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Advancements in Technologies for Water Treatment

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Abstract : Seawater desalination and wastewater treatment for its reuse are rapidly evolving technologies as water crisis is one of the major issues around the globe. Different purification technologies and advancements in the processes, for instance variation in pretreatments for a better separation process and other related aspects are the areas frequently worked on. Evolution of water treatment techniques over last 40 years is fairly vast and new ideas related to nanotechnology are emerging in the industries with a view of more efficient functioning. The article focusses on the large scale water treatment techniques, their characteristics, relative principles, methodology and evolution. It also indicates the variety of membranes manufactured by established company over the years and emphasizes on their different properties and applications with changing compositions. The article narrows down to concentrate on the membrane separation processes as they are globally popular techniques in bulk water treatment.

Introduction:

Water scarcity is the major problem the world is facing and it is essential to develop efficient techniques that emphasize on waste water treatment or some methods of recycling and conservation of water. While the world faces this problem it is necessary to treat industrial waste streams, as water is usually the medium through which the sludge is expelled out of the industries [1]. This water mixture contains dissolved and dispersed hydrocarbons, surfactants, clay particles and salts. Simple filtration techniques like deep bed filtration, precoat filtration, cartridge filtration, etc. are not sufficient for removing impurities such as stabilized oil droplets(<10^-6m) from filtered water. Pharmaceuticals active compounds (PhACs) (human and veterinary) are emerging pollutants and have received a lot of attention in the past decade not only because of the persistence and potential toxicity of the substance but also due to their accumulation as a result of an uninterrupted introduction into receiving water bodies coming from wastewater treatment plants (WWTPs) effluents [2,3]. Combined treatment techniques such as membrane separation and advanced oxidation processes (AOPs) is an extensively implemented technology for complete removal of these pollutants because each technique complements the advantages and overcomes the challenges of the other [3]. Waste water treatment techniques such as membrane separation and oxidation processes (AOPs) are not implemented individually because neither have they proven to be technically viable as are not able to remove all the impurities nor are

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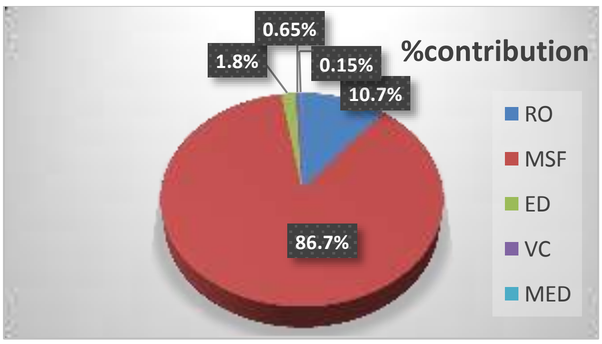
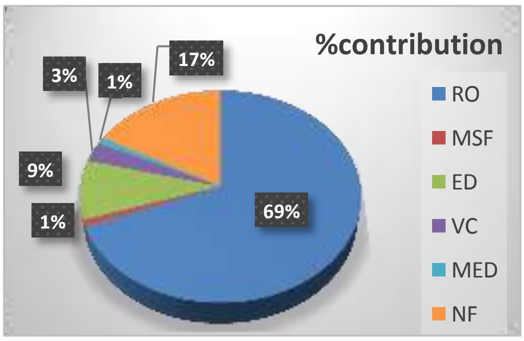
economical on a commercial scale. Membrane distillation (MD) is an emerging separation process based on the principle of vapor transport through the hydrophobic microporous membrane driven by the vapor pressure gradient across the membrane. This process can be used for various applications such as seawater desalination, industrial wastewater treatment, separation of volatile compounds from solvents, the concentration of non-volatile compounds and processing of dairy fluids. This article focuses on the different techniques involving water purification on the community scale and the constituents of these membranes which play an important role on the molecular level in the purification process. It emphasizes on the current types of membranes and processes used in the world and also the membrane composition, operating conditions, and its properties. The extensively used membrane separation techniques include microfiltration, ultrafiltration, nanofiltration, reverse osmosis, electrolysis, dialysis, gas separation, electrodialysis, vapor permeation, pervaporation, membrane distillation, and membrane contactors. Reverse osmosis (RO), nanofiltration (NF), and electrodialysis (ED) are the three membrane processes implemented for desalination of saline water. Reverse osmosis (RO) is currently the most broadly implemented demineralization method for large-scale seawater desalination and water reclamation activities.

Reverse Osmosis:

96.5% of Earth's water is found in seas and oceans and 1.7% of it in the ice caps according to the US survey [4]. Approximately 0.8% is estimated to be fresh water. The remaining percentage consists of brackish water which is slightly brine water found as surface water in estuaries and as groundwater in salty aquifers. Over a billion people are without clean drinking water and about 41% of the global population reside in regions with a shortage of water. Water recovery is an important aspect of the work for the personnel of desalination plant. Membrane technologies have brought about essential and vital improvements to desalination technology, as they happen to be more energy efficient and easier to scale-up than thermal methods. Reverse osmosis is a physical process in which a proportion of water from a supply under pressure (feed water) is passed through a semi-permeable membrane (permeator) resulting into product water (permeate) with the left over being almost all the impurities in the remaining water (concentrate). Reverse Osmosis is put into application mainly concerning desalination of saline water. Desalination is the process of removing salt from water to produce fresh water. One of the most important parameters of any desalination process is water recovery. It describes the amount of treated water that can be obtained from a constant volume of the contaminated feed stream. Higher water recovery leads to a lower amount of generated waste, higher energy efficiency because of less energy spent on pretreatment, and lower costs. A recovery ratio of 40% to 50% is generally estimated for seawater solutions but this ratio can vary significantly depending on the application and the salinity of the feed water, especially for brackish water which contains lower amounts of dissolved salts and therefore requires less energy. Freshwater is defined as containing less than 1000 mg/L of salts or total dissolved solids (TDS). Desalination processes fall into two main categories, thermal processes or membrane processes. Thermal desalination (distillation) has been implemented for hundreds of years for production of fresh water, but large-scale municipal drinking water distillation plants began to operate during the 1950s [5]. Countries in the Middle East pioneered the design and put into implementation seawater thermal desalination, first using a process called multi-effect distillation (MED) and later using a process called multi-stage flash (MSF) distillation [6]. Desalination process contributions are mentioned below in the form of a pie chart. RO enables the separation of salts and water molecules through a semi-permeable membrane as a result of the pressure gradient. Reverse Osmosis process is currently the leading technology for new large scale plants (capacity over 1000m^3 d^(-1)) and integration of Reverse Osmosis in seawater treatment routes continues to develop manifolds.



(a)



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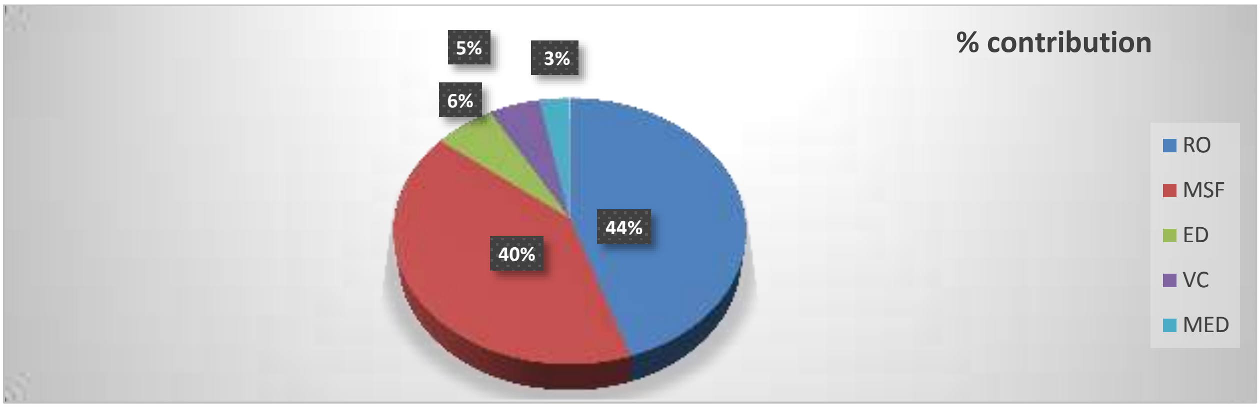


(c)

Fig1. Distribution of desalination production capacity by process technology [7,8,9]

Abbreviations for the pie chart:

(RO): Reverse Osmosis
(ED): Electro-dialysis
(NF): Nano-filtration
Distillation processes include,
(VC):Vapor compression
(MSF):Multi-stage flash
(MED): flash multiple effect distillation
(a): Middle East
(b): United States
(c): The world

Basic Principles of Reverse Osmosis:

Reverse osmosis is widely used for desalination technique for two types of water, brackish water (slightly saline) and sea water. Parameters like the type of membrane, the porosity of the membrane, Maximum operating temperature and pressure, Material of construction of membrane, pH range, etc. differ according to the type of input liquid properties and desired output liquid properties. Reverse osmosis technology can now produce fresh water (from seawater) at one-half to one-third of the cost of distillation techniques [10]. Brackish water desalination is even less expensive than seawater desalination. RO membranes do not have distinct pores that traverse the membrane and lie at one extreme of commercially available membranes. The polymer material of reverse osmosis membranes forms a layered, web-like structure, and water follows a tortuous pathway through the membrane to get to the permeate side

The fluid is forced through the pores by a positive hydrostatic pressure and this flow is termed as pore flow. The fluid flow depends upon the membrane porosity, the fraction of membrane volume that consists the void space and can contain liquid, and tortuosity, the ratio of the distance a molecule must travel through the membrane to the thickness of the membrane. The general relationship that describes transport due to pore flow and diffusion can be expressed as follows: [11]

$$N_{Ax} = \frac{\rho_A k}{\mu}\frac{dp}{dx} - D_{AB}\frac{d\rho_A}{dx} \qquad (1)$$

Where N_{Ax}stands for mass flux of A in the x-direction (perpendicular to the membrane surface), $\rho_A$is the mass density of A, k denotes permeability, m denotes viscosity, dp/dx is the pressure gradient in the x-direction, and D_{AB}denotes binary diffusion coefficient for the diffusion of A in B (the membrane).

