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Desalination of Seawater

Tushar Kahandal[1], Tushar Ekhande[1], Saurabh Hawaldar[1],Shrikrushan Jadhav[1]and Prof. Ashwini Kharde[2]

1Student of Department of Chemical Engineering and 2 Prof. of Department of Chemical Engineering,
P. Dr. V. V. Patil Poly. College, Loni, Pravaranagar, Ahmednagar - 413736.

ABSTRACT

1.
Effort made by authorities and researchers, multiple countries with poor economic One of the main problem our actual society faces is the shortage of water. Despite the great resources are experiencing serious difficulties derivatives of water scarcity. Desalination provides a feasible solution for inland and coastal areas. Through literature and reviewed articles analysis the reader will meet the actual issues regarding .designing desalination plant. And moreover with reverse osmosis (RO) processes. Which are the main arguments of this work. One of the big deals is the environmental concern when handling the concentrate disposal. Another important point about desalination processes

Is the increasingly interest in coupling the units with renewable energy sources (RES). The results point out that regardless of the efforts made until today, Additional achievement is required in fields such as membranes structure materials for RO method, concentrate disposal system , governmental water policies review and update , and greater dis1inction researchers between brackish water and seawater RO desalination processes. Taking into consideration the previous outcomes it is finally concluded that some particular steps must be accomplished when beginning a desalination plant design.

In recent years, numerous large-scale seawater desalination plants have been built in water-stressed countries to augment available water resources, and construction of new desalination plants is expected to increase in the near future. Despite major advancements in desalination technologies, seawater desalination is still more energy intensive compared to conventional technologies for the treatment of fresh water. There are also concerns about the potential environmental impacts of large-scale seawater desalination plants. Here, we review the possible reductions in energy demand by state-of-the-art seawater desalination technologies, the potential role of advanced materials and innovative technologies in improving performance, and the sustainability of desalination as a technological solution to global water shortages

Keywords: desalination, thermal desalination, membrane desalination, reverse osmosis, renewable energy sources

1. INTRODUCTION

Seawaterdesalinationhasthepotentialtobeamajor21stcenturysourceofurbanpotable water. In addition to advancements in the technology of desalination, public attitudes toward desalination will help shape its ultimate role in urban water supply. A growing literature on publicperceptionofemergingwatersupplieshasexaminedresponsestoseawaterdesalination in general, as well as attitudes toward new facility installation at the planning/proposal stages, and during facility operational stages. Studies from different countries topically overlap but havereachedvaryingconclusionsonpublicattitudes andtheirdrivers.Demographicvariables appear to be minimally helpful in predicting support for desalination, while an individual's activeuseofmarineresourcesandstrongoceanattachmentareconsistentpredictorsoflackof support. Coastal residents seem aware of subsurface ocean processes and are opposed to subsurface infrastructure development that impacts these processes. Positive or negative attitudes toward the public agencies and private companies regulating or proposing/operating desalination facilities influence whether the public supports the projects themselves. While residents of affluent coastal communities demonstrate tin-my-backyard (NIMBY) attitudes, there are mixed results when the desalination facility is located with a coastal power plant in an industrial coastal area. Efforts to mitigate CO2 emissions from California desalination facilitiesdidnotmeetwithpublicsupport.Numerous areasforfutureresearchwillhelpclarify public attitudes toward seawater desalination and could influence public policy processes for approving and setting operating conditions for newfacilities.

Humans cannot drink saline water, but, saline water can be made into freshwater, for which there are many uses. The process is called "desalination", and it is being used more and more around the world to provide people with needed freshwater. Distillation desalination is one of mankind's earliest forms of water treatment, and it is still a popular treatment solution throughout the world today. In ancient times, many civilizations used this process on their ships to convert sea water into drinking water. Today, desalination plants are used to convert sea water to drinking water on ships and in many arid regions of the world, and to treat water in other areas that is fouled by natural and unnatural contaminants.

Distillation is perhaps the one water treatment technology that most completely reduces the widest range of drinking water contaminants.

In nature, this basic process is responsible for the water (hydrologic) cycle. The sun suppliesenergythatcauseswatertoevaporatefromsurfacesourcessuchaslakes,oceans,and streams.Thewatervaporeventuallycomesincontact withcoolerair,whereitre-condensesto form dew or rain. This process can be imitated artificially and more rapidly than in nature, usingalternativesourcesofheatingandcooling.Sea waterdesalinationisareliablesolutionto the shortage of potable water in numerous regions in the world. However, the separation processisenergyintensiveandexpensiveandhasahighcarbonfootprint[Darwishetal.2009]. The production of freshwater using renewable energy sources (RES) is thought to be a viable solution, but the technology is still expensive and not mature. The application ofsolar-thermal energyforseawaterdesalination[Alarcón-Padillaetal.,2008;andHardimanetal.,2009]is in

Particular interesting due to several reasons such as: a) solar energy is abundant in almost all regionsthatpotablewaterisscarce,b)whilewindenergyandphotovoltaicsolarcellscanonly be used indirectly (i.e., generatingelectricityfollowed(desalination), solar- thermal energy systems can be used directly as well as indirectly for large-scaleseawater

Desalination. Herein, the use of solar energy for combined power generation and seawater desalinationisstudied.Anewreceiverwithintegralstorage[SlocumandCodd,2009;Slocum et al., 2010], known as CSPD, is considered. This system provides the thermal energy to a downstream steam cycle and a multi-effect distillation (MED) unit, a thermal-based seawater desalination system, see Figure 1. The modelling of the plant and its validation are given in [Ghobeity et al., 2010]. The article focuses on optimization of operation. Particular emphasis is given to the influence of energy policy on optimal plant operation. Two case studies are presentedforCyprus,oneusingthecurrenteconomical parametersandincentivesandtheother using a time-variable feed-in-tariff (TVFIT). This demonstrates the effect of regional renewable energy policies on optimal operation of a cogeneration solar-thermalplant.

