International Journal of Advance Research in Science and Engineering
Volume No.06, Issue No. 12, December 2017
www.ijarse.com
IJARSE
ISSN: 2319-8354

A REVIEW ON WATER DESALINATION BY REVERSE OSMOSIS PROCESS

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ABSTRACT

It is well known scarcity of water is the most well-known problem faced by the mounting population all around the world. The need for water covers not only the water needed for human consumption but also, most of the time, mainly the consumption in agriculture and industry. To suffice the needs of rising water needs, desalination has been increasing adopted all around the world. Desalination uses a huge amount of energy to remove a fraction of pure water from a saline water source. The main steps in the desalination process are based on using methods like evaporation and condensation or membrane technology in order to remove the dissolved salts from the salt water to obtain potable water .Our main objective is to study the process of Reverse Osmosis (RO) in better detail and explore its potential to the fullest. In RO driving force is represented by a difference between an applied transmembrane pressure (TMP) and the osmotic pressure difference across the membranes. Highly concentrated solutions cannot be treated as a consequence of a physical limit imposed by their osmotic pressure value.

***Key words:* Reverse Osmosis, Desalination, membrane technology**

I. INTRODUCTION

Water is the most common essential in the world, however, 97% is seawater and only 3% is fresh water. The availability of water for human consumption is decreasing due to increasing the ecological effluence. According to the World Health Organization (WHO), about 2.4 billion people do not have access to basic cleanliness amenities, and more than one billion people do not have access to safe drinking water. Moreover, the world's population is likely to rise to nine billion from the current six billion in the next 50 years. The US geological study found that 96.5% of earth's water is located in sea sand oceans and 1.7% of earth's water is located in the icecaps. The remaining percentage is made up of brackish water, salty water found as surface water in estuaries and as groundwater in salty aquifers [1,2]. constant water pollution and growing economies are driving municipalities and companies to consider the desalination as a answer to their water supply problems. Although India occupies only3.29 million square km geographical areas, which forms 2.4% of the world's land area, it supports over 15% of world's population. The population of India as of March 31, 2011was 1,210,193,422 persons [3]. Desalination uses a large amount of energy to remove a portion of pure water from a salt water source. This system is described as filtering salty water through membranes and removing the salt through electro dialysis and reverse osmosis. This procedure has worked for about 130 nations in North Africa and the Middle East. With this system, these nations are currently producing six billion gallons of usable water a day. Also, the United States has a total of about 1,200 desalinating plants, most of which are in modest-sized communities. Recently, however, the desalination process has become much more practical for urban areas and reverse-osmosis systems have made significant improvements. Reverse osmosis (RO) is a water purification technology that uses a semi permeable membrane to remove larger particles from water. In reverse osmosis, an applied pressure is used to overcome osmotic pressure. Reverse osmosis can remove many types of molecules and ions from solutions, including bacteria, and is used in both industrial processes and the production of potable water. The result is that the solute is retained on the pressurized side of the membrane and the pure solvent is allowed to pass to the other side. To be "selective", this membrane should not allow large molecules or ions through the pores (holes), but should allow smaller components of the solution (such as the solvent) to pass freely.

So it is necessary to do the process efficiency, flux performance and energy consumption for desalination of salty water to meet the water crisis problem and global economic challenges. This paper explains a detailed study of the Reverse Osmosis process.