Water transport across an RO membrane occurs in three separate steps: absorption onto the surface of the membrane, diffusion through the thickness of the membrane, and desorption from the membrane's permeate surface. As water moleculeare absorbed onto the membrane surface, the difference in water concentration (of the water-membrane system) across the membrane results in the transport of the water molecules down the concentration gradient to the other side of the membrane where permeate is formed. The water molecule then desorbs from the membrane and becomes part of the bulk permeate.

An RO membrane works by achieving a hydrostatic pressure greater than the osmotic pressure of the solution which proves to be the driving force of the separation process. The positive pressure difference induces a chemical potential difference (concentration gradient) across the membrane that leads to the passage of the liquid through the membrane against the natural direction of osmosis (the movement of water molecules from the region of high concentration to the region of low concentration), while the salts are retained and concentrated on the influent surface of the membrane. Some salt passage through the membrane does occur; salt passage increases for the same membrane with an increase in salt concentration and temperature. Mass transport through RO membranes can be described as follows:

$$N_A = L(\Delta p - \Delta \pi) \qquad (2)$$

WhereN_A is liquid flux across the membrane, L is the permeability coefficient, $\Delta p$is the transmembrane pressure difference, and $\Delta \pi$ is the osmotic pressure difference between the influent and thepermeate.The osmotic pressure depends on the solution concentration and the solution temperature.

$$\pi = CRT \qquad (3)$$

where C stands for ion concentration (molar units), R is the ideal gas constant, and T is the operating temperature.The permeability coefficient, L depends on characteristics of the membrane and is described as[12],

$$L = \frac{DSV}{RTl} \qquad (4)$$

where D is the diffusivity of water, S is the water solubility, V is the partial molar volume, R is the ideal gas constant, T is the operating temperature, and l is the membrane thickness. The osmotic pressure, p, in the concentrate is related to the recovery, R_w by, [13]

$$\pi_{concentrate} = \left(\frac{1}{1 - R_w}\right) \qquad (5)$$

also $R_w = \frac{Q_p}{Q_f}$ (6)

where,

$Q_p = permeate\ volumetric\ flow$

$Q_f = feed\ volumetric\ flow$[14]

Reverse osmosis recovery ranges from 35% to 85%, contingent upon feed water composition, feed water salinity, pretreatment, concentrate disposal options, and optimum energy design configuration.

An increase in feed pressure and an increase in permeate flux leads to an increase in recovery; higher optimized recovery necessarily requires increased membrane area.

When permeate flux increases, permeate salinity decreases due to a dilution increase [15]. However, a Reverse Osmosis module operating at a higher permeate flux often leads to the decline in flux, and operating an RO module at high recovery value without an increase in flux causes an increase in salt passage. During RO operation, concentration polarization occurs at the surface of the membrane, where dissolved ions accumulate in a thin layer of the feed water; concentration polarization is the ratio of the salt concentration at the membrane surface and the salt concentration in the bulk solution [16]. At any recovery, concentration polarization causes greater salt permeation through the membrane than what would be expected based on the bulk solution salinity. A membrane module in operation at higher recovery leads to the saturation of the concentrate or reject stream, thus increasing the concentration at the membrane surface. The local osmotic pressure increases as the salinity increases at the membrane surface. Consequently, the overall pressure difference between the hydrostatic pressure and the osmotic pressure decreases which in turn decreases the permeate flow, and the increase in salinity at the membrane surface increases salt transport through the membrane. In addition, phenomena such as salt precipitation and fouling can increase due to the higher local salinity.

RO membrane performance can also be measured by salt flux through the membrane, but it is more often measured by salt rejection. Salt flux is a function of salt concentration at a particular location, and salt transport occurs from a region of high salt concentration to a region of low salt concentration. Salt flux is described by, [17]

$$N_s = B\left(C_{feed} - C_{permeate}\right) \qquad (7)$$

where N_s is the salt flux across the membrane, B is a constant (similar to L in the water flux equation) that depends on membrane characteristics,C_{feed} is the ion concentration in the feed solution, and $C_{permeate}$is the ion concentration in the permeate.

Now,B is described by:

$$B = \frac{D_s K_s}{l} \qquad (8)$$

where Ds is the diffusivity of the salt particles through the membrane, Ks denotes the salt partition coefficient between the solution phase andthemembrane phase, and l is the thickness of the membrane.

Membrane salt rejection is a measure of overall membrane system performance, and membrane manufacturers typically state a specific salt rejection for each commercial membrane available. Salt rejection through an RO membrane (cross-flowoperation) is nominally given by:

$$R_s = \left(1 - \frac{C_{permeate}}{C_{feed}}\right) \times 100\% \qquad (9)$$

However, RO membranes packing is typically done in a spiral wound element, where several membranes are wound around a central tube and separated by spacers. In a spiral wound element, the feed gradually becomes concentrated from the entrance to the end of the tube and the salt rejection is described by:

$$R_s = \left(1 - \frac{C_{permeate}}{\frac{C_{feed}+C_{concentrate}}{2}}\right) \times 100\% \qquad (10)$$

Where $C_{concentrate}$ is the ion concentration in the concentrate. When membranes are tested using dead-end operation, Eq. (9) becomes: [21]

$$R_s = \left(1 - \frac{C_{permeate}}{C_{concentrate}}\right) \times 100\% \qquad (11)$$