[1] Many human activities, such as drinking, agriculture, sanitation, among others, require significant amounts of water. Fortunately, in many cases centers of population are located near sources of useable water. However, oceans, which cover more than 70% of the earth's surface and contain 97% of earth's water, have salt water. [1] Since this salty water is unsuitable for many application, it must be desalinated (have the salt content reduced or eliminated) before it can be used. Several years ago, more than 13000 desalination plants processed 12 billion gallons of water daily. [2] However, desalination tends to be energy intensive, causing significant economic and ecologic impact from desalination.

[2] He market for water desalination has witnessed a significant upturn during the last years. Driven by the increasing world population and the diminishing freshwater sources, a resultofglobalwarming,desertationandenvironmentdestruction,manycountriesintheworld haveconstructedorareconstructingwaterdesalinationplantsforwatersupply.Meanwhilethe technological innovations have been largely raising the energy efficiency of the desalination process and reducing the running costs, which are always the key concern for the large-scale water desalination. Especially, the innovations in energy utilization, such as solar energy and terrestrial heat, the advances of nanotechnology and molecular technologies have been elevating the outcome efficiency so largely that the desalination is really becoming a realistic solutionforthewatershortageinmanypartsoftheworld.Themarketvolumehasbeensoaring from$2.5bnin2002to$3.8bnin2005withagrowthrateover15%perannum.Thesefigures are only plant and equipment but not the whole value chain. The market figures for the whole market,youwillfindinthestudy.Itispredictedthat thisfastdevelopmentisgoingtolastand evenaccelerateforatleastthenexttenyears.Themarketworldwideistoreachnearly$30bn upto2015.DramaticincreaseisexpectedinAsiamainlyChina,innewtechnologiesandsmall systemsapplications. Dividedbyregions,MiddleEast still takes over 50% of the market share, followed by Asia-Pacific, where economic boom, urbanization, population growth and environment deterioration make the municipalities and industrials eager to search for new water sources. These two regions are going to remain the leading forces for the global markets. America and Europe share about 10% of the market respectively. The construction there is mainly for the purpose of reducing the use of groundwater or adding alternativewatersources[3] The traditional dominating technology MSF (Multiple Stage Flash) is continuing to lose its share to RO (ReverseOsmosis)andMED(Multi-effectDistillation),duetotheimprovementofmembrane technologies and the cost advantage. Other innovations, mainly focused on reducing the costs and raising the efficiency, are also entering the market in fast paces. The establish of the first hybrid plant, Fujairah plant, in the United Arab Emirates in 2004 is just anexample. [4] Divided by value chain, manufacturing has the biggest market share, 45% of total market in 2004. It is followed by operation & maintenance with a market share of 27%. Installation, design and training & support share the rest of the market, with different profitability and growth potential. In the residential systems, the proportion verify. The tendency in the residential segments is that manufacturing & installation take more and more market share from operation & maintenance through the supply of more sophisticated equipment.

[5] The running costs, especially the ratio of the energy consumed for every unit water output, largely decide the future of individual

technologies and the competitive ness of the desalination methods against other water treatment approaches. The R&D worldwide is thus focused on raising the energy efficiency and reducing the running costs. The exciting progresses, above all in the nano technology, during the last years demonstrate that the full-scale utilisationa of sea water will probably come true in the near future.

[6] The market has been undergoing fundamental changes during these years. Two important actions in 2004: GE´s acquisition of Ionics for $ 1.1 billion and Siemens´ purchase of U.S. Filter for $ 983 million, indicate that chances in the related water market are highly valued and the competition is intensifying. The new competition.

1.2 Terminology

The mineral or salt content of water is usually measured by the water quality parameter.

Called total dissolved solids (TDS), the concentration of which is expressed in milligrams.

Per liter (mg/L) or parts per thousand (ppt). The World Health Organization, as well as.

The United Sates Environmental Protection Agency (US EPA) under the Safe Drinking.

Water Act, have established a maximum TDS concentration of 500 mg/L as a potable.

Water standard. This TDS level can be used as a classification limit to define potable.

(Fresh) water.

Typically, water with a TDS concentration higher than 500 mg/L and not higher than

15,000 mg/L (15 ppt) is classified as brackish. Natural water sources such as sea, bay, and

Ocean waters that have TDS concentrations higher than 15,000 mg/L are generally classified as seawater. For example, Pacific Ocean seawater along the West Coast of the UnitedStates has an average TDS concentration of 35,000 mg/L. This concentration can actuallyRange from 33,000 to 36,000 mg/L at various locations and depths along the coast.

1.3 Overview of Desalination Technologies

Sea and brackish water are typically desalinated using two general types of water treatment technologies: thermal evaporation (distillation) and reverse osmosis (RO) membrane separation.

In thermal distillation, freshwater is separated from the saline source by evaporation.

In reverse osmosis desalination, freshwater is produced from saline source water by pressure-driven transport through semipermeable membranes. The main driving force in

RO desalination is pressure, which is needed to overcome the naturally occurring

Osmotic pressure that in turn is proportional to the source water’s salinity.

Besides thermal distillation and RO membrane separation, two other mainstream

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Of the source water IX is the selective removal of salt ions from water by adsorption onto ion-selective Resin media. The driving force in this desalination process is the ion charge of the IX Resin, which can selectively attract and retain ions of the opposite charge contained in The saline source water. Table 1.1 provides a general indication of the range of source water salinity for Which distillation, RO separation, ED, and IX can be applied cost effectively for desalination? For processes with overlapping salinity ranges, a life-cycle cost analysis for the Site-specific conditions of a given desalination project is typically applied to determine The most suitable desalination technology for the project. Currently, approximately 60 percent of the world's desalination systems are RO Membrane separation plants and 34 percent are thermal desalination facilities (GWI And IDA, 2012). The percentage of RO desalination installations has been increasing Steadily over the past 10 years due to the remarkable advances in membrane separation And energy recovery technologies, as well as the associated reductions of overall water Production costs. At present, ED- and IX-based technologies contribute less than 6 percent Of the total installed desalination plant capacity worldwide.

