sealing edge
- 23 — main effluent outlet
- 24 —main back washing inlet
- 25 — connection/assembling device

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Description of Exemplary Embodiment

The followings are the exemplary embodiments

Figure 1 shows the MBR with micro stainless steel wire mesh filtration module

After coarse filtration and preliminary settlement, the wastewater was introduced
 10 into the bioreactor 2 by pump 1. The wastewater level was monitored by level meter 18,
 which sent signal to PLC to control the on-off of the pump 1. The aeration for the
 bioreactor 2 was supplied by the aeration system, which was comprised of air blower 13,
 air valve 14, air flow meter 15 and aeration system 17. The air flow rate was controlled
 by PLC through the adjustment of air valve 14. The wastewater was filtered by module
 15 3, to which an effluent suction system was connected. This effluent suction system was
 comprised of an effluent pressure meter 4, effluent valve 5, effluent suction pump 6 and
 effluent flow meter 7. The effluent flow meter monitored the flux rate and sent signal to
 PLC to adjust the valve 5 so that a constant flux rate of $150\text{-}200\text{ L/m}^2\cdot\text{h}$ was maintained.
 The mesh module was cleaned by a back washing system, which was comprised of a
 20 back washing pressure meter 9, back washing flow meter 10, back washing valve 11
 and back wash pump 12. When the flux rate dropped to below $150\text{ L/m}^2\cdot\text{h}$, the PLC
 controlled back washing started to run for about 30 second. During the back washing
 period, effluent valve 5 was closed and back washing valve 11 was opened, back
 washing pump took the clear water from the effluent storage tank 8 and sent it to the
 25 module 3 for cleaning. After back washing, valve 11 was closed and valve 5 was opened
 to resume normal operation.

After filtration, the sludge and suspended solids were rejected and kept in the
 bioreactor, a sludge reflux pump was used to maintain the homogenous sludge
 30 distribution in the whole reactor.

For further purification of the effluent of high quality, an ultrafine filtration or
 reverse osmosis system can be coupled with this new MBR.

Figure 2 shows the micro stainless steel wire mesh flat filtration device, which consists of micro stainless steel wire mesh 19, effluent outlet 20, back washing inlet 21 and framework 22. The framework 22 can be made of stainless steel, synthetic resin, etc. The two pieces of mesh 19 can be welded, mechanically attached or glued to the framework to form a sealed chamber. When the device is submerged in a bioreactor, the mixed liquid is induced through the mesh as permeate to the chamber and the outlet. The back washing is achieved when pressurized water is pumped back to the chamber via back washing inlet 21. Different size of the mesh in the filtration device can be employed to meet different wastewater treatment requirements.

Figure 3 shows the MBR module assembled from micro stainless steel mesh flat type filtration device. 10 of the flat type filtration devices are connected with the connection/assembling device 25, the effluent outlet and the back washing inlet for each device are connected to the main effluent outlet 23 and main back washing inlet 24, respectively.

Summary of the Invention

This invention has modified the conventional membrane bioreactor and dynamic membrane bioreactor with the replacement of organic/inorganic membrane, nonwoven cloth, coarse meshes and other filtration media by micro stainless steel wire mesh with the pore size (opening size) ranged from 1 μm to 10 μm (or up to 50 μm in some cases). The wire mesh can be fabricated into flat type, tube type or other types of filtration device, together with the framework, connection/assembling device, effluent outlet and back washing inlet, a new MBR wastewater filtration module is fabricated. The complete MBR is comprised of an aeration system, a novel filtration module and an automatically controlled effluent suction and back washing system.

Compared with the conventional MBR, the new set-up has the following advantages when it is submerged in a bioreactor: (1) the filtration device and MBR module can resist to the corrosion from acid, alkaline, resist to high temperature and abrasion; (2) the filtration device and MBR module are easy to fabricate; (3) the filtration device and MBR module have longer life time; (4) the filtration device and MBR module have low fabrication cost; (5) the micro stainless steel wire mesh in the filtration device and MBR module can be cleaned by simple back washing, reducing the

operation cost; (6) the new MBR module has large and stable flow rate; (7) the filtration device and MBR module have less fouling; (8) the wire mesh in the filtration device and MBR module has even opening sizes; wire meshes with different opening sizes are available on the market for different applications; (9) the effluent or permeate has the quality higher than that for the effluent from the conventional activated sludge process with sand filter; (10) The effluent can be recycled if ultrafiltration or reverse osmosis system is coupled with the new MBR; (11) The invention has solved the fouling, low flux rate and high cost problems for conventional MBR, providing higher potentials for the extensive application of the MBR technology in wastewater treatment.

Claims

1. Application of micro stainless steel wire mesh in membrane bioreactor (MBR). The new MBR has the core micro-filtration device, which is comprised of micro stainless steel wire mesh, frame, effluent outlet and back washing inlet. The flat type of mesh is attached to a frame by welding, mechanical means or gluing to form a sealed chamber, together with effluent outlet and back washing inlet, a micro mesh filtration device is assembled. In Figure 3, 10 flat type micro filtration devices are connected to form a MBR module, which can be connected to an automatically controlled effluent suction system and back washing system.
2. Based on claim 1, application of micro stainless steel wire mesh in membrane bioreactor, the said stainless steel wire mesh is used to replace the organic membrane, ceramic membrane, non-woven cloth, coarse meshed and other filtration media in the conventional MBR and dynamic membrane bioreactor.
3. Based on claim 1, application of micro stainless steel wire mesh in membrane bioreactor, the pore or opening size of the micro mesh is from 1 μm to 10 μm (or up to 50 μm in some cases). In future, with the advancing of new technology, the opening size can be fabricated to less than 1 μm . Types of weaving for the mesh include plain weave, twilled weave, plain Dutch weave, twilled Dutch weave, reverse plain Dutch weave as well as reverse twilled Dutch weave. The stainless steel wire diameters range from 1 μm to 50 μm .
4. Based on claim 1, application of micro stainless steel mesh in membrane bioreactor, the new MBR can be applied in biological wastewater treatment processes, such as anaerobic, anoxic and aerobic processes. The effluent from the new MBR has the higher quality than that of the effluent from conventional activated sludge process with sand filter.
5. Based on claim 1, application of micro stainless steel mesh in membrane bioreactor, the wastewater is filtered and settled to remove the large particles. It is further treated with micro stainless steel wire mesh MBR, where the main contaminants are decomposed. After filtration, the sludge and suspended solids are rejected and kept in the bioreactor and the clear permeate is produced. If the

permeate is to be reused, further treatment can be achieved via the coupling of ultrafiltration or reverse osmosis system.

6. Based on claim 1, application of micro stainless steel mesh in membrane bioreactor, during treatment process, the effluent is induced out of the bioreactor by an automatically controlled suction system and the module cleaning is achieved by an automatically controlled back washing system.

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