OVERVIEW ON REVERSE OSMOSIS TECHNOLOGY FOR WATER TREATMENT

Dr. Pavan Kumar Singh*

*Assistant Professor,
Department of Physics, Teerthanker Mahaveer University,
Moradabad, Uttar Pradesh, INDIA
Email id: pavan.engineering@tmu.ac.in

DOI: 10.5958/2249-7137.2021.02506.4

ABSTRACT

Reverse osmosis (RO) is becoming more used both in water treatment & salinity applications throughout the globe. It is a pneumatically process in which dissolved components in the input water are rejected by a semi-permeable membrane. Size exclusion, charging exclusion, and physiological interactions between the solute, solvent, and membrane all contribute to this rejection. The efficiency of the process is determined by operating factors as well as membrane and appropriate water characteristics. Iterative and hollow fiber modules are the most widely accessible. This article examines current developments in reverse osmosis technique in relation to the main problems that have arisen in this fast expanding distillation technique. Fouling research and control approaches, membrane characterization methods, and applicability to various water types and components present in the feed solution are among these problems. A review of key advancements in RO efficiency and mechanism modelling is also provided, as well as an introduction to current transport models. The two major problems of RO brine discharge as well as energy prices and recovery techniques are also addressed. Finally, future studies trends and requirements in the field of robotics are discussed.

KEYWORDS: *Brine, Characterization, Costs, Fouling, Models, Reverse Osmosis.*

INTRODUCTION

The latter has a very high density and therefore produces a lot of permeate, but it is far more susceptible to fouling. **[1]** Asymmetric membranes with one protective film or composite membranes with two sheets are also possible. The valence and intensity of the labelled are controlled by the functional groups incorporated into the polymeric material, whereas membrane hydrophobicity, charge, and roughness influence the degree of sorption of dissolved species. High-area components have recently become accessible, resulting in a smaller footprint and fewer pressure vessels. This article examines current developments in RO technology in terms of membrane fouling research and management, membrane characterization techniques, applicability to various water types and components, and RO efficiency and mechanism modeling. It also addresses the crucial problems of brine and prices. Finally, future research requirements are identified.**[2]**

DISCUSSION

Fouling of the membrane In RO applications, fouling is a major limiting issue. Pore blockage or solute adsorption on the membrane inducing it. Pretreatment of feed water is required to extend membrane life and avoid fouling. Coagulant, fine filtration, ultrafiltration, or microfiltration, scaling control, such as softness, and acid for pH management are common pretreatment methods. Membrane fouling may occur as a result of: (1) microbial development, (2) scaling, (3) soluble organic compounds, or (4) particle and colloidal debris forming compact cakes. Membrane surface smooth and hydrophobicity have been shown in many studies to decrease fouling susceptibility. Biofilms are formed when bacteria adhere to the membrane surface and embed themselves in an external polymeric material matrix generated by the microbes. The use of chlorine may prevent microbial development. **[3]**

RO membranes, on the other hand, are sensitive to free chlorine but extremely resistant to chloramines, that are frequently employed to inhibit bio growth. A novel platform of extremely chlorine tolerant polymers built on polysulfone, on either hand, was recently presented. High amounts of calcium, silica, phosphate, carbonate, and other ions induce scaling. It lowers production and lowers the quality of the permeate. Whenever the sum of the concentrations of the soluble components surpasses the solubility limit, as measured by saturation indices higher than 1, scale layer development becomes crucial.[**4**] Antiscalants are injected, the pH is lowered, and the recovery rate is slowed to reduce scaling. The high expense of antiscalants, as well as the higher brine quantities as well as the fact that excessive doses may encourage scaling, are all disadvantages. Feed flow reversal may be used to avoid scale by employing magnetic valves to change the feed flow direction, extending the reaction rate before scale crystals form and enabling the scale that has accumulated just on membrane surface to dissolve. Due to high organic food content (10–20 ppm) in wastewater effluent compared to the surface waters (2–5 ppm), organic fouling is a significant problem in RO treating wastewater effluent. An filtration or microfiltration stage may successfully control colloidal fouling. Table 1 highlights the main results of current fouling and scaling research. [**5]**

1. Methods of characterization of membranes:

Membrane characteristics and morphology may be studied using a variety of techniques. New methods are being developed to get a better knowledge of the polymer membranes at the molecular, microcrystalline, and colloidal levels. Estimating the molecular weight cut-off (MWCO), bubble gas transport, water flux and solute rejection measurement, mercury porosimetry, liquid vapor equilibrium, gas liquid equilibrium or permporometry, liquid solid equilibrium or thermo-porometry, and microscopic methods are all well-established methods.