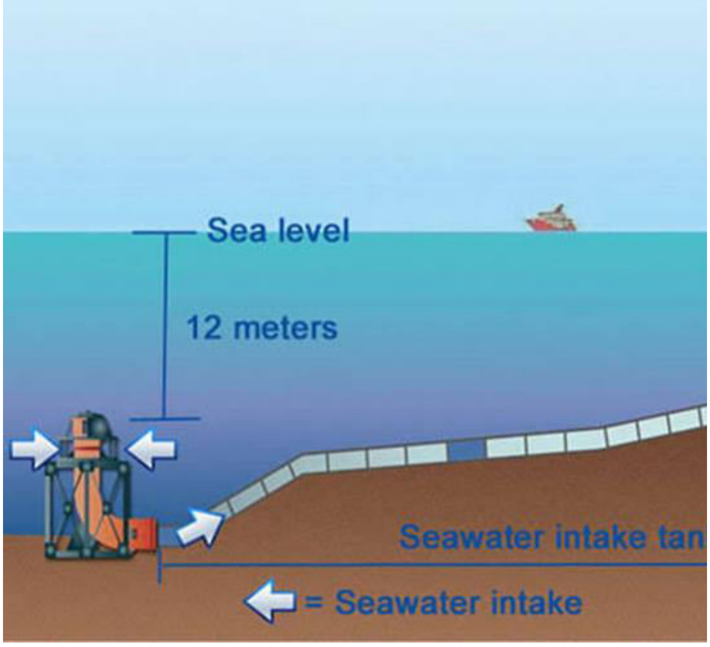
1.4 Advantages of seawater desalination:

1. Provides people with potable water (clean & fresh drinking water).
2. Provides water to the agricultural industry.
3. Uses tried-and-tested technology (the method is proven and effective).
4. Water quality is safe (not dangerous or hazardous to any living thing).
5. Helps preserve current freshwater supplies.
6. Unlimited ocean water as source.
7. Independent of changing factors.
8. Plants are safely located.
9. Help with habitat protection.

1.4 Environment aspects:

1. Intake:

In the United States, cooling water intake structures are regulated by the Environmental Protection Agency (EPA). These structures can have the same impacts to the environment as desalination facility intakes. According to EPA, water intake structures cause adverse environmental impact by sucking fish and shellfish or their eggs into an industrial system. There, the organisms may be killed or injured by heat, physical stress, or chemicals. Larger organisms may be killed or injured when they become trapped against screens at the front of an intake structure. Alternative intake types that mitigate these impacts include beach wells, but they require more energy and higher costs.The Kianna Desalination Plant opened in Perth in 2007. Water there and at Queensland's Gold Coast Desalination Plant and Sydney's Kernel Desalination Plant is withdrawn at 0.1 m/s (0.33 ft./s), which is slow enough to let fish escape. The plant provides nearly 140,000 m3 (4,900,000 cu ft.) of clean water per day.



2. Outflow

This section needs additional citations for verification. (January 2012)

Desalination processes produce large quantities of brine, possibly at above ambient temperature, and contain residues of pretreatment and cleaning chemicals, their reaction byproducts and heavy metals due to corrosion (especially in thermal-based plants).[64][65] Chemical pretreatment and cleaning are a necessity in most desalination plants, which typically includes prevention of bio fouling, scaling, foaming and corrosion in thermal plants, and of bio fouling, suspended solids and scale deposits in membrane plants.

To limit the environmental impact of returning the brine to the ocean, it can be diluted with another stream of water entering the ocean, such as the outfall of a wastewater treatment or power plant. With medium to large power plant and desalination plants, the power plant's cooling water flow is likely to be several times larger than that of the desalination plant, reducing the salinity of the combination. Another method to dilute the brine is to mix it via a diffuser in a mixing zone. For example, once a pipeline containing the brine reaches the sea floor, it can split into many branches, each releasing brine gradually through small holes along its length. Mixing can be combined with power plant or wastewater plant dilution. Furthermore, zero liquid discharge systems can be adopted to treat brine before disposal.

Another possibility is making the desalination plant movable, thus avoiding that the brine builds up into a single location (as it keeps being produced by the desalination plant). Some such movable (ship-connected) desalination plants have been constructed.

Brine is denser than seawater and therefore sinks to the ocean bottom and can damage the ecosystem. Brine plumes have been seen to diminish over time to a diluted concentration, to where there was little to no effect on the surrounding environment. However studies have shown the dilution can be misleading due to the depth at which it occurred. If the dilution was observed during the summer season, there is possibility that there could have been a seasonal thermocline event that could have

Prevented the concentrated brine to sink to sea floor. This has the potential to not disrupt the sea floor ecosystem and instead the waters above it. Brine dispersal from the desalination plants has been seen to travel several kilometers away, meaning that is has the potential to cause harm to ecosystems far away from the plants. Careful reintroduction with appropriate measures and environmental studies can minimize this problem.

1.5 Objective:

Based on the gaps in understanding of biofilms on RO membrane surfaces of SWRO systems,

The objectives of this research were definedas follows:

- Exploration of bacterial communities on RO membrane surfaces from a full-scale Desalination plant.
- Isolation of bacteria from different locations of a full-scale desalination plant and

Accurate identification.

- Comparison of cultured bacteria to the membranebiofilm bacterial Community an Selection of suitable models for biofilm studies.
- Characterization of exopolysaccharides from key bacterial species that Foul Ro Investigation of compounds that degrade polysaccharides and disperse biofilms on Industrially fouled RO membrane surfaces with special reference to free-radical generating compounds.
- Screening of bacterial isolates for production of oxidizing enzymes xanthine oxidase

2. LITERATURE REVIEWS

❖ Water is one of the most precious assets of nature and is necessary for the survival of living beings, which is why science does not stop its research to provide the human being with a product increasingly suited to its dignity and excellence.

The Greeks. Historically, the ***first known desalination plant*** dates from the time of Thales of Miletus and Democritus, who commented that fresh water it was obtained by filtering the sea water through the earth and at the end of the 1st century (150-249) by the Greek physicist-mathematician Alejandro de Aphrodisiac, who describes for the first time, the process of distillation as a method of obtaining fresh water from seawater. Later, in the middle Ages, John Gadsden referred to four techniques for the desalination of sea water in the work Rosa medicine.

❖ **Alexander Zarchin** (1897–1988) was a Ukrainian-Israeli chemist and inventor. He is most noted for inventing a process of sea water desalination.