II.PROCESSES FOR DESALINATION

Desalination is a procedure of removing dissolved salts from water also called as desalting. Desalination process is divided into two broad categories namely 1) Thermal Processes, 2) Membrane Processes Thermal processes include multi-stage flash, multiple effect distillation and mechanical vapour compression. Membrane processes are detailed as –

2.1 Reverse osmosis (RO): Although the overall capacity of reverse osmosis is moderately small. Desalination plants based on this process is one of the most popular types installed now-a-days. Reverse osmosis being a membrane process; the salt is separated from the water by means of a selective membrane. Energy is required exclusively to pump the feed water at a pressure above the osmotic pressure. However, higher pressures must be used, typically 50-80 bar, in order to have an adequate amount of water pass through a unit area of membrane [4]

2.2 Electro dialysis (ED): As the name implies, this technology utilize an electrochemical separation process in which charged membranes are applied to separate ionic species from a mixed aqueous solution of different components and water through ion exchange membranes, which cause the concentration variations of solute in dilute and concentrated compartment. [5]

2.3 Membrane distillation (MD): Membrane distillation (MD) is a thermally driven process that utilizes a hydrophobic micro-porous membrane to support a vapour-liquid interface. Vapour pressure difference arises if a temperature difference is maintained across the membrane. As a result, water gets evaporated at the hot interface, crossing the membrane in the vapour phase and condenses at the cold side, which gives rise to a net trans-membrane water flux.[6, 7, 8]

The above mention text gives an overview about the techniques presently utilized for the purpose of Desalination of water. The next section explains the process of Reverse Osmosis in great detail.

III.REVERSE OSMOSIS

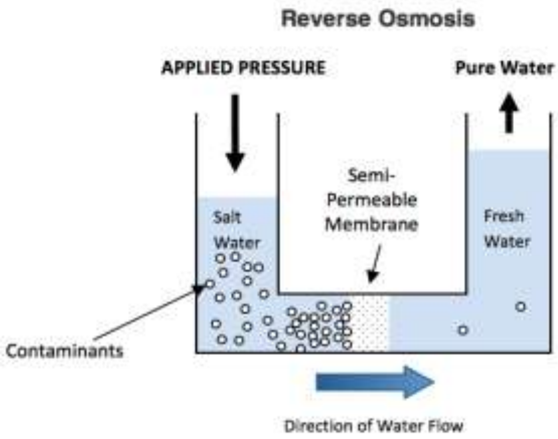

Figure No. 1 – Reverse Osmosis Diagram

Reverse Osmosis is the process of Osmosis in reverse. Where Osmosis is a natural phenomenon which can be defined as the movement of pure water through a semi permeable membrane from a low to a high concentration solution Osmosis occurs naturally without energy required, to reverse the process of osmosis you need to apply energy to the saline solution. A reverse osmosis membrane is a semi--permeable membrane that allows the passage of water molecules but not the majority of dissolved salts, organics, bacteria etc. However, you need to 'push' the water through the reverse osmosis membrane by applying pressure that is superior than the naturally occurring osmotic pressure in order to desalinate water in the process, allowing pure water through while retaining back a majority of contaminants

3.1 PRINCIPLE OF REVERSE OSMOSIS

RO is a physical process that utilizes the osmosis phenomenon, that is, the osmotic pressure difference between the salt water and the pure water to remove the salts from water. RO is a pressure-driven membrane process where a feed stream flow under pressure through a semi permeable membrane, separating two aqueous streams, one rich in salt and other almost free in salt.[9]