The literature is replete with comprehensive evaluations of various methods. As a result, here's a quick rundown of the most important ones. The reject of a round solute of a given molecular weight is linked to MWCO, which is a pore size characteristic. Photogenerated electrons interactions between both the membrane and solutes, it is an overly approximate technique of determining actual membrane rejection properties. Methods are mainly based on bubbling pressure and gas movement assess a membrane's pore size distribution in wet circumstances, which is how they're really utilized, and therefore minimize structural change during sample preparation.[**6**]

Permporometry is based on the capillary forces of liquids in micropores, which allows you to fill holes of a certain diameter with liquid by adjusting the relative pressure. Pores with a size matching to the vapour pressure exerted are emptied and become accessible for gas transmission when the pressure is decreased. By monitoring the gas flow across the membrane while lowering the relative pressure, the average diameter of active holes may be determined.**[7]**

The Hagan-Poiseuille equation and the micro porous diffusion model establish the concept of the water permeability technique. This technique determines the mean pore radius as a function of water viscosity, membrane thickness and surface porosity, hydraulic permeability, water flow, and trans-membrane pressure. It's a quick and easy way to estimate pore size indirectly, particularly when it comes to regulating the spinning parameters during the production of hollow-fiber membranes. The major drawback is that quantifying surface permeability and pore tortuosity, which is defined as pore length divided by membrane thickness, is challenging. The pore size distribution is estimated in thermoporometry, where pore structures are also assessed in wet settings, by measuring the freezing and/or melting thermodiagram, since the temperatures of liquid crystallization and/or solid melt is lower in smaller pores.[**8]**

The hydrophobicity of a membrane, which is usually measured by the contact angle, is one of its most significant characteristics. The captive bubbles contact area or the sessile drop method, in which the angle, contacting radius, and altitude of a motile drop are examined via an optical microscope from its edge, yields this angle. Electrokinetic phenomena like streaming potential are often employed to describe a membranes surface or zeta potential, which is vital to understanding colloidal and interfacial events. Streaming potential, on the other hand, is influenced by electrolyte content and may be deceiving owing to ion sorption and surface conductance-related events. Hurwitz used contact angle titration to create a quick method for determining charge functioning. Alienating active membranes layers on quartz crystal monitor and thin glass substrates and measuring water mass uptakes and biaxial stresses against humidity was also utilized as acharacterisation technique. Another approach is indeed the EX-situ Scale Observation Detector (EXSOD) device, which uses automated picture analysis software to identify scale crystals before flow declines. Lee also used the fractional rejection idea with nonionic and charged solutes to estimate pore size ranges in terms of molecular mass. Finally, nuclear magnetic resonance (NMR) and electron scattering methods are two newly used characterisation techniques.**[9]**

2. *Applicability to certain water types and components:*

Semiconductor materials, food manufacturing, electricity production, pharmaceutical drugs, water recycling, biotechnology, helped produce water from oil production, textile, pulp and paper, mine as well as diary wastewater, procedure and boiler water, leather tanning, and beverage industry are just a few of the applications for reverse osmosis plants. The findings of current study on RO efficacy in treating various kinds of feed solution and components.

3. *Modeling of performance and mechanisms:*

System automation and dependability are important in RO plants, and automated systems are prone to valve or pump failure, membrane fouling, and sensor data loss. In the flow reversal operation, switching back to normal flow fast may create scale crystals on the membrane, and running the reversal for too long can produce scale on the output end of a membrane surface. Understanding these processes is therefore critical for ensuring consistent plant performance. The mass transfer rate in the presence of low operating pressures and thermodynamic limits for highly permeable membranes are two potential processes that regulate the RO process. Although there is no precise technique for determining the shape of the barrier layer, osmosis transport models may be classified into three categories:

(i) Irreversible thermodynamics models

(ii) Porous membrane models

(iii) Non - porous or homogeneous membrane models

(iv) Nonporous or uniform membrane models

(v) Non - porous or homogeneous membrane models

There are additional sophisticated transport models and linear dynamic models available, such as assuming a layer of polymer macromolecule clusters or incorporating the fractal character of pore distribution and shape in the barrier. Size restriction and charging or dielectric exclusion are two concepts that play a role in transport processes.**[10]** A sieving effect or steric hindrance rejects uncharged solutes, whereas solutes with a molecular weights cut-off (MWCO) are kept. Convection owing to a pressure differential and diffusion via a concentration difference across the membrane also contribute to the transfer of uncharged solutes. The mechanism for charged solutes is primarily regulated by charge exclusions or the Donnan effect. This is due to the interplay between the membrane matrix's fixed electric charges and the rejection of co-ions.

