Membrane filtration literature review example

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Introduction

Membrane filtration is a technique used to separate a liquid from any particles present in it. In membrane filtration, a liquid is passed through a semi-permeable membrane. The size of the pores on the membrane determines its permeability thereby enabling the membrane to act as a barrier to all particles larger than the pore sizes. Different approaches and systems can be employed in membrane filtration depending on the type and capacity of the liquid being purified but the overall goal is to obtain a clean liquid. Membrane filtration can be used in the treatment of wastewater, filtering milk during its processing among other applications. This literature review focuses on membrane filtration to purify water.

The importance of clean and safe water in the sustenance of life on earth remains paramount. Statistics from the United Nations show that more than 3. 4 million people die annually from water, hygiene and sanitation causes (Gupta & Imran, 8). More than 780 million people in the world do not have access to an improved source of water; this translates to one in every nine people requiring clean and safe water (Gupta & Imran, 8). This grim statistics can be attributed to pollution of natural water sources like rivers and lakes with industrial waste. Moreover, the changes in climate have led to low and unreliable rainfall in most parts of the world, drying up rivers and lakes thereby decreasing the amount of water needed to sustain quality life on earth (Zhang, 12).

It is therefore crucial that cost effective and efficient means of cleansing water be adopted to ensure people world over access clean and safe water. Membrane filtration is a cheap and effective method of cleaning water.

According to Zeman and Andrew (1996) membrane filtration can be used to effectively clean a wide variety of source waters at low costs and hence it's increasing preference over other methods of cleaning water. Some of the techniques of membrane filtration include ultrafiltration, microfiltration and nanofiltration. Membrane filtration processes are cost effective in that they do not require chemical additives. Moreover, they are energy efficient as they can be designed to take advantage of gravity for pressurization eliminating the need for pumping systems (Zeman & Andrew, 1996). This review is aimed at enhancing the understanding of membrane filtration in the world by assessing the treatment of brackish and seawater.

Relevance of Water Quality issue

Water is a limited resource whose importance is overwhelming. It is one the single-most valuable resources that finds usage in all areas of human life- domestic purposes, industries, hospitals, schools and all places people congregate. As such, the economic importance of water cuts across the entire society from government regulators to ordinary members of the society. Many regions in the world such as the Middle East and in developing countries lack water due to their reliance on natural water sources such as rivers, lakes and streams which are at times absent. They therefore resort to filtration of seawater. Apart from dissolved salt and other solids most water sources in the Middle East are contaminated with waste from offshore platforms (oilrigs) as gas and oil are explored and mined. Oil and other contaminants affect water sources either during the mining or the processing of the resources in the gulf region. Some water experts in North America handle filtration of fresh water while other parts of the world have to rely on seawater. Seawater such as the one relied on in the Middle East is highly saline. Therefore, a method to remove the water salinity such as Reverse Osmosis (RO) is used in the desalination process (Zeman & Andrew, 1996). RO process is so effective that it can even be used in the purifying of water for medical applications. Ultrafiltration (UF) and Microfiltration (MF) have also been found to be highly effective in the purifying of water contaminated with oil and other related contaminants.

Technical Review

Membrane filtration while used in the purifying of seawater involves allowing permeate from the sea to pass through a membrane leaving all solid contaminants in the membrane (Zhang, 18). The extent to which water is to be purified depends on the intended use of the water. For instance water meant for industrial use only needs mechanical filtration process while water meant for domestic use requires more elaborate and effective methods of purification such as Reverse Osmosis or Nanofiltration (Mallevialle, 21). The classification of RO and NF processes is usually based on the ability of the process to reject salt and other dissolved contaminants as well as their water flux (Zhang, 18).

Figure 1 and 2 showing the filtration process using NF/RO elements (Zhang, 24)

The main distinguishing factor between the NF and RO is the difference between feed pressures and the hydrostatic or osmotic pressures of the respective feed waters. While the NF requires low feed pressures due to its high permeability and the significantly low osmotic pressures of its feed waters. The RO on the other hand requires high feed pressures to differentiate its membrane permeability in feed water Total Dissolved Solids (TDS) level and osmotic pressure from the NF (Zhang, 21). Seawater contains high TDS and has an osmotic pressure of approximately 400psi therefore it would require significantly high feed pressures greater than 800 PSI. Brackish water has characteristics in between those of seawater and fresh water. It has a higher salt content than fresh water but lesser than that of seawater. Therefore, brackish water would have less osmotic pressure requiring lower feed pressures. The approximate feed pressure for brackish water lies between 100-250 PSI.

Water flux and salt rejection are the main factors that define the separation performance of a given membrane. The following equation represents the local water and salt fluxes through a membrane:

Jw = A (Δp – fos rs cm) (1)

Js = JwCp = Brs cm (2)Where:

Δp = applied hydraulic pressure (feed water pressure). A = Jw /Δp is the pure water permeability. B = the solute permeability.

fos = osmotic coefficient. rs = (1-cp/cm), the intrinsic or real solute rejection.

cp & cm = concentrations at the membrane-solution interface on permeate and feed sides (Jawor. et al., 2009).

