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International Journal of Current Research
Vol. 9, Issue, 03, pp.47310-47312, March, 2017

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

MICROFILTRATION TECHNOLOGY IN WASTE WATER TREATMENT

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ARTICLE INFO

Article History:
Received 09th December, 2016
Received in revised form
24th January, 2017
Accepted 25th February, 2017
Published online 31st March, 2017

Key words:
Microfiltration,
Waste water treatment,
Recent developments.

ABSTRACT

Microfiltration usually serves as a pre-treatment for other separation processes such as ultrafiltration, and a post-treatment for granular media filtration. The typical particle size used for microfiltration ranges from about 0.1 to 10 µm. In terms of approximate molecular weight these membranes can separate macromolecules generally less than 100,000 g/mol. The filters used in the microfiltration process are specially designed to prevent particles such as, sediment, algae, protozoa or large bacteria from passing through a specially designed filter. More microscopic, atomic or ionic materials such as water (H_2O), monovalent species such as Sodium (Na^+) or Chloride (Cl^-) ions, dissolved or natural organic matter, and small colloids and viruses will still be able to pass through the filter. The suspended liquid is passed though at a relatively high velocity of around 1–3 m/s and at low to moderate pressures (around 100-400 kPa) parallel or tangential to the semi-permeable membrane in a sheet or tubular form. A pump is commonly fitted onto the processing equipment to allow the liquid to pass through the membrane filter. There are also two pump configurations, either pressure driven or vacuum. A differential or regular pressure gauge is commonly attached to measure the pressure drop between the outlet and inlet streams. The most abundant use of microfiltration membranes are in the water, beverage and bio-processing industries. The exit process stream after treatment using a micro-filter has a recovery rate which generally ranges to about 90-98 %.

Citation: Manimekalai, D., Deepika, S., Brema, K., Rajeswari, C. and Juliet Selvarani, A. 2017. "Microfiltration technology in waste water treatment", *International Journal of Current Research*, 9, (03), 47310-47312.

INTRODUCTION

Microfiltration can be defined as the separation of particles of one size from particles of another size in the range of approximately 0.01 µm through 20 µm. The fluid may be either a liquid or a gas. Membrane microfiltration (MF) or ultrafiltration (UF) systems of activated sludge is crucial part of a bioreactor process used in municipal wastewater treatment. Microfiltration media are available in a wide variety of materials and methods of manufacture. They can be rated either 'absolute' or 'nominal' depending upon the percentage of capture of particles of the same size or larger than the retention rating of the media. Membrane filters are generally rated as absolute media. They can be manufactured of various polymeric materials, metals and ceramics. Nominal media includes filters made of glass fibers, polymeric fibers, discrete particles (diatomaceous earth), ceramics, etc. However, even absolute media can be considered absolute only within a finite time span because of the possibility of bacterial grow-through.

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Microfiltration membranes can be divided into two broad groups based on their pore structure. These are membranes with capillary-type pores, hereafter called screen membranes, and membranes with tortuous-type pores, hereafter called depth membranes.

Membrane materials

- Polypropelene (PP)
- Polyethylene (PE)
- Polycarbonate (PC)
- Ceramic (CC)

Microfiltration is a pressure driven process. This is effective for removal of suspended solids. Two modes of filtration process.

- **Dead end filtration**– feed is forced normal to the membrane
- **Cross flow filtration–** feed is forced tangential to the membrane

Description of Technology: MF has the largest pore size (0.1 – 3 micron) of the wide variety of membrane filtration systems. UF pore sizes range from 0.01 to 0.1 micron. In terms of pore size, MF fills in the gap between ultrafiltration and granular media filtration. In terms of characteristic particle size, this MF range covers the lower portion of the conventional clays and the upper half of the range for humic acids. This is smaller than the size range for bacteria, algae and cysts, and larger than that of viruses. MF is also typically used for turbidity reduction, removal of suspended solids, Giardia and Cryptosporidum. UF membranes are used to remove some viruses, color, odor, and some colloidal natural organic matter. Both processes require low transmembrane pressure (1- 30 psi) to operate, and both are now used as a pretreatment to desalination technologies such as reverse osmosis, nanofiltration, and electrodialysis. MF membranes can operate in either crossflow separation or dead-end filtration. Cross flow separation is where only part of the feed stream is treated and the remainder of the water is passed through the membrane untreated. In dead-end separation, all of the feed water is treated. There are also two pump configurations, either pressure driven or vacuum-type systems. Pressure driven membranes are housed in a vessel and the flow is fed from a pump.

