A Brief Review on Reverse Osmosis Technology

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Abstract-It is reported that 96.5% of the earth's water is located in seas and oceans, 1.7% in the ice caps, 0.8% is considered to be fresh water with the rest being brackish water. The world's water consumption rate is doubling every 20 years, outpacing by two times the rate of population growth. The availability of good quality water is on the decline and water demand is on the rise. The purification of waste water from various industrial processes is a worldwide problem due to the restricted amounts of water suitable for direct use, the high price of the purification and the necessity of utilizing the waste products. Since water shortage has been a problem for many communities and humans have been searching for the solution for a long time, desalination, is not necessarily a new concept. Now a day's wastewater treatment is not an easy task. Development of RO membranes of very high rejection, while maintaining high permeability, has potential to reduce the energy consumption. Development of better energy recovery devices can further reduce the energy consumption. As the success of RO desalination hinges on the proper pre-treatment of the feed water, various membranes could precede RO in order to selectively remove suspended solids, colloids/turbidity & organics and hardness and sulphates. This paper intends to provide an overall vision of RO technology as an alternative method for treating wastewater in different Industrial applications.

Index Terms- Membrane technology, Reverse osmosis, Nano filtration, Desalination, Microfiltration, Ultrafiltration.

1. INTRODUCTION:

Worldwide availability of fresh water for industrial needs and human consumption is limited. Water shortages and unreliable water quality are considered major obstacles to achieve sustainable development and improvement in the quality of life. Various industrial and developmental activities in recent times have resulted in increasing the pollution level and deteriorating the water quality. The water demand in the country is increasing fast due to progressive increase in the demand of water for irrigation, rapid industrialization, population growth and improving life standards.

A holistic approach is therefore required to be considered to deal with water problem. It includes:

- Seawater desalination in coastal areas
- Brackish water desalination
- Water purification
- Water reuse
- Rain water harvesting
- Water supply schemes [2]

Maintaining the drinking water quality is essential to public health. Although various water treatments is a common practice for supplying good quality of water from a source of water, maintaining an adequate water quality throughout a distribution system has never been an easy task.

Municipal, agricultural and industrial liquid or solid wastes differ very much in their chemical, physical and biological characteristics. The diverse spectrum of wastes requiring efficient treatment has focused the attention of researchers on membrane, ion-exchange and biological technologies. The most effective and ecological technological systems developed during the past 20 years are as a rule based on a combination of the chemical, physical and biological methods. Anaerobic digestion, anaerobic filters, lagoons, activated sludge and trickling filters have all been successfully applied to the treatment of distillery wastewater. Membrane and membrane separation techniques with immobilized microorganism or enzyme have very significant role in treatment of distillery wastewater. [4]

In recent years, membranes and membrane separation techniques have grown from a simple laboratory tool to an industrial process with considerable technical and commercial impact. Today membranes are used on a large scale to produce potable water from the sea by reverse osmosis, to clean industrial effluents (distillery wastewater) and to recover valuable constituents by electro dialysis. In many cases, membrane processes are faster, more efficient and more economical than conventional separation techniques. With membrane, the separation is usually at ambient temperature, thus allowing temperature-sensitive solutions to be treated without the constituents being damaged or chemically altered. There are two major types of waste inorganic waste and organic waste. Organic wastewaters are potent sources of water pollution. [4]

Water treatment processes employ several types of membranes. They include microfiltration (MF), ultrafiltration (UF), reverse osmosis (RO), and nanofiltration (NF) membranes. MF membranes have the largest pore size and typically reject large particles and various microorganisms. UF membranes have smaller pores than MF membranes and, therefore, in addition to large particles and microorganisms, they can reject bacteria and soluble macromolecules such as proteins. RO membranes are effectively non-porous and, therefore, exclude particles and even many low molar mass species such as salt ions, organics, etc. NF membranes are relatively new and are sometimes called “loose” RO membranes. They are porous membranes, but since the pores are on the order of ten angstroms or less, they exhibit performance between that of RO and UF membranes. [5]

Reverse Osmosis (RO) is a membrane based process technology to purify water by separating the dissolved solids from feed stream resulting in permeate and reject stream for a wide range of applications in domestic as well as industrial applications. It is seen from literature review that RO technology is used to remove dissolved solids, colour, organic contaminants, and nitrate from feed stream. Hence RO technology used in the treatment of water and hazardous waste, separation processes in the food, beverage and paper industry, as well as recovery of organic and inorganic materials from chemical processes as an alternative method