RO membranes achieve NaCl rejections of 98–99.8% [18].The membranes do not retain the initial salt rejection throughout the course of the membrane's service life (up to 7 years with effective pretreatment) although membrane manufacturers offer high salt rejection membranes for RO plants. Normal membrane aging causes the salt passage (salt passage% = 100-R_s) to increase around about 10% per year [19], and other factors, such as operating temperature, salinity strength, target recovery, and methods of cleaning, can also affect salt passage.RO membranes have an overall negative surface charge and repel negatively charged ions or molecules [20]. As negative ions are repelled, more cations than anions are present near the membrane surface; this phenomenon creates an electric potential known as the Donnan potential [18; 21].The Donnan potential enhances the repulsion of ions from the membrane, but an increase in salinity or divalent ions decreases the Donnan potential effect on membrane salt rejection. The extent of the change in salt rejection of specific membranes can vary greatly depending on the composition of water and membrane charge strength.

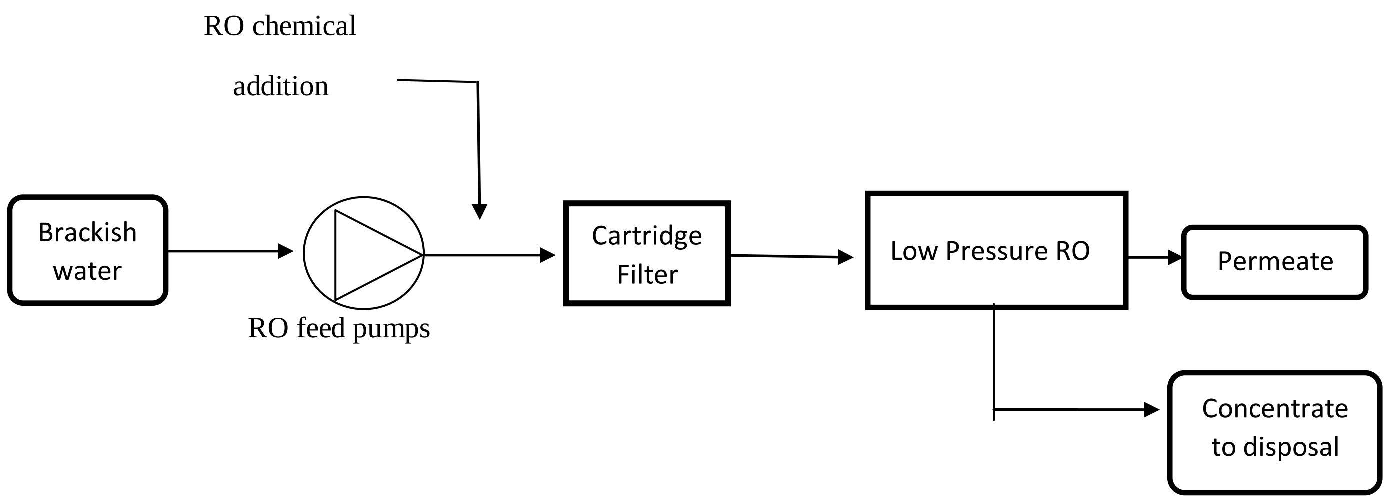
The salt rejection,R_s and the recovery,R_w are essential in calculating the concentration factor (CF) of the concentrate stream [22; 23; 24].