In Eq. (1) fos rs cm represents the trans-membrane osmotic pressure, Δ and in Eq.(2) rs cm represents the solute concentration difference across the membrane, Δc (Jawor. et al., 2009). Δ can also be also expressed as:

= (n/V) RT = MRT

Where:

M = molarity grams/L C = gas constant 0. 08260 L atm/mol K

T = absolute temperature, K

When contaminants or products remain on the NF or RO membrane surfaces, they can be effectively fouled resulting in clogging the module flow. The feed water containing greater than 1mh/l of TSS (Total Suspended Solids), 1 ntu turbidity or 5. 0 (SDI) silt would affect the performance resulting in the need for frequent cleanings. In order to avoid this problem, NF and RO feed water should have less than 1. 2 ntu and less than 3. 0 SDI (Zhang, 21).

When treating oily wastewaters, bilge waters or chemical contamination in water, several studies have shown that UF and MF are the most effective membranes for use in filtration (Zhang, 22). One of the very important things to be considered when treating contaminated waste water is pore size. The pore sizes must have a pore size small enough to decrease the oil concentration below 15ppm (Parts per minute). The membrane must have high porosity. An ultrafiltration must have pore sizes in the range of 1-10 nm2 9 (Zhang, 22).

In the same manner the suspended solids clog the RO and NF membranes; they can also clog and block the feed channels resulting in the clogging of modulus flow. There are a variety of methods to use in the removal of solid waste or foulants from the surface of the membrane. These include air sparing, sponge ball cleaning, vibration and ultrasonication among others. Alternatively, chemical agents such as acids, alkalis, surfactants, formulated agents, enzymes and sequestering agents can be used (Gupta & Imran, 45)

Analysis of Technical Concept

In the use of membrane filtration as a method to purify water, osmotic pressure is one concept that can give the operator of the system an idea of how much water is likely to pass though a given standard membrane. The osmotic pressure is defined as the force per unit area that acts to prevent water or any other liquid from passing through a given membrane (Zeman & Andrew, 18). Moreover, the overall area and size of the membrane bears on the capacity of the membrane to handle different amounts of feed waters. It is also imperative that the membrane be stretched and maintained in a tight position to ensure that no parts are folded up since this can lead to faster clogging of the membrane due to reduced surface area for permeation. When the solvent movement is blocked by a membrane it gains momentum to be transferred to it and thus it will generate pressure to pass through it. Since the velocity is the same as that of a free molecule, the pressure will be equivalent to the pressure of an ideal gas of the same molecular concentration Therefore, the osmotic pressure the osmotic pressure , as shown in the formula mentioned earlier is: = (n/V)RT = MRT.

The following scenario can help elaborate on the application of this formula: The Dead Sea shores are considered to be the lowest points on earth. These shores have water that is 6 times more saline as compared to normal seawater at 400 meters above sea level. To obtain the osmotic pressure of a sample of water from the Dead Sea, the following solution applies: Assumptions: The solute consists completely of NaCl. Temperature = 23. 5 °C. Seawater contains 4. 21 grams of salts per liter. Solution: Salt per liter in Dead Sea = 6 x 4. 21g/L = 25. 26 g/L Molecular mass of NaCl = 22. 990

g/mol + 35. 453 g/mol = 58. 443 g/mol Moles of NaCl = 25. 26 g /58. 443 g/mol= 0. 4322 moles Molarity = moles/liter = 0. 4322/1 = 0. 4322 moles/L T = 23. 5 + 273. 15 = 296. 65 K R = 0. 08206 L atm mol-1 K-1 = (n/V) RT = MRT = (0. 4322moles/liter) (0. 08206 L atm mol-1 K-1) (296. 65K) = 10. 52 atm We must assume that the suspended particles perform an irregular movement- even if they are in a liquid with low viscosity. This is on account of the molecular movement of the liquid; if they are prevented from leaving the volume by the partition, the particle exerts a pressure on the partition just like molecules n a solution.

Summary

The use of membrane filtration technology has become a method of choice for many water purification plants due to its low cost and efficiency. Membrane filtration requires no chemical additives and can eliminate the requirements for motorization thereby requiring lesser energy. The use of membranes can be used in the purification of seawater and brackish water for use in areas with fewer sources of fresh water. The use of membrane filtration can be attributed to three factors. First there is the increased regulatory pressure providing better and effective treatment for waste and potable water. Secondly, the increased demand for water requiring exploitation of water resources from lower quality sources as compared to those previously relied on. Thirdly, the market forces surrounding the development of membrane technologies in wastewater and clean water industries. With the application of different formulae on osmotic pressure such as osmotic pressure () = (n/V) RT = MRT. Where M = molarity grams/L C = gas constant 0. 08260 L atm/mol K and T = absolute temperature, K In relation to other formulae it is possible to design effective filtration membrane systems for water that is contaminated with different materials ranging from oils to salts and dense particulate substances.

References

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