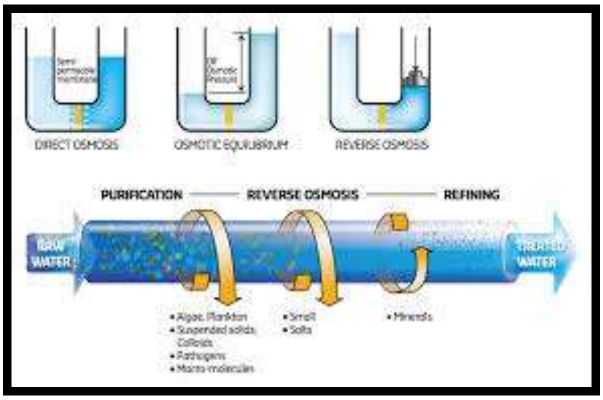

Figure No. 2: Representation Of Reverse Osmosis Process

3.2 THEORY

RO is a separation method in which there is a separation of dissolved solids from water. This is done by applying a differential pressure across a semi permeable membrane. As the name suggests, this process is the exact opposite of the natural phenomena called osmosis. In osmosis, water molecules flow through a semi-permeable membrane from the less concentrated solution to the more concentrated one, without external influence. In reverse osmosis, pressure is applied to the more concentrated solution (containing dissolved solids) which causes water molecules to flow through a semi-permeable membrane to the dilute solution (without dissolved solids).). The membrane, made of either cellulose acetate or polyamide, rejects most of the solids creating two streams: one of pure water, product or permeate, and one with dissolved solids, concentrate or reject. The ratio of pure water to raw feed water is called the recovery.

Absolutely, 100% of the feed water cannot go through the membrane because there must be enough concentrate to flush away the rejected solids. Most RO systems provide a recovery of 25% to 90%, with 60% as the accepted standard. The recovery and the overall performance of an RO system is govern by many factors. Feed water quality is important because there are certain things in water that are known to harm RO membranes. Treating the feed water with chemicals merely creates compatibility between it and the membrane. There are four major factors which influence pre-treatment: colloidal & biological fouling, and the solubility of calcium carbonate & calcium sulphate. The performance also vary with the feed water temperature. Due to higher viscosities at lower temperatures, product rates drop with temperature.[10,11,13]

3.3 CHARACTERISTICS OF RO MEMBRANE

The membranes used for reverse osmosis method should have the following characteristics:

1. The membrane should be chemically, physically and thermally steady in saline waters.
2. They should be hydrophilic and have high water flux i.e. highly permeable to water and less susceptible to fouling.
3. Membrane should be easily manufactured with good salt rejection.

4. They need to be strong enough to withstand high pressures and variable feed water quality.

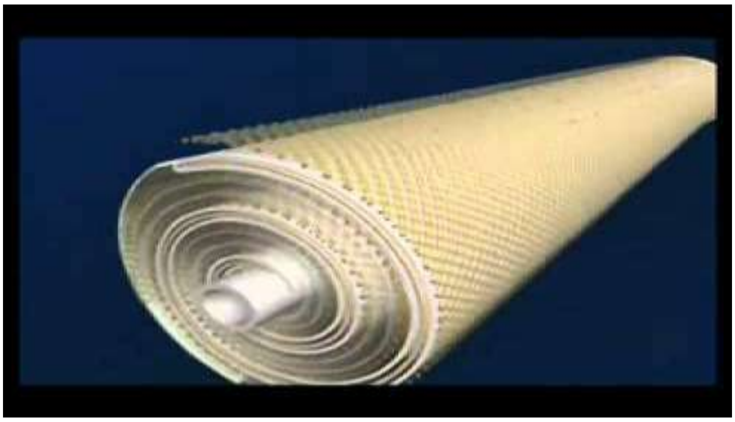

Figure No. 3: Spiral Wound Reverse Osmosis Membrane[14]

3.4 WORKING

In an RO process plant, water will pass through the membrane, when the applied pressure is higher than the osmotic pressure, while salt is retained. The membranes used for reverse osmosis have a dense layer in the polymer matrix—either the skin of an asymmetric membrane or an interfacial polymerized layer within a thin-film-composite membrane—where the separation occurs. In most cases, the membrane is designed to allow only water to pass through this dense layer, while preventing the passageway of solutes (such as salt ions).As a result, a low salt concentration permeate stream is obtained and a concentrated brine remains at the feed side.RO operating pressure ranges from 17 to 27 bars for brackish water and from 55 to 82 bars for groundwater. Brackish groundwater has a much lower osmotic pressure than groundwater; therefore, its desalination requires much less energy. Also, lower pressures found in brackish-water RO system permit the use of low-cost plastic components.[17]

A typical RO system consists of four major stages:

1. Pre-treatment system.
2. High-pressure pump.
3. Membrane module assembly.
4. Post-treatment system.

3.4.1 PRE-TREATMENT

Pre-treatment is vital when working with reverse osmosis and Nano-filtration membranes due to the nature of their spiral-wound design. The material is engineered in such a fashion as to allow only one-way flow through the system. As such, the spiral-wound design does not allow for back-pulsing with water or air agitation to clean its surface and remove solids. Since accumulated material cannot be removed from the membrane surface systems, they are highly susceptible to fouling (loss of production capacity). Therefore, pre-treatment is a necessity for any reverse osmosis or Nano-filtration system., even as the membrane rejects the passage of salt through it. Typical pressures for brackish water range from 225 to 376 psi (15.5 to 26 bar, or 1.6 to 2.6 MPa). In the case of groundwater, they range from 800 to 1,180 psi (55 to 81.5 bar or 6 to 8 MPa). This requires a large amount of energy. Where energy recovery is used, part of the high pressure pump's work is done by the energy recovery device, reducing the system energy inputs

3.4.2 PRESSURE PUMP **:**

The high pressure pump provides the pressure needed to push water through the membrane, even as the membrane rejects the passage of salt through it. Typical pressures for brackish water range from 225 to 376 psi (15.5 to 26 bar, or 1.6 to 2.6 MPa). In the case of groundwater, they range from 800 to 1,180 psi (55 to 81.5 bar or 6 to 8 MPa). This requires a large amount of energy. Where energy recovery is used, part of the high pressure pump's work is done by the energy recovery device, reducing the system energy inputs

3.4.3 MEMBRANE ASSEMBLY:

The membrane assembly consists of a pressure vessel with a membrane that allows feed water to be pressed against it. The membrane must be strong sufficient to withstand whatever pressure is applied against it. Reverse osmosis membranes are made in a variety of configurations, with the two most common configurations being spiral-wound and hollow-fibre.

Figure No. 4: Layers of Membrane

Only a part of the saline feed water pumped into the membrane assembly passes through the membrane with the salt removed. The remaining "concentrate" flow passes along the saline side of the membrane to flush away the concentrated salt solution. The percentage of desalinated water produced versus the saline water feed flow is known as the "recovery ratio". This varies with the salinity of the feed water and the system design parameters: typically 20% for small groundwater systems, 40% - 50% for larger groundwater systems, and 80% - 85% for brackish water. The concentrate flow is at typically only 3 bar / 50 psi less than the feed pressure, and thus still carries much of the high pressure pump input energy. The desalinated water purity is a function of the feed water salinity, membrane selection and recovery ratio. To achieve higher purity a second pass can be added which generally requires re-pumping. Purity expressed as total dissolved solids typically varies from 100 to 400 parts per million (ppm or milligram/litre) on a groundwater feed. A level of 500 ppm is generally accepted as the upper limit for drinking water, while the US Food and Drug Administration classify mineral water as water containing at least 250 ppm.[18,19]

IJARSE
ISSN: 2319-8354

3.4.4 PH ADJUSTMENT:

The desalinated water is "stabilized" to protect downstream pipelines and storage, usually by adding lime or caustic to avoid corrosion of concrete-lined surfaces. Liming material is used to adjust pH between 6.8 and 8.1 to meet the pure water condition, primarily for efficient disinfection and for corrosion control. Remineralisation/ PH adjustment may be needed to replace minerals removed from the water by desalination. Although this process has proved to be costly and not very convenient if it is intended to meet mineral demand by humans and plants. A very same mineral demand that freshwater sources provided previously. For instance water from Israel’s national water carrier typically contains dissolved magnesium levels of 20 to 25 mg/litre, while water from the Ashkelon plant has no magnesium. After farmers used this water, magnesium deficiency symptoms appeared in crops, including tomatoes, basil, and flowers, and had to be remedied by fertilization. Current Israeli drinking water standards set a minimum calcium level of 20 mg/litre. The post desalination treatment in the Ashkelon plant uses sulphuric acid to dissolve calcite (limestone), resulting in calcium concentration of 40 to 46 mg/litre. This is still lower than the 45 to 60 mg/litre found in typical Israeli freshwaters.[20,21]