chloride may be added to form pinfloc and help improve rejection.

Maintenance

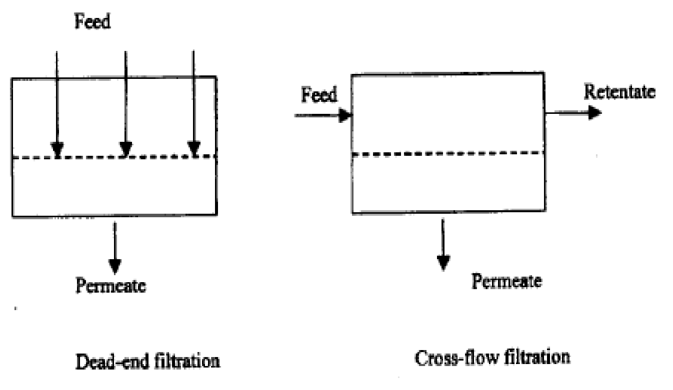
It is necessary to monitor filtrate turbidity to give a rough indication of membrane integrity. Membrane integrity can be tested through a pressure decay test. In this test, pressurized air is applied to the membranes at a pressure less than would cause the air to flow through the membrane, and the pressure decay is measured. Regular monitoring of membrane performance is necessary to ensure the membrane system is operating at the most effective loading rate and backwash regime.

Waste Disposal

Waste includes pretreatment waste, backwash flow, retentate flow (if applicable), and CIP waste. Waste streams are either discharged to the sewer or treated if discharging to surface waters.

	MF	UF	NF	RO
Membrane	Porous isotropic	Porous asymmetric	Finely porous asymmetric/composite	Nonporous asymmetric/composite
Pore size	50nm-10μm	5-20 nm	2-5 nm	---
Transfer mechanism	Sieving and adsorptive mechanism	Sieving and preferential adsorption	Sieving/electrostatic hydration/ diffusion	diffusion
Pressure applied (bars)	0.5-5	1-10	7-30	20-100

Vacuum-type systems are membranes submerged in non-pressurized tanks and driven by a vacuum created on the product side. Typical recoveries can range from 85% to 95%. Flux rates range from 20 to 100 gpd/ft^2 depending on the application. Backwashes are usually carried out for short durations (3 to 180 s) and occur in relatively frequent intervals min to several-hour). The frequency and duration depend on the specific application. A clean in place (CIP) can also be performed as a periodic major cleaning technique. Typical cleaning agents are sodium hypochlorite, citric acid, caustic soda and detergents. They can be initiated manually, and automatically controlled. CIP's occur when backwashing and chemically enhanced backwashes are not sufficient enough. Factors influencing membrane selection are, cost, percent recovery, percent rejection, raw water characteristics, and pretreatment requirements. Factors influencing performance are raw water characteristics, trans-membrane pressure, temperature, and regular monitoring and maintenance.



Pretreatment

A self backwashing 100 um strainer is often necessary to protect the membranes and moderate particulate loading. Depending on the raw water, a coagulant such as ferric

Waste streams being discharged to surface waters are typically processed for turbidity removal through settling ponds or other treatment systems. CIP waste is neutralized and usually combined with the rest of the waste.