$$CF = \left(\frac{1}{1-R_w}\right) \times [1 - R_w(1 - R_s)] \quad (12)$$

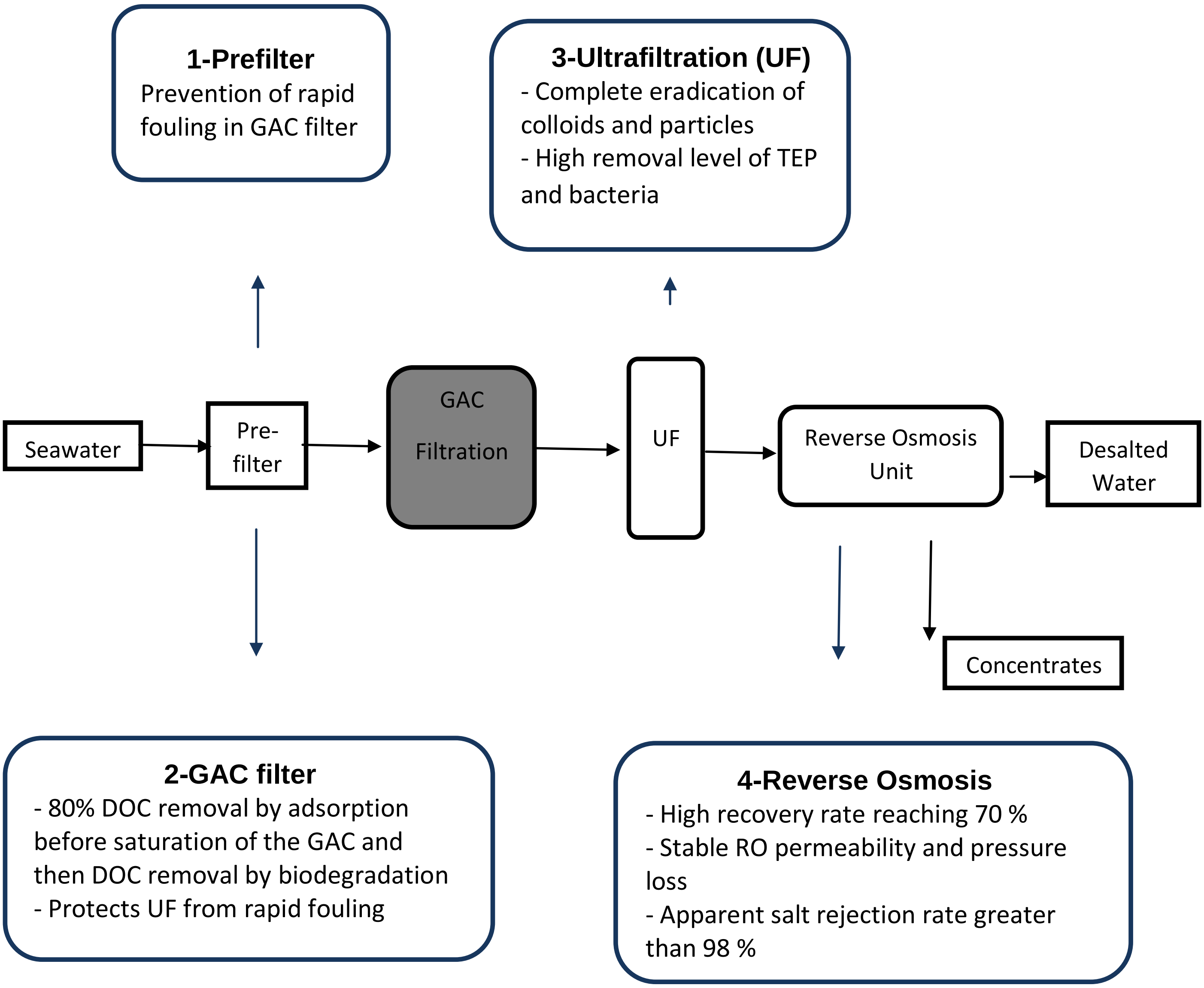
CF increases appreciably as recovery increases; small changes at high recovery can greatly increase the TDS concentration in the concentrate.

Methodology:

Membrane fouling is a process whereby a solution or particles in the solution accumulate on the membrane surface or in membrane pores in the course of the process which leads to a decline in the efficiency of the separation process. Bio-fouling of RO membranes usually results when a particular bacteria their potential nutrients like dissolved organic carbon (DOC) and precursors such as transparent exopolymer particles (TEP), found in natural seawater, and are not successfully removed by the pretreatments. Consequently, in this study, coupling granular activated carbon (GAC) adsorption and ultrafiltration are put into application as a pretreatment before RO is proposed on a large-scale desalination plant. The two-month study of this desalination plant showed that the GAC bed could highly reduce by 20 % to 80 % DOC concentration. Ultrafiltration could successfully retain most of TEP and bacteria before RO treatment. This impurity (consisting of biological and organic waste) removal leads to increase in efficiency and service life of an RO membrane. For the production of drinking from seawater among all the desalination processes, reverseosmosis (RO) is by far the most efficient and reliable process. Process intensification is crucial in determining the drastic improvements in decreasing the size of the equipment and consumption of energy, raising plant efficiency, reducing capital costs, minimizing waste production, increasing safety andreducing environmental impacts [25; 26]. For seawater desalination, good pretreatment is essential before RO to maintain its performance in terms of permeate flux and retention rate and to increase the usage tenure of theRO membrane, which is very sensitive to fouling, especially biological fouling [27].Ultrafiltration (UF) is a physical separation process in which a low-pressure gradient is maintained through a membrane with pores of approximately 0.01 µm. The major advantage of UF is that it is responsible for intensification of the plant and produces a consistent quality of permeate irrespective of the condition of the feed water [28]. It particularly enhances the removal of colloids, particles, and micro-organisms in sea water [29; 30].However Ultrafiltration alone is not sufficient, some researchers report that UF removes only around 10 % of marine dissolved organic compounds [31;32]. Water for treatment is pumped from the UF permeate buffer tank by a booster pump and a high-pressure pump and then made to pass through a 5-µm cartridge filter before entering the reverse osmosis module.The process is mentioned below in terms of a flowchart.



Now for efficient seawater desalination a suitable pre-treatment prior to reverse osmosis is required[33; 34]



As we can infer from the flowchart different types of feed water alters the type of pretreatment, properties like salinity and amount of TDS (Total Dissolved Salts) are the factors responsible for the type of pretreatment implemented.