3.4.5 DISINFECTION

Post-treatment consists of preparing the water for distribution after filtration. Reverse osmosis is an effective barrier to pathogens, but post-treatment provides secondary protection against compromised membranes and downstream problems. Disinfection by means of ultra-violet (UV) lamps (sometimes called germicidal or bactericidal) may be employed to sterilize pathogens which bypassed the reverse osmosis process. Chlorination or chloromination (chlorine and ammonia) is done by adding chlorine alone or chlorine with ammonia so as to protect against pathogens which may have lodged in the distribution system downstream, such as from new construction, backwash, compromised pipes, etc. Reverse Osmosis (RO) technology has undergone rapid transition. This transition process has caused signification transformation and consolidation in membrane chemistry, module design, and RO plant configuration and operation. RO technology is widely used because of its high efficiency and it is cost efficient.[22]

3.5 EFFECT OF OPERATING PARAMETERS

1 Pressure :

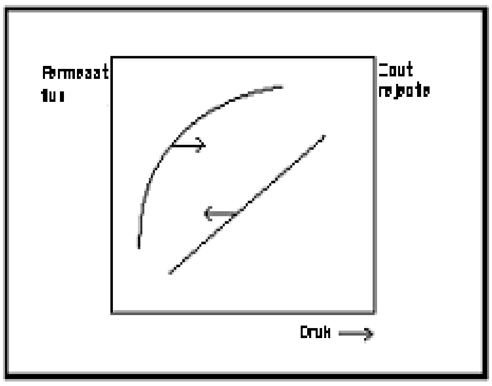

Figure No. 5: Effect of Pressure

When the effective pressure of the feed water is increased, the dissolved solids content of the permeate will decrease, while the permeate flux increases.

2.Temperature **:**

When temperatures increase and other parameters are constant, the permeate flux and the salt flow will increase.

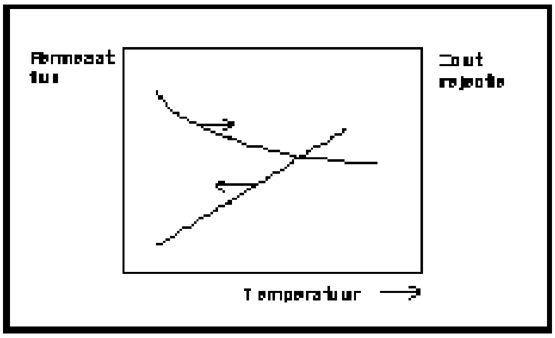

Figure No. 6: Effect Of Temperature

3. Recovery :

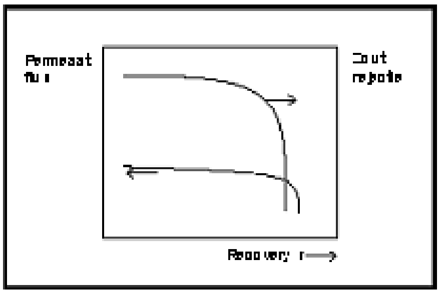

Figure No. 7: Effect Of Recovery

The recovery means the relation between the permeate flow and the feed water flow. When recovery increases, the permeate flux will decrease and stagnate, when salt concentrations are of a value where osmotic pressure equals feed pressure. When recovery increases, the salt retention will decrease.