2. REVERSE OSMOSIS PHENOMENON:

Reverse osmosis is the process by exerting a hydraulic pressure greater than the sum of the osmotic pressure difference and the pressure loss of diffusion through the membrane can cause water to diffuse in the opposite direction into more concentrated solution. The greater the pressure applied, the more rapid will be the diffusion. [3]
Higher water efficiency works under optimum design pressure and varies for different membrane model. RO membrane is hydrophilic in nature. A typical RO system consists of four major subsystems, pretreatment system, high-pressure pump, membrane module, and post treatment system. Using a high-pressure pump, the pretreated feed water is forced to flow across the membrane surface. Brackish ground water has a much lower osmotic pressure than seawater; therefore, its desalination requires much less energy. Total Energy consumption for SWRO plant is around 3-4 kwhr/m^3 for 50% recovery [3]

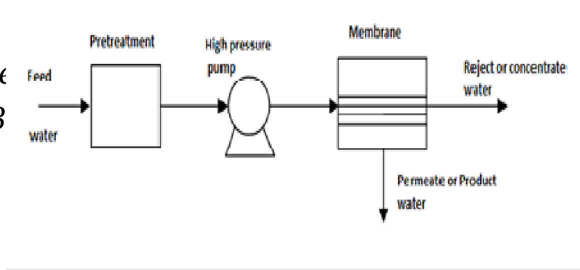

Figure1. Schematic Diagram of the RO Process [3]

RO is used for both brackish water and seawater desalination as well as for waste water treatment and water recovery/reuse. A typical RO desalting plant consists of three sections, namely pretreatment section, membrane section and post treatment section. Conventional pretreatment section typically consists of particulate filtration, micron filtration and chemicals additions. Membrane section consists of membrane elements housed in pressure vessels through which pretreated saline water is passed under pressure in excess of its osmotic pressure with the help of a high pressure pump coupled with energy recovery device. The post treatment section consists of lime treatment for pH correction and chlorination for disinfection as required to meet public health standards and to make the water noncorrosive to the water distribution systems. Energy consumption depends on the salt content of the feed water. [2]

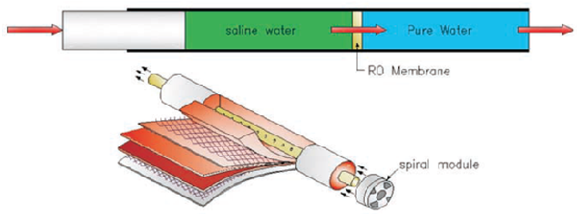

Figure 2: Reverse Osmosis (RO) [2]

2.1 Advantages of the RO process that make it attractive for dilute aqueous wastewater treatment include: [3]

(1) RO systems are simple to design and operate, have low maintenance requirements, and are modular in nature, making expansion of the systems easy;
(2) Both inorganic and organic pollutants can be removed simultaneously by RO membrane processes;
(3) RO systems allow recovery/recycle of waste process streams with no effect on the material being recovered;
(4) RO systems require less energy as compared to other technology
(5) RO processes can considerably reduce the volume of waste streams so that these can be treated more efficiently and cost effectively by other processes such as incineration
6) The RO plant is normally operated at ambient temperature which reduces the scale formation and corrosion problems, because of antiscalent and biodispersent use, which will reduce maintenance cost.

(7) The modular structure of the RO process increases flexibility in building desalination plants within a wide range of capacities.
(8) The specific energy requirement is significantly low 3- 9.4 kWh/m^3 product.
(9) The process is electrically driven hence it is readily adaptable to powering by solar panels.
In addition, RO systems can replace or be used in conjunction with others treatment processes such as oxidation, adsorption, stripping, or biological treatment (as well as many others) to produce high quality product water that can be reused or discharged. [3]

1. Desalination of Well water by Solar Power Membrane Distillation and Reverse Osmosis and its Efficiency Analysis , Selvi S. R*, R.Baskaran

This paper gives an idea for new researchers to make a attempt in the area of solar integrated mode of membrane distillation for desalination of various water resources which can solve the global water crisis in arid regions. The present work also contributes on comparison of water quality analysis for well water using both the desalination membrane technology. A novel technology of coupling of thermal membrane distillation with solar energy for the design and operation of DCMD for desalination was investigated. It was well understood that there is a greater scope for the feasibility of solar powered MD for good quality of product flow, high rejection of salts, low energy consumption and efficiency in desalination of water process provided extensive research is to be focused for constant success of work.

Reverse osmosis desalination technology, hence integrated solar MD will be a boon for long run operation with less Maintenance, less energy consumption and one time capital investment which is more economical.