In order to assess the applicability and to replace the conventional pre-treatments Electrocoagulation (EC) process was used as an alternative pre-treatment method to mitigate membrane fouling prior to seawater desalination by reverse osmosis process. Electrocoagulation is an electrochemical process where metal cations are produced in situ as a result of the electro-dissolution of sacrificial anode under the influence of electric current applied between the electrodes. The metal cations are susceptible to hydrolysis thereby leading to the metal hydroxide species, depending on the pH of the aqueous medium, which will behave as coagulants and/or adsorbents and/or an electrostatic attractor of pollutants for their removal.In general, an RO membrane pre-treatment system will be comprised of one or more of the following unit operations, as a function of the source water quality:

- Intake or well screening
- Chemical dosing for biological control
- Flotation
- Coagulation/flocculation and associated chemical addition
- One or more stages of filtration, often using a range of effective pore sizes
- Chemical addition for scale inhibition and/or chlorine reduction

Material of construction of RO membranes:

Reid and Breton [35] and Reid and Kuppers [36] demonstrated a century ago that cellulose acetate (CA) polymers manifested salt rejection and thus was thought to be a useful candidate for desalination. But the flux of these membranes was too low to be economically viable. Loeb and Sourirajan [37] discovered the first practical RO membrane with high flux that constituted an asymmetrical cellulose acetate (CA) film.It was construed that salt rejection occurred in a thin dense discriminating layer on the surface of CA membranes [38]. This crucial observation led to the concept of the thin-film composite(TFC) membrane design.By the mid-1960's TFC membranes consisting of a thin (about 250 nm) permselective polyamide (PA) film cast onto a porous polysulfone (PS) support were discovered [39].While extensive advancements have been made in polyamide (PA) membrane performance and durability over the past several decades, understanding the structure of the membrane and its function on the molecular and atomic level has not grown as rapidly. Reverse Osmosis membrane market is dominated by thin film composite (TFC)polyamide membranes consisting of three layers: A polyesterweb acting as structural support (120–150_m thick), a micro porousinterlayer (about 40_m), and an ultra-thin barrier layeron the upper surface (0.2_m) [40]. The polyester support web lacks regularity and is porous and thus cannot provide direct support for the barrier layer. Therefore, between the barrier layer and the support layer, an additional micro-porous interlayer of polysulfonicpolymer is applied to enable the ultra-thin barrier layer to withstand high pressure compression. The thickness of the barrierlayer is reduced to minimize resistance to the permeatetransport. Membrane pore size is normally less than 0.6nm toachieve salt rejection consistently higher than 99%. The selectivebarrier layer is most often made of aromatic polyamide, for example via interfacial polymerization of 1,3-phenylenediamine(also known as 1,3-benzenediamine) and the tri-acid chloride ofbenzene (trimesoyl chloride) [41]. With improved chemical resistance and structural robustness, it offers reasonable tolerance to impurities, enhanced durability and easy cleaning characteristics.T here are four major membrane module suppliers which provide RO membranes forlarge scale desalination plants, namely DOW, Toray, Hydranautics and Toyobo.

DOW is a leading supplier of RO membranes and the different types of membranes produced by DOW are mentioned below with respective physical and chemical properties are mentioned below.

Table 2. Dow Chemical Company properties and operating conditions. [42]

The DOW Company.						
Reverse Osmosis						
Type of feed water	Types	Material of Construction	Max Operating Temp	Max Operating Pressure	pH Range	Stabilized Salt Rejection (%)
Brackish Water < 4" Elements	BW30-2540	Polyamide Thin-Film Composite	113F (45C)	600 psi (41 bar)	2 to 11	99.5
	TW30-2026	Polyamide Thin-Film Composite	113F (45C)	600 psi (41 bar)	2 to 11	99.5
	TW30-2514	Polyamide Thin-Film Composite	113F (45C)	600 psi (41 bar)	2 to 11	99.5
	TW30-2521	Polyamide Thin-Film Composite	113F (45C)	600 psi (41 bar)	2 to 11	99.5
	TW30-2540	Polyamide Thin-Film Composite	113F (45C)	600 psi (41 bar)	2 to 11	99.5
	XLE-2521	Polyamide Thin-Film Composite	113F (45C)	600 psi (41 bar)	2 to 11	99
	XLE-4021	Polyamide Thin-Film Composite	113F (45C)	600 psi (41 bar)	2 to 11	99
Brackish Water = 4	BW30-365 Element	Polyamide Thin-Film Composite	113F (45C)	600 psi (41 bar)	2 to 11	99.5
	LC HR-4040	Polyamide Thin-Film Composite	113F (45C)	600 psi (41 bar)	2 to 11	99.7
	LC LE-4040	Polyamide Thin-Film Composite	113F (45C)	600 psi (41 bar)	2 to 11	99.2
	TW30-4014	Polyamide Thin-Film Composite	113F (45C)	600 psi (41 bar)	2 to 11	99.5
	TW30-4021	Polyamide Thin-Film Composite	113F (45C)	600 psi (41 bar)	2 to 11	99.5
	TW30-4040	Polyamide Thin-Film Composite	113F (45C)	600 psi (41 bar)	2 to 11	99.5
	XLE-4021	Polyamide Thin-Film Composite	113F (45C)	600 psi (41 bar)	2 to 11	99
	XLE-4040	Polyamide Thin-Film Composite	113F (45C)	600 psi (41 bar)	2 to 11	99
Brackish Water = 8	BW30-365	Spiral-wound element with polyamide	113F (45C)	600 psi (41 bar)	2 to 11	99
		thin-film composite membrane				

Table 3.Applications of the membranes used in DOW Company. [37]

Type of feed water	Used In	Advantages
Brackish Water Reverse Osmosis < 4" Elements	Commercial water treatment systems	High flux results in high yields
	Food service	High rejection provides good water quality
	Medical and research institutions	Durable with good cleanability for long element life
	Hospitality industry	
Brackish Water Reverse Osmosis = 4	Industrial water demineralization	High rejection gives good water quality
	Production of municipal drinking water	Durable with good cleanability for long element life
	Water reuse	
Brackish Water Reverse Osmosis = 8	Industrial water demineralization	Decades of proven performance
	Production of municipal drinking water	Delivers high quality permeate water while minimizing unit cost
		Offers the most effective cleaning performance, robustness and
		durability due to its widest cleaning pH range (1 – 13) tolerance
		and the support of Dow technical representatives

Other techniques used as major water purification techniques on community-scale include, Multistage Flash Distillation (MSF), Granular Activated Carbon (GAC) filtration, Nanofiltration(NF), etc. Ultrafiltration is usually used as a pretreatment process.