Irreversible thermodynamic models consider the membrane as a black box in which relatively slow processes approach equilibrium and solute and solvent fluxes are believed to be proportional to biochemical possible differences between both the sides of the membrane. In the classic hydrodynamic or pore model, the membrane is managed to cross by cylindrical pores of uniform diameter rp and length Ax, solute compounds are designed to simulate as rigid spheres of radius rs slowly moving inside the pores, Poiseuille flow occurs in the pore spaces of the solvent, steady-state flow occurs, and the solute concentration is so low that there is no interaction between solute molecules.

Modern pore models were created to improve on the traditional hydrodynamic model, which has two major flaws. First, the classical model employs the very same wall correction factor f(q) for both diffuse and convection flow, which isn't always the case, particularly when the liquid within the pores isn't stationary. Second, since the equation of motion must be averaged across the membrane, using the identical concentrations on both sides is inaccurate.

A quantifiable structure activity relationship (QSAR) has indeed been suggested to predict the rejections of developing pollutants by polyamide membranes in addition to the aforementioned models. The QSAR model combined data on membrane interactions, filration operating conditions, and solute properties to determine that salt rejection, equivalent molecular width, depth, and length, and the ratio of concentration levels of all organisms of a particle in octanol to the same species in the water phase were the most important variables. In other research, a flow reversal mechanism was suggested to avoid membrane scaling, and multi-criteria problems were combined to choose the best post-treatment technique. For an existing unit, the operational pressure differential from across membrane was found to be the sole important decision variable.[**11]**

4. RO costs:

The cost of reverse osmosis systems is still a significant issue, since it is determined by both energy usage and membrane replacement prices. Water production costs may be lowered by combining two or even more desalination techniques in a hybrid system. Energy recovery devices, like the Pelton wheel, turbocharger, pressure exchanger, and Grundfos Pelton wheel, have been designed to transfer the energy contained in the brine of RO systems back to the high-pressure pumps used in the water treatment process. Energy consumption may be decreased from 6–8 kWh/m^3 to 4–5 kWh/$m^3$and even further to 2kWh/m^3. Electric power, membrane replacement, and the chemical treatments are all cost factors that may be improved in the future. Automation systems may help to improve plant reliability and safety, as well as decrease membrane fouling and improve problem detection. Increases in the amount of RO units in series and the size of single RO units have also been shown to be effective. RO systems powered by gas/steam turbines are less expensive (0.43$/m3), and brine-staging units may improve water recovery while lowering specific energy usage.

5. Brine disposal:

The cost of disposing of reject brine is determined by brine properties, degree of treatment prior to disposal, disposal technique and environment, and salt volume. Direct sea release, well injection, and evaporation ponds are some of the current disposal options. The first two alternatives have a direct cost of 0.05–0.06 US$/$m^3$ of product water, but the latter option has a cost of 0.56 US$/$m^3$, however this is the only technique which allows for resource recovery. The indirect expense is unknown, since it is mainly determined by whether or not environmental harm occurs. As a result, dilution and salt recovery have been used to minimize the effect. By eliminating the scaling elements of input water, less brine is produced and excellent recovery rates are achieved. Furthermore, new RO membranes have been developed to handle the highly concentrated brine of a traditional RO system, recovering 60% of the brine as drinkable water with a TDS of b200 ppm and lowering total desalination costs by 15–20% and plant size by 30%.[**12]**

CONCLUSION

RO systems have been the subject of much research, and many improvements have been developed. These include using a photovoltaic solar system to power RO desalination and developing new membranes with novel materials, like the polyetherurea and polyamide–urea barriers, which have been shown to reduce microbial adhesion and therefore fouling potential. A pass matrix of polymers with engineered nanoparticles intended to pull in water ions yet reject virtually all pollutants, including dissolved salts, organics, and bacteria are examples of other membrane advances. Water is pumped through the membranes with less energy, and the new membrane foul more slowly than traditional membranes because they resist particles that normally cling to the surface.

Release of RO concentration or brine, management and decrease of membrane fouling, and use of membrane materials other than polymers are all areas that need further study. Chemically modified membranes' long-term fouling resistance has to be studied. Although the majority of research using membranes as a tertiary treatment procedure indicates complete removal, just a few studies on the efficacy of full-scale membranes treatment in eliminating endocrine disrupting chemicals (EDCs) and pharmaceuticals are known. Certain chemicals, such as unexplained organic halides generated by disinfecting and their possible elimination by RO, as well as membrane cleansing and susceptibility to humic acids, need more investigation. Another study topic is automating and accurate performance modeling, since reliability is essential in automated facilities that are susceptible to component failure. When it comes to costs, creating less power systems is a top priority. Existing cost estimation methods and tools are insufficiently precise and do not take into consideration all relevant factors. Further study on the direct and indirect costs of brine discharge is also required.

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