Born in Ukraine to a family of religious Zionists, as a young man, Zarchin studied industrial chemistry and specialized in metallurgy. In 1934, he was arrested by the authorities for the crime of Zionism (he patented a chemical process using magnesium as "LCLA" an acronym for the phrase "L'ma'anTzion Lo Achsheh" ("for the sake of Zion I will not hold my peace") from the Book of Isaiah) and was sentenced to five years in prison. Zarchin was then recruited into the Red Army, and by the end of World War II, he managed to reach West Germany, and from there he immigrated to Palestine in the summer of 1947. Since his arrival and settlement in Israel, his work was in the area of sea water desalination, petroleum production from bitumen stone, wind operated generators, and other areas.

❖ Invention of seawater desalination

In 1964, Alexander Zarchin obtained a patent for seawater desalination.[4] Zarchin's method of sea water desalination involved freezing sea water in a vacuum, forming pure water crystals which are then melted to produce salt-free water. The salt is drained off in the vacuum stage.[5] One of Alexander Zarchin's main contributions to the vacuum freezing vapor compression (VFVC) system was the incorporation of a compressor having a rotor with flexible machined Hades,[clarification needed] made of thin stainless strip.

Due to its energy consumption, desalinating sea water is generally more costly than fresh water from surface water or groundwater, water recycling and water conservation. However, these alternatives are not always available and depletion of reserves is a critical problem worldwide. [5][6] Desalination processes are usually driven by either thermal (in the case of distillation) or mechanical (in the case of reverse osmosis) as the primary energy types.

Kuwait was the first country in the world to use desalination to supply water for large scale domestic use. First desalination plant was commissioned in 1951.

Saudi Arabia produces the most amount of brine at 22% the world total. At al-jubail the world’s largest desalination plant which makes more than 1.4 million cubic meters daily. About 15000 desalination plant around the world.

2.1 PRODUCT WATER QUALITY

The treatment processes used in seawater desalination result in a product water that has Been stripped of nearly all the mineral content, with the exception of a few constituents That are either insufficiently removed by RO membranes (such as boron and bromide) or are exceptionally high in the source water (such as sodium and chloride). These water quality characteristics result in unique water that must be further conditioned, treated, and possibly blended to produce a finished water that is acceptable for potable water systems. The key issues that must be addressed include:

1. Health concerns

2. Product water stability

3. Irrigation and industrial use concerns

4. General aesthetic concerns

While seawater quality in the open ocean does not vary more than 10 percent over time and location, large variability can be seen in partially isolated seawater bodies, such as bays, estuaries, and seas, where influences from freshwater flows and evaporation have considerable impact on the water quality patterns. Figure 2-1 shows the worldwide surface salinity of oceans, as modeled by the Ocean Climate Laboratory of the National Oceanographic Data Center (World Ocean Atlas 2005). The figure presents salinity in Practical Salinity Units (psu), with one psu equal to 1,000 milligrams per liter (mg/L). While higher than average salinities are common in areas receiving little rainfall, such as the Red Sea, the

Mediterranean, and the Arabian Gulf, seawater bodies surrounding the United States are typically average or below average in salinity. Considerably lower salinities are also seen in the U.S. in partially closed water bodies receiving high contributions from freshwater flows, such as the San Francisco Bay, Tampa Bay, and Chesapeake Bay, where seawater desalination facilities are either currently operational or are being actively evaluated. Extensive monitoring of seawater quality was first documented by William Dittmar in 1884, after four years of water quality sampling over nearly 70,000 nautical miles. The extremely high concentrations of dissolved minerals, many of which are orders of magnitude higher than typical fresh water supplies (see Table 2-1), demonstrate the challenge of treating seawater to a quality acceptable for potable water use.

2.2 HEALTH CONCERNS

Issues related with public health in drinking water are regulated under the United States Environmental Protection Agency (USEPA) as administered through state health and Environmental protection departments. While the requirements for seawater desalination Facilities are the same for all public drinking water systems, the key health concerns with Desalinated product water differ somewhat because of the unique nature of the source Water and the processes used in desalination. The key health issues can be divided into Issues related to potentially high levels of specific minerals in the RO product, (2) issues Related to pathogen removal, and (3) issues related to distribution system water quality. Mineral Content of Product Water Seawater RO membranes used in desalination produce high quality water that meets water Quality requirements for most regulated compounds. It is generally only boron that has a Significant risk of exceeding current federal or state guidelines, and these guidelines are based primarily on issues other than public health, as will be discussed later. Similar to Boron, the chloride concentrations produced by seawater RO membranes may also be a Concern for nonhealth related issues; however, these concentrations are unlikely to exceed State and federal guidelines for chloride. The presence of some unregulated organic com-Pounds, such as algal toxins, has also caused some concern among State and Federal reguLatory agencies, with numerous studies being done to document the removal effectiveness And prevalence of these compounds. Boron. Because of its low molecular weight and weak ionic charge, boron is difficult To remove with most RO membranes. Typical removals vary from 40 to 90 percent at near Neutral pH. Higher removals can be achieved at elevated pH, with greater than 99 percent Removal reported at pH greater than 9.5 (Oo and Song 2009). With levels of boron in sea-Water typically at 4.4 mg/L, RO product from a single-pass treatment approach is typically On the order of 1 to 2 mg/L, depending on the temperature, flux, and specific membranes Employed. Animal tests with boron have shown adverse effects on the reproductive systems Of rats and male dogs; however, the USEPA recently decided not to regulate boron with a Maximum contaminant level (MCL), due to its low prevalence at levels of concern in U.S. Drinking water supplies (USEPA 2007). The USEPA has established a long-term health Advisory level for children of 2 mg/L and for adults at 5 mg/L, based on health effects Observed during animal testing. In addition, several states (California, Florida, Maine, Minnesota, New Hampshire, and Wisconsin) have adopted standards, guidelines, or noti-Fiction levels for boron ranging from 0.6 to 1 mg/L (USEPA 2008). Beyond U.S. guidelines, The World Health Organization has set a health guideline for boron since 1993. This was Set initially at 0.3 mg/L, was increased to 0.5 mg/L in

1998, and is expected to increase to 2.4 mg/L in 2011.