Multi-stage Flash (MSF):

The capacity of membrane based desalination technologies (RO) has surpassed thermal based processes (MSF and multi-effect distillation MED) mainly due to their lower cost of operation and investment [43-48]. Although the current desalination market has bent towards the reverse osmosis (RO) process, the thermal process is still found to be a major in the Gulf countries. The thermal desalination processes are generally classified into two processes namely, multi-stage flashing (MSF) and the multi-effect distillation (MED). From the perspective of thermal efficiency, the MED type process is more advantageous over the MSF type, but the MSF type process is more feasible for a large capacity in the market share of the operated desalting plants up to 2000, the MSF process globally covered about 44% while the RO process coped with about 42%. In the case of MSF and MED processes, plants cannot operate more efficiently at Top Brine Temperature (TBT) because of the issues such as reactor scaling [49; 50]. However, they indicated that the RO process overwhelmed the thermal process in the newly contracted desalination plants [51]. The installed RO plants have reached two times of the installed thermal process based plants based on the freshwater production capacity [52; 53]. Many remote and coastal areas do not possess resources of electric power for the production of potable water by the implementation of conventional desalination techniques such as multi-stage flash, reverse osmosis and vapor compression [54–57]. Conventional processes like MSF and RO require large amounts of energy in the form of thermal energy (MSF) or electric power (RO) for functioning [58].

The MSF plant consists of two main sections, the heat rejection, and the heat recovery section, comprising of NJ and NR-stages, respectively. The rejection section is installed to remove the excess thermal energy from the plant thereby cooling the distillate product and the concentrated brine to the lowest attainable temperature. At the end of the first rejection stage, the seawater stream gets divided into two parts. The first one is expelled back to the sea, whereas the second one is mixed with the recycle brine. The combination of both the streams pass through a series of continuous heat exchangers and its temperature rises as it proceeds from right to left across the stages finally passing through the brine heater. The brine temperature elevates to its maximum value which is near to its saturation temperature at the maintained pressure of the plant. At this point, the flashing brine is passed into the first heat recovery stage through an orifice where it is superheated and flashes giving a stream of desalted water vapour. This vapor is carried forward to the tube bundle of the heat exchanger where it undergoes condensation and drips into the product tray, where the distillate is collected. The brine then flows into the next stage and this process is repeated; at the end of the last rejection stage, an output of concentrated brine is discharged. Two main recycle loops are present. In the first loop, a portion of concentrated brine is recirculated to merge with the make-up seawater flow, while in the second one part of the cooling water from the rejection section is recycled back to maintain a constant seawater temperature at the entrance of the rejection section. This arrangement enhances the minimization of the load on the deaerator and to the chemical water treatment, thus improving the overall economics of the process.

Nanofiltraton:

Nanofiltration (NF) is an is an effective pressure-driven membrane separation process, first put into practice in 1980, whose performance lies between that of reverse osmosis (RO) and ultrafiltration (UF). NF membranes have a pore size of one nanometer and a corresponding molecular weight cut-off (MWCO) of around about 300 to 500 which lies between that of RO and ultra-filtration [59-62]. In comparison with RO process, it functions not only under lower operation pressures, higher water fluxes, and lower investment but also with high rejection rates for scale formation bivalent ions, especially anions [63–65].With these characteristics, it is gaining popularity quickly in the seawater desalination field [66]. Llenas et al. [67] investigated the performance of NF membranes (NF270, NF200, NF90 (Dow Filmtec)) and they found them to be more suitable for the pretreatment in RO desalination. Commercially available NF membranes are dominated by polyamide membranes manufactured by interfacial polymerization and many researchers are working on improving the flux of these membranes [68-70]. In order to obtain high salt rejection, NF membrane surface has been cross linked to narrow the pore size. Chung et al. produced an NF membrane by crosslinking P84 porous hollow fiber membrane with polyethylene imine [71]. Despite the increase in salt rejection due to cross linked membranes the membrane permeability decreases. Other researchers have highlighted the ability to increase the rejection rate by slowing down the phase separation rate [72-75]. Most of the results are in favor with the relationship between membrane flux and salt rejection [76-78]. NF membranes have varied applications [79].The major applications of NF include water treatment for production of potable water as well as treatment of wastewater and its reuse [80]. NF technique can be used for all kinds of water treatments including groundwater, surface water, and wastewater and alternatively as a pretreatment for desalination [81-83]. The introduction of NF as a pretreatment is considered as a vital development in the desalination process. NF membranes have the ability to remove turbidity, microorganisms, and hardness, as well as a fraction of the dissolved salts. This provides a much more energy-efficient process compared with RO resulting due to the significant lowering of operating pressure[84]. Thin-film nanocomposite (TFN) membranes are fabricated by consolidating nanomaterials into the active layer of TFC membranes by the process called doping into casting solutions or by a surface modification which is known as interfacial polymerization; their advantages are enhanced separation, reduction in fouling, antimicrobial activity, and some other novel properties. For TFN membranes, the particles most used are zeolites, carbon nanotubes, TiO_2, silica, and silver [85-89]. Tiraferri, Vecitis, and Elimelech (2011) [90] used covalently bonded single-walled carbon nanotubes (SWCNT) to a TFC membrane. Nanofiltration membranes manufactured by DOW and their properties and operating conditions are mentioned below.