4. Salt Concentration Of The Feed Water **:**

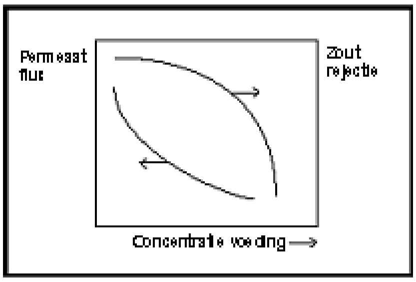

Figure No. 8: Effect of Salt Concentration

The effects of the salt concentration of the feed water on the permeate flux and salt retention are shown here.

IV.APPLICATIONS

4.4.1 In food industry

Besides desalination purposes, Reverse Osmosis System is also an application in filtering food liquids (such as juices) instead of normal process so far. Researches were conducted on concentration of orange juice and tomato juice. The advantage of RO System includes lower operating costs and the ability of avoiding heat treatment process. This system is consistent with heat-sensitive substances such as proteins and enzymes in most of food products. RO System is extensively used in the dairy industry to produce whey protein powder (the remaining liquid from cheese production) and concentration of milk to reduce shipping costs. Milk will be concentrated by Reverse Osmosis System; the solids total is from 5% up to 18-22% in order to reduce crystallization and lactose powder.

4.4.2 Car wash water treatment

Because of lower mineral content, Reverse Osmosis System is popularly used in car washing for the final phase which prevents water spotting on the vehicle. RO System is popular in US for conserving and reusing water within the car washing industry. Especially in areas which are effected by the droughts, water conserving and reusing are incredibly important. It also helps car wash workshop owners to reduce costs of drying vehicles and blowing equipment drying costs. In wine production industry, Reverse Osmosis System is widespread used. About 60 Reverse Osmosis System machines are in operation in Bordeaux (France) by the end of 2002.

4.4.3 In Syrup production

In 1946, a syrup factory started to use RO System to remove water from tree sap before boiling it to produce syrup. Using RO System allows 40 – 50% of water volume to be removed from tree sap, it helps to reduce energy consumption and limit exposure of the syrup to high temperatures.

4.4.4 In hydro production

For small-scale hydrogen production, RO System is occasionally used for preventing formation of minerals on the surface of the electrode.

4.4.5 In fish cultivation

Many coral reefs and fish lakes are installed a Reverse Osmosis System to make an artificial mixture of groundwater. Ordinary tap water may contain too much chlorine, chloramines, copper, nitrogen, phosphate, silicate, and other chemicals which are harmful for sensitive creatures in coral reefs environment. Pollutants such as nitrogen compounds and phosphates can lead to eutrophication. A great combination of RO System and deionization is quite popular for fish cultivation treatment in coral reefs and lakes. It is ideal for a low ownership costs and minimal operating costs

4.4.6 Desalination

Reverse Osmosis System does not use heat to operate so it requires less energy than other desalination methods in comparison. The typical desalination system of RO System includes: Pre-treatment, high pressure pump, filter installation, chemicals for filter preservation and pH adjustment, disinfection and control panel. Pre-treatment is very important to protect Reverse Osmosis filter and Nano filtration or ultra-filtration. This requires high pressure pump. The filter wall must be strong enough to withstand the pressure of the pump. RO filter is made of several constructions of matrix filter; with the two most common structures are spiral and hollow fibre.

4.4.7 Antiseptic

Reverse Osmosis System is an effective barrier to prevent the pathogenic bacteria. However, in some cases of water treatment process, the RO filter may be damaged and water will possibly have recontamination. Antiseptic with a combination of RO System and ultraviolet light are totally safe and sure for completely sterile water.[24]

V.CONCLUSIONS

Desalination technologies create new sources of fresh water from groundwater or brackish water. Various desalination processes were studied. Due to the compactness and ease of operation in reverse osmosis process forms a very effective method for desalination/purification of seawater and /or brackish water. The processes that seemed to be convenient and implemented on an experimental and laboratory level was reverse osmosis. Feed Water containing suspended particles, organic matter as well as inorganic salt may deposit on the membrane and fouling will occur or damage the membrane because of applied pressure and size of particles.

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