Chloride. Chloride is generally not raised as a health issue for drinking water but is Established as a secondary MCL (set at 250 mg/L), primarily for aesthetic concerns related To the taste of high chloride water. Because of the high concentration of chloride in sea-Water, RO product from a single-pass system can range from 100 to 200 mg/L, depending On the temperature, flux, and specific membranes employed. Lower levels may be sought By some utilities based on aesthetic concerns.Nonregulated parameters. A large number of emerging contaminants or contami-Nants of emerging concern are being studied in terms of their health effects and preva-Lence in U.S. water supplies. While some of these contaminants can be found in seawater Sources at concentration approaching those in freshwater supplies, most are considerably Lower in seawater and are less of a concern to seawater desalination than they are to con- Ventional water treatment facilities. However, compounds that are of unique concern to Seawater desalination are currently unregulated toxins related to periodic algal blooms or Red tide events. Two common algal toxins detected in U.S. waters are found off the Pacific.

Coast and include domoic acid, the cause of amnesic shellfish poisoning, and saxitoxin, The cause of paralytic shellfish poisoning. The toxins are typically not found in the water Column at concentrations that are considered toxic but have been found to accumulate in Shellfish to levels that are toxic to both humans and other mammals. The algae that pro-Duce the toxins are readily removed by the pretreatment filters within a desalination plant And by the RO membranes; however, there is a concern that cells will break during the pre-treatment filtration process and release more dissolved toxins into the water. Pilot studies In Southern California (Carlsbad and West Basin) have demonstrated excellent removal of The toxins during large harmful algal blooms; also, a spiking of dissolved toxins at 1,000

Times typical concentrations during pilot testing in Santa Cruz demonstrated greater than 3 log (>99.9%) rejection using clinic acid, a common surrogate for domoic acid.

1. Membrane Technology

2. Membrane desalination technologies have been designed around the ability of semipermeable membranes to selectively permit or minimize the passage of certain ions. Three Fundamental driving forces can be used in membrane desalination systems including pressure, electric potential, and concentration gradient. RO and nanofiltration (NF) are pressure Driven processes. Electrodialysis (ED) and electrodialysis reversal (EDR) are electric potential driven processes. Forward osmosis (FO) is a concentration-driven process. Membrane-based seawater desalination processes have typically applied only RO. Although NF and ED/EDR are also mature technologies and can be used for desalination, ED/EDR are typically not cost competitive for desalination of seawater (Amjad 1993), and NF is not ordinarily considered for seawater desalination for potable water production. However, a novel approach employing two-pass (NF) configuration has been developed and tested for seawater desalination by the Long Beach Water Department in California. Similarly, FO is a developing technology and has not yet been commercialized for largescale applications.

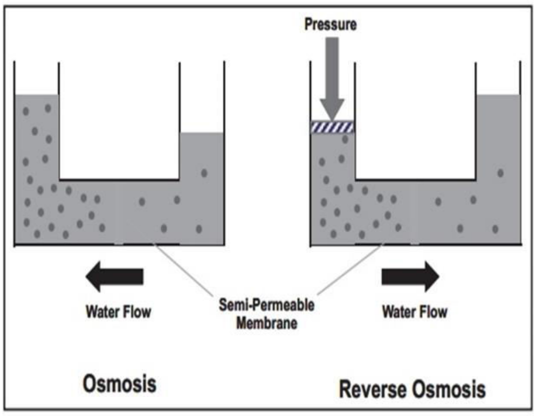
3.

4.

2. Reverse Osmosis (RO)

5. Desalination through RO is a well-established and nonproprietary unit process that currently represents the state-of-the-art of desalination technology for a number of reasons. In addition to the ability to reject a variety of contaminants, RO treatment generally has lower energy consumption, lower feed water flows, and no thermal impacts in the concentrate

discharge in comparison to thermal desalination processes. Improvements in membranes and energy recovery devices used for seawater RO (SWRO) have improved the overall process efficiency thereby lowering the costs associated with treatment. Reverse osmosis is based on overcoming the natural phenomenon of osmotic pressure, which occurs when a semi-permeable membrane separates two solutions with different concentrations of ions. The osmotic pressure created by the concentration gradient drives the flow of water from the dilute solution to the concentrated solution, until chemical equilibrium is established. The flow of water can be reversed with the application of an external hydraulic force (pressure) if this force is greater than the osmotic pressure.



Sandeep Sethi

Basic concept of osmosis and reverse osmosis

RO membranes are designed to retain salts and low-molecular weight solutes while allowing water to pass through. The original asymmetric cellulose acetate (CA) membranes, developed in the 1960s, were less permeable than modern thin-film composite (TFC) membranes and required a higher driving pressure, in excess of 1200 pounds per square inch (psi) or 8.3 megapascals (MPa) for seawater at typical operating fluxes. Additionally, the ability of CA membranes to reject salts was originally less than current materials.