2. Treatment Of Distillery Wastewater Using Membrane Technologies, Pawar Avinash Shivajirao

In this paper three case studies on microorganism which are helpful for distillery wastewater and also about biofiltration has been carried out. Reverse osmosis technique generate about 50% clean colorless reusable water & the balance 50% concentrate can be easily composted by available pressmud. This method thus creates an opportunity to arrive at zero discharge status. Hence it can be concluded that the above mentioned specific membrane configuration has the distinct ability of processing both the raw & biogas treated distillery spentwash, to obtain two streams, one containing clear & colorless water & the other a concentrated spentwash. Their quantitative proportion was average 50: 50. Thus the processing of the spentwash by this technique offers an opportunity to reduce the volume by 50%, facilitating its convenient composting. The overall pressmud & land requirement also is reduced to 50%, thus saving operating cost. The clear & colorless water may offer another opportunity to recycle the same, which could be a great boon to distilleries operating in water scarce areas or those spending large amounts of money for their water supply. Alternatively it can simply be given to irrigation to benefit the farmers.

3. Recent Advances In Membrane Science And Technology In Seawater Desalination – With Technology Development In The Middle East And Singapore,Takeshi Matsuura and Dipak Rana, Mohamed Rasool Qtaishat, Gurdev Singh

In this paper attempts have been made to increase the flux and to improve membrane stability by incorporating nanoparticles and by modifying the membrane surface. Moreover, fabrication of membranes that can reject boron, arsenics, and organic compounds of low molecular weights to higher degrees than currently available membranes is required to produce less hazardous drinking water. membrane distillation, forward osmosis, and carbon nanotube membranes are considered potentially applicable for seawater desalination. Development of seawater desalination membranes is continuously progressing and has demonstrated highly remarkable achievement in performance. Indeed, there appears to be no limit to the performance of these membranes in sight. The fluxes of currently available commercial membranes are an order of magnitude. higher than the RO membranes of 1960s with salt rejection as high ad 99.8 %. The current status and future direction of membrane desalination in the Middle East and Singapore have been discussed as case studies.

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The objective of the paper was to show the effectiveness of membrane technologies in removing nitrate and atrazine from a natural surface water source. Regardless of feed water quality variations, nitrate and atrazine were found to be significantly reduced (97% reduction of nitrate, and atrazine reduced below detection limits) using reverse osmosis membrane elements.
Reverse osmosis (RO), or hyper filtration, membranes have the capacity to remove solids 0.0001 microns in diameter or larger, creating a water practically void of all dissolved material. Originally designed for the

desalination of brackish seawater, high-pressure RO elements (800-1000 psi or 5516-6895 kPa) are able to reduce TDS from 34,000 mg/L to 500 mg/L for potable drinking water. Today, lower pressure RO elements (200-400 psi or 1379-2758 kPa) offer an affordable treatment option for the removal of dissolved solids from fresh water sources. The RO permeate SUVA values were within the range of 0 - 11 L/mg m. For most of the elements tested, SUVA values were below 4 L/mg-m. The ESPA membrane exhibited SUVA values below 2 l/mg-m. Because both TOC and UV absorbents were reduced to such low levels in the RO permeate. Blending the RO water (UV<0.013, TOC<0.930 mg/L) with tap water (UV<0.051, TOC<7-8 mg/L) would have very little effect in decreasing SUVA measurements. As suggested by a strict interpretation of the M/DBP rule, enhanced coagulation may still be required prior to RO/tap water blending to reduce SUVA values below 2 L/mg-m. However, this seems unlikely with lower TOC concentrations (<2 mg/L) in the RO permeate.

RO offers a cost-effective solution that has the potential to improve the lives of people drinking water with high levels of contaminants. (Na+) can be separated as well.

5. Comparative Study Of Nano And Ro Membrane For Sodium Sulphate Recovery From Industrial Waste Water , R. S. Gawaad, S. K. Sharma And S. S. Sambi

In the present work, performance of two commercial CSM membranes model NE-1812-70 (Nano membrane) and model RE 1812-50 (reverse osmosis membrane) were evaluated for concentrating the waste water stream to recover water and sodium sulphate for reuse. The NF membranes have separation characteristics in the intermediate range between reverse osmosis (RO) and ultra-filtration (UF). The aim of the work was simultaneous recovery of by-product sodium sulphate and recycling the membrane permeates to process plant so that fresh water consumption could be reduced. Compared to reverse osmosis membranes Nanofiltration membranes have a loose structure, resulting in higher permeate fluxes and lower operating pressures. Synthetic aluminium silicate is synthesized by hydrothermal treatment of sodium silicate and aluminium sulphate resulting dilute sodium sulphate as waste stream. Concentration of sodium sulphate in aluminium silicate industries waste is in the range of 1000 mg L-1 to 5000 mg L-1. From the study it was found that membrane performance was largely affected