The DOW Company						
Nanofiltration						
Type of feed water	Types	Material of construction	Max Operating Temp	Max Operating Pressure	pH Range	Stabilized Salt Rejection (%)
Nanofiltration 8" Elements	NF345HP-370	Spiral-wound element with polyamide	113°F (45°C)	600 psig (41 bar)	2 to 11	98.50%
		thin-film composite membrane				
	NF90-400/34i	Spiral-wound element with polyamide	113°F (45°C)	600 psig (41 bar)	2 to 11	98.70%
		thin-film composite membrane				
	NF270-400/34i	Spiral-wound element with polyamide	113°F (45°C)	600 psig (41 bar)	3 to 10	97
		thin-film composite membrane				
Nanofiltration 4" Elements	NF245-3838/30-FF	Polypropylene thin membrane	122°F (50°C)	800 psig (54.8 bar)	2 to 11	-
	NF245-3840/30-FF	Polypropylene thin membrane	122°F (50°C)	800 psig (54.8 bar)	2 to 11	-
	NF270-4040	Polyamide Thin-Film Composite	113°F (45°C	600 psi (41 bar)	2 to 11	>97.0
	NF90-4040	Polyamide Thin-Film Composite	113°F (45°C	600 psi (41 bar)	2 to 11	>97.0

The DOW Company			
Nanofiltration			
Type of feed water	Types	Uses	Advantages
Nanofiltration 8" Elements	NF345HP-370	Recovery of metals from acid mine drainage streams	1) Helps reduce the acid mine drainage (AMD) stream, ultimately reducing CAPEX and OPEX
			2) Enhances concentration and recovery of valuable metals from AMD waters
			3) Provides high permeability, and low pH stability enabling longer element lifetime and more reliable operation
	NF90-400/34i	Production of drinking water Water reuse Industrial water demineralization	1)Delivers high productivity and cleanability due to its high active area and widest cleaning pH range (1 – 13) tolerance 2)Offers a nanofiltration technology that selectively removes these components, color and operates at low operating pressures 3)Including iLEC™ interlocking end caps, reducing system operating costs and the risk of o-ring leaks that can cause poor water quality
	NF270-400/34i	Production of municipal drinking water	1)Provides organic removal with partial softening in order to maintain a minimum level of hardness for organoleptic properties and preservation of distribution networks 2)Delivers high productivity, cleanability and low energy consumption due to its high active area and wide cleaning pH range (1 – 12) tolerance 3)Includes iLEC™ interlocking end caps, reducing system operating costs and the risk of o-ring leaks that can cause poor water quality
Nanofiltration 4" Elements	NF245-3838/30-FF	Desalting food products Dewatering and concentration of liquid foods	1)High water flux to reduce energy usage and cost 2)food-grade design and construction
	NF245-3840/30-FF	Same as above	Same as above
	NF270-4040	Production of municipal drinking water	1)Good organic (NOM) removal 2)Partial softening preserves water character 3)High flux results in high yields
	NF90-4040	1)Production of drinking water 2)Demineralization in commercial applications	1) High flux results in high yields 2) Low energy usage reduces power consumption and costs 3)Durable with good cleanability for long element life

The above mentioned water purification are the most frequently used techniques on large scale. Rest are implemented for specialty cases.

Conclusion:

Pure drinking water is a basic need for life existence and sustainability and thus large scale seawater desalination is the major method of meeting this problem. Nanotechnology is the recent advancements that comprises of use of development in application of carbon nanotube CNT and also the solar desalination technique is developing manifolds. Solar ponds are used as thermal batteries both during the day and night for the conservation of energy and prevention of toxic hazards that are released during primary wastewater purification process. Solar desalination and purification is one of the major advancement in the purification technology. Reverse osmosis though is the primary and most efficient technique suitable for a new water purification plant installations. It is the most convenient and economical technique for water treatment on a large scale. Diverse treatments prior to the RO process are developing over the years with the motive of fouling control thereby increasing the service life of the RO membranes. Development in membrane technology is leading to significant increases in optimum production and cost savings.Various nano-structured RO membranes have been proposed to have appreciable permeability and it is believed that nanotechnology can bring about the revolutionary change for the problem of water scarcity. There is a growing trend of applying nanofiltration and reverse osmosis units (NF/RO) to municipal wastewater treatment plant(MWTP) effluents and other water matrices (groundwater, surface and drinking water), specifically for the removal of MCs (priority and emerging contaminants. With the rapid growth in the water treatment technologies it is only fair to say that water purification is a global issue which is being dealt with by rapidly developing techniques with the major contribution currently being from RO modules.

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