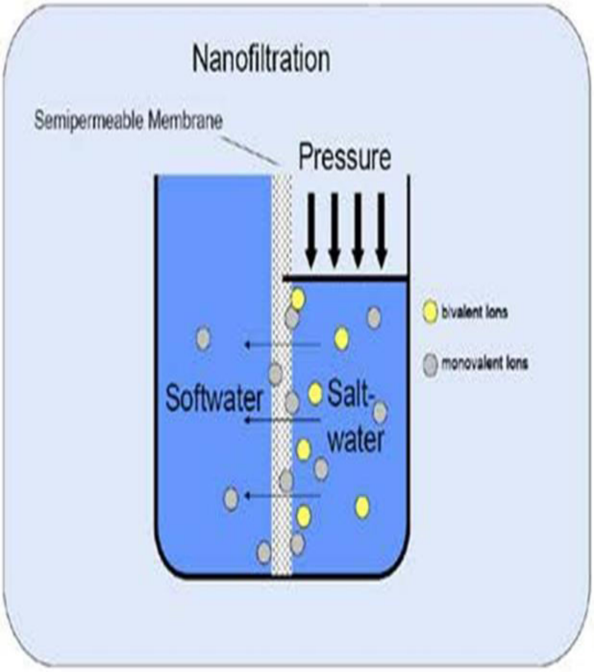
Cellulose acetate membranes utilized an asymmetric structure while the TFC contained multiple layers made from different materials. In the asymmetric configuration, the membrane consists of the same material throughout with a dense layer at the top and porous layer beneath. In contrast, the TFC membrane consists of a thin but dense layer of one material over a porous support consisting of a different material.Currently, there are a variety of modified and improved blends of CA membranes available to the desalination industry, but these membranes are rarely used in large-scale desalination applications. CA membranes can tolerate continuous exposure to low concentrations of chlorine (0.1 to 0.5 mg/L at 25ºC), which is an advantage for biofouling control in seawater applications. They are, however, susceptible to hydrolysis, which compromises the membrane's salt rejection performance. Hydrolysis of CA membranes is accelerated if the operating pH is less than approximately 4 or greater than approximately 7 and temperatures are greater than 30ºC (Mallevialle et al. 1996). Therefore, pH depression into this range is needed for seawater desalination with CA membranes.The development of TFC membranes provided greater salt rejection and higher water production per unit membrane area. TFC membranes are made by combining a thin, dense membrane film with a porous underlying material that provides structural support. The thin film typically consists of aromatic polyamide (PA) and the bottom support layer is typically polysulfone. Most of the solute rejection occurs at the thin nonporous film, and its small thickness can significantly reduce the pressure required to drive water through it in comparison to CA membranes. TFC membranes are stable over a broad pH range (2-11) . and can withstand temperatures as high as 45ºC. However, unlike the CA membranes, they are susceptible to degradation by strong oxidants such as free chlorine. Although the degradation rate caused by free chlorine is a function of pH, membrane materials generally deteriorate upon exposure to chlorine (sometimes catastrophically). High pressures are required to overcome the osmotic pressure of the salts and minerals, and the resistance from the membrane material, and other associated system losses. SWRO membranes are typically operated at feed pressures of approximately 800 to 1,000 psi (5.5 to 6.9 MPa). RO membranes are capable of rejecting contaminants as small as 0.1 nm; however, the process of water transfer is mostly diffusion controlled rather than convection controlled as with microfiltration and ultrafiltration. In addition to the effects of the major ion matrices, mass transfer of ions through RO membranes is also impacted by broader water quality characteristics, such as temperature and pH. The amount of water recovered using SWRO membranes ranges from 35 to 60 percent, and commercially available SWRO membranes typically reject 99.5 to 99.8 percent of the total dissolved solids (TDS) in the feed water. However, removal of a few constituents, such as boron, is sometimes not as great as might be required (see Chapter 2). If product water goals are not met, additional treatment may consist of two-pass RO, in which a portion or all of the permeate produced in the first pass is treated again in a second pass. New membranes with improved boron rejection are currently being developed by SWRO manufacturers to avoid the need for two-pass treatment; however, other water quality goals besides boron may also impact the need for a two-pass system. An optimized SWRO design will therefore depend on the feed water quality, system operating conditions, and specific finished water quality requirements. Because membrane processes are based on physical separation, they do not require thermal energy to vaporize the water (with the exception being membrane distillation, discussed later in this chapter). As a result, the energy consumption for treatment components of an SWRO plant typically falls in a range of 10 to 20 kilowatt-hours (kWh)/1,000 gallons (2.6 to 5.3 kWh/m3). In comparison, total energy used for thermal desalination treatment processes can range from 10 to 40 kWh/1,000 gallons (2.6 to 10.6 kWh/m3), depending on

the unit processes. Energy recovery devices are increasingly used in SWRO applications

These devices can recover from 25 to over 45 percent of input energy for SWRO. Examples of such devices as presented in Chapter 3, include Pelton wheels, work exchangers, pressure exchangers, and hydraulic turbo-exchangers. One of the greatest challenges for membrane desalination processes is ouling and scaling of the membranes. Fouling can occur as a result of inadequate pretreatment or measures for reduction of particulate, colloidal, or organic matter to tolerable levels, or biological growth in the membrane pressure vessels. Scaling results from precipitation of sparingly soluble salts in the system and tends to be less of a concern in seawater desalination than in brackish water systems, which run at higher recoveries. Compounds such as calcium carbonate, calcium sulfate, silicate, barium sulfate, and strontium sulfate in the feed water may, however, contribute to limiting the recovery of the RO process. Acid or scale inhibitors (also known as antiscalants) may be added to reduce alkalinity and prevent formation of scale, allowing for higher recovery than otherwise possible. As a result of high levels of particulates and the generally aerobic state of seawater, SWRO plants require comprehensive pretreatment and chemical conditioning of the feedwater for successful operation.

3. Nano Filtration

Nanofiltration is typically used to soften water and remove disinfection by-products (DBP) precursors such as dissolved organic matter. NF is typically not used for seawater desalination, although unique configurations of two-pass NF have been successfully used to desalinate seawater. Nanofiltration uses semi-permeable membranes and a driving force of hydraulic pressure; however, in comparisons to RO, NF membranes typically have a higher molecular weight cut-off (MWCO). NF membranes remove a high percentage (90 to 98 percent) of divalent ions (i.e., those associated with hardness) but removal of monovalent ions is somewhat limited (typically 60 to 85 percent) Because a higher concentration of monovalent ions can pass through the NF membrane, the osmotic pressure is lower compared to RO. This, combined with a more permeable membrane skin layer, reduces the hydraulic pressure requirements to 500 to 700 psi (3.4 to 4.8 MPa) for seawater applications. Recognizing these advantages, the Long Beach Water Department (California, United States) has developed and patented an innovative two-pass nanofiltration method for the desalination of seawater. This will be discussed.



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4. Thermal Evaporation

Thermal desalination technologies work by evaporating water from a saline on and then condensing the vapor (steam) to produce distilled water. All large-scale thermal processes involve heating water to its boiling temperature to produce the maximum amount of water vapor. The pressure of the system is typically decreased so that the temperature required for boiling is reduced. Commercially available distillation systems are designed to allow for “multiple boiling” in a series of vessels that operate at successively lower temperatures and pressures. Thermal technologies that are used for desalination include multistage flash (MSF), multiple effect distillation (MED), and vapor compression (VC). MSF and MED systems typically use direct heat exchange from steam as the energy source for evaporation, while VC systems use the heat from the compression of the vapor as the energy source for evaporation. Thermal processes can produce water with very low salt concentrations (TDS levels of 10 mg/L or less) from TDS levels as high as 60,000-70,000 mg/L TDS; however, there are limitations associated with distillation processes for seawater desalination. One of the most significant limitations of thermal technologies is the energy requirement of the vaporization step. High levels of salts result in boiling point elevation, and the energy required to vaporize seawater ranges from around 25 to 100 kWh/1000 gal of fresh water produced (Wade 2001). It should be noted that these thermal energy requirements are in addition to the electrical energy required for the other aspects of the process. Often, large distillation plants are coupled with steam or gas turbine power plants, making use of low grade heat to reduce power input requirements. Thermal technologies are more commonly used in the Middle East, where energy costs are relatively low, the large land requirements are not cost prohibitive, and ecological permitting requirements are less stringent. There has long been interest in using solar energy as a source of heat for accomplishing the evaporation in distillation, but suitable technologies for a large-scale project are not yet available. Operational issues for thermal desalination include corrosion and scaling. Because seawater is highly corrosive in nature, special alloys, such as cupronickel alloys, aluminum, and titanium, are used most commonly in desalination with distillation processes. These special alloys contribute significantly to the capital cost of a distillation plant, particularly with the large surface area required for efficient distillation. The scaling of sparingly soluble salts at elevated temperatures on the inner walls of pipes and equipment is another operational issue that reduces the heat transfer efficiency of the heat exchangers, increasing the overall energy required for distillation. Also, additional permitting concerns may arise because concentrate discharged from a thermal distillation process has a higher temperature than the ambient water in the discharge location. While the cost of thermal desalination is often considerably higher than RO, very little pretreatment is required ahead of thermal processes, and the product water quality is extremely high (less than 10 mg/L TDS), avoiding the need for additional treatment to address boron, chloride, or bromide concerns.

5. Multistage Flash Distillation (MSF)

6. MSF accounts for the greatest installed thermal distillation capacity worldwide. In the MSF process, water is heated in a series of stages, each with successively lower pressures and temperatures. Typically, MSF plants can contain from 15 to 25 stages. Vapor generation or boiling caused by reduction in pressure is known as flashing (illustrated in Figure 1-3). As the water enters each stage through a pressure-reducing nozzle, a portion of the water is flashed to form vapor. In turn, the flashed water condenses on the outside of the condenser tubes and is collected in trays. As the vapor condenses, the latent heat is used to preheat the seawater that is being returned to the main heater, where it will receive additional heat before being introduced to the first flashing stage. The condensate collected in each stage forms the product, and the whole process is driven by a subatmospheric pressure gradient through the stages. Evaporation or flashing of a small portion of the feed continues in each successive stage at a lower pressure. The MSF process generates and condenses vapor in the samestage or effect. The range of recoveries for conventional MSF desalination processes is limited to about 10 to 30 percent for seawater desalination.

6. Multiple Effect Distillation (MED)

The MED process, like the MSF process, uses multiple vessels (or effects) arranged inseries with reduced ambient pressure in each subsequent effect. Typically, 8 to 16 effects are used in MED to minimize the energy consumption. The feed water is distributed on the outside of the evaporator tubes in a thin film (see illustration in Figure 1-4) to promote rapid boiling and evaporation. Steam is condensed on the colder inside surface. Vapor produced by evaporation is condensed in a way that uses the heat of vaporization to heat the remaining saline solution at a lower temperature and pressure in each succeeding effect, allowing water to undergo multiple boiling without supplying any additional heat after the first effect. Thus, the vapor produced in each effect is used to heat the feed water in the next effect. This not only reduces the energy required for distillation but also the overall electrical power consumption. As a result, energy costs for operating an MED plant are lower than that of an MSF plant. The steam generated in the final effect is typically at a pressure and temperature too low to be of further use. MED systems normally condense this steam using an external cooling source to remove the heat of condensation. Energy is required in an MED system as follows: to create steam of sufficient pressure to drive evaporation in the first stage; to power vacuum systems to reduce the boiling pressure in the downstream effects (if operated at low temperatures); to pump influent water through the heat exchangers to the evaporator(s), to recirculate the concentrate within each evaporator stage, and to pump the condensate and concentrate through the heat recovery prior to exiting the system; cooling water to condense the steam from the final stage. Energy efficiencies may be gained via the combination of the evaporator systems with available low-pressure or waste steam/heat sources or by the addition of efficiency enhancement devices to the conventional MED system. The range of recoveries for conventional MED is limited to approximately 20 to 35 percent for seawater desalination.

7. Vapor Compression (VC)

Heat for evaporation in VC systems is provided by one of two approaches: mechanical

vapor compression (MVC) or thermo vapor compression (TVC); an illustration of the former is provided in Figure 1-5. MVC systems use electricity while TVC systems use high pressure steam to compress the water vapor created from distillation to higher pressure

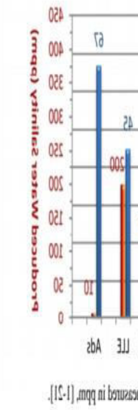
and temperature, so that it can be returned to the evaporator and used as a heat source.

The vapor compression process is well established and is used for seawater desalination

as well as treating RO concentrate for residuals management. Vapor compression systems typically have recoveries in the range of 40 to 50 percent for seawater desalination.

Element	Concentration (mg/l)	Element	Concentration (mg/l)
Oxygen	8.57x 10+5	Potassium	380
Hydrogen	1.08 x 10+5	Bromine	65
Chloride	19000	Argon	0.6
Sodium	10500	Nitrogen	0.5
Magnesium	1350	Lithium	0.18
Sulfur	885	Iron	0.01
Calcium	400	Silicon	3

7. C hart



9 . Ana lysis

World water resources are mainly salty (97.5%) and fresh water (2.5%). Salty water is found in oceans, seas and some lakes while fresh water is either stored underground (30%) or in the form of ice / snow covering mountainous regions, Antarctic and Arctic (70%) but only 0.3% is usable by humans [1]. With this limited amount of usable fresh water, desalination offers the means to meet the increasing demand for fresh water. Desalination technologies are divided into three major groups, namely: (i) thermally activated systems in which evaporation and condensation are the main processes used to separate salts from water, (ii) pressure-activated systems where a pressure is applied on the salty water that forces it through a membrane, leaving salts behind and (iii) chemically-activated desalination methods.