Benefits

- A low pressure process
- Can typically produce water of satisfactory turbidity with feed waters exceeding 100 NTU.
- MF and UF can receive state removal credits for *Giardia* and viruses up to 3 log and 4 log, respectively. However, virus removal is typically 0.5 log or less due to the smaller pore size of MF and UF.3

Advantages

- MF with ceramic filter (0.8μm) is effective in removing the turbidity due to the suspended solids
- Ceramic filter removes BOD_5 up to 85%
- UV treatment on the turbidity was less effective, 29–32%, which is due to the lowering of the biological activity in the treated water.
- Ceramic membranes have good thermal, chemical and structural stability
- Backpulsing is used to remove fouling mechanism
- MF membrane used to achieve very low turbidity effluent
- Most microorganisms can be removed
- Recovery of enzymes

Environmental Issues, Safety and Regulation

Although environmental impacts of membrane filtration processes differs between applications a generic method of evaluation is the Life-cycle assessment (LCA), a tool for the analysis of the environmental burden of membrane filtration processes at all stages. It accounts for all types of impacts upon the environment including emission to land, water and air. In regards to microfiltration processes there are a number of potential environmental impacts to be considered. They include: global warming potential, photo-oxidant formation potential, eutrophication potential, human toxicity potential, freshwater ecotoxicity potential, marine ecotoxicity potential and terrestrial ecotoxicity potential. In general, the potential environmental impact of the process is largely dependent on flux and the maximum transmembrane pressure, however other operating parameters remain a factor to be considered. A specific comment on which exact combination of operational condition will yield the lowest burden on the environment cannot be made as each application will require different optimisations. In a general sense, membrane filtration processes are relative "low risk" operations, that is, the potential for dangerous hazards are small. There are, however several aspects to be mindful of. All pressure-driven filtration processes including microfiltration requires a degree of pressure to be applied to the feed liquid stream as well as imposed electrical concerns. Other factors contributing to safety are dependent on parameters of the process. For example, processing dairy product will lead to bacteria formations that must be controlled to comply with safety and regulatory standards.

Comparison with Similar Processes

Membrane microfiltration is fundamentally the same as other filtration techniques utilising a pore size distribution to physically separate particles. It is analogous to other technologies such as ultra/nanofiltration and reverse osmosis, however, the only difference exists in the size of the particles retained, and also the osmotic pressure. The main of which are described in general below:

Ultrafiltration (UF): Ultrafiltration membranes have pore sizes ranging from 0.1 µm to 0.01 µm and are able to retain proteins, endotoxins, viruses and silica. UF has diverse applications which span from waste water treatment to pharmaceutical applications.

Nanofiltration (NF): Nanofiltration membranes have pores sized from 0.001 µm to 0.01 µm and filters multivalent ions, synthetic dyes, sugars and specific salts. As the pore size drops from MF to NF, the osmotic pressure requirement increases.

Reverse Osmosis (RO): Reverse Osmosis is the finest separation membrane process available, pore sizes range from 0.0001 µm to 0.001 µm. RO is able to retain mostly all molecules except for water and due to the size of the pores, the required osmotic pressure is significantly greater than that for MF. Both reverse osmosis and nanofiltration are fundamentally different since the flow goes against the concentration gradient, because those systems use pressure as a means of forcing water to go from low pressure to high pressure.

Recent Developments: Recent advances in MF have focused on manufacturing processes for the construction of membranes and additives to promote coagulation and therefore reduce the fouling of the membrane. Since MF, UF, NF and RO are closely related, these advances are applicable to multiple processes and not MF alone. Recently studies have shown dilute $KMnO_4$ preoxidation combined $FeCl_3$ is able to promote coagulation, leading to decreased fouling, in specific the $KMnO_4$ preoxidation exhibited an effect which decreased irreversible membrane fouling. Similar research has been done into the construction high flux poly(trimethylene terephthalate) (PTT) nanofiber membranes, focusing on increased throughput. Specialised heat treatment and manufacturing processes of the membrane's internal structure exhibited results indicating a 99.6% rejection rate of TiO_2 particles under high flux. The results indicate that this technology may be applied to existing applications to increase their efficiency via high flux membranes.

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