Thermally activated systems include: multi-stage flash distillation (MSF), multiple-effect distillation (MED), vapor compression distillation (MVC), humidification **Major Element of Seawater**

- dehumidification desalination (HDH), solar distillation (SD) and freezing (Frz). In these systems, heat transfer is used either to boil or freeze the seawater or brackish water to convert it to vapor or ice so the salts are separated from the water. Pressure- activated systems use permeable membranes to create two zones where water can pass through leaving salt behind. Corresponding author. Tel.: +44-0121-4143513; fax: +44-0121-4143598. E-mail address: r.k.al-dadah@bham.ac.uk. © 2014 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license Peer-review under responsibility of the Organizing Committee of ICAE2014 P.G. Youssef et al. / Energy Procedia 61 (2014) 2604 – 2607 2605 These technologies consist of reverse osmosis (RO), forward osmosis (FO), electro-dyalysis (ED) and nanofiltration (NF). Chemically-activated desalination systems include ion-exchange desalination (I.Ex), liquid–liquid extraction (LLE) and gas hydrate (G.Hyd) or other precipitation schemes [1, 2]. Recently, adsorption technology (Ads) has been investigated for desalination application. In this technology an adsorbent material with high affinity to water like silica gel can be used to separate the water from the salts . Figure 1 shows flow chart of the various desalination technologies [1, 2]. This work aims to critically assess the performance of all available desalination systems in terms of energy required, cost, quality of feed and produced fresh water and environmental impact.

10. Result

- Several parameters affect the selection of desalination systems including; quality of salty water to be desalinated, salinity level of produced potable water, input energy, environmental impact and cost. According to salinity of water, it could be categorized into brackish or seawater. Brackish water contains total dissolved solids (TDS) higher than potable water and lower than seawater. Potable water should have TDS lower than 1000 ppm (or mg/l) and brackish water in the range of 1,000 to 25,000 ppm while seawater has an average of 35,000 ppm TDS concentration . Figure 2 shows the variation of feed water and produced water salinity for the listed technologies. It is clear from this figure that MSF and Ads desalination technologies can handle feed water with the highest salinity and produce water with the lowest salinity.

Conclusion

The desalination of brackish water and seawater proves to be a reliable source of fresh water and is proves to be a solution for the world's water shortage problem. Desalination processes are normally used to produce drinking water in areas where only seawater or brackish water is the source of water. A number of technologies have been developed and many more methods are under R&D for desalination. They can be used for small scale, that is, supplying water for small communities (e.g. solar distillation) and large scale to supply water to cities, that is, huge plants (e.g. reverse osmosis).Though desalination costs seem to be progressively decreasing, but they are still costlier than conventional drinking water processes. Coming to environmental aspects each desalination plant has to take proper measures in case of intake of water, pre-treatment of water as well as disposing concentrate reject water that is produced in the process because environmental aspects are equally important as commercial aspects.

References

1. American Water Works Association. 2004. Water Desalting Planning Guide for

Water Iltilities. New York, N.Y.: John

Wiley & Sons.

2. Amjad, 2. 1993. Reverse Osmosis: Membrane Technology. Water, Chemistry, and Industrial Applications, Van

Nostrand Encyclopedia of Chemis-try. Reinhold, New York John Wiley & Sons.

3. Cath, T.Y., and A.E. Childress. 2005. Membrane contactor processes for wastewater reclamation in space. Combined direct osmosis, osmotic distillation, and membrane distilla-tion for treatment of metabolic waste-

water, Joumal of Membrane Science

4. Global Water Intelligence. 2010. DeSal-Data.com. Oxford, England. Holloway, R.W., A. E. Childress, K.E. Den-nett, and T.Y. Cath. 2007. Forward osmosis for concentration of centrate from anaerobic digester, Water Research 41: 4005-4014.5. Ingo, L., S.J. Metz, G. Rexwinkel, and G.F. Versteeg. 2009. Desalination via Supercritical Water: A New Approach for Desalination without Brine Streams. Proceedings of the International Desalination Association 2009 World Congress, November 7-12,2009, Dubai, UAE.6. Lundin, C., J.E. Drewes, T.Y. Cath. 2009. A Novel Hybrid Forward Osmosis-Reverse Osmosis Process for Water Purification and Reuse, Using 257: 111-119.

Impaired Water and Saline Water. roceedings of the American Water Works Association 2009 Membrane

7. Technology Conference, March 16-18, 2009, Memphis, Tennessee. Mallevialle, J., P.E. Odendaal, and M.R. Wiesner. 1996. Water Treatment Membrane Processes. Denver, Colo.: AWWA and AWWA Research Foundation.

8. McCutcheon, J.R. and M. Elimelech. 2006. Influence of Concentrative and Dilutive Internal Concentration Polarization on Flux Behavior in Forward Osmosis. Journal of Membrane Science, 284(1-2):2 37-247.

9. Sethi, S., Walker, S., Xu, I? and Drewes,

J.E. 2009. Desalination Product Water Recovery and Concentrate Volume Minimization. Water Research Foundation. Wade, N.M. 2001. Distillation plant development and cost update. Desalination, 1363-12.

10. Yang K-L, T-Y Ying, S. Yiacourmi, C. Tsouris, and E.S. Vittoratos. 2001. Electrosorption of ions from aqueous solutions by carbon aerogel an electrical double layer model. Langmuir 12. Ying, T-Y., K-L Yang, S. Yiacoumi, and C. Tsouris. 2002. Electrosorption of Ions from Aqueous Solutions by Nanostructured Carbon Aerogel. Journal of Colloids and Interface Science 17: 1961-1969. 250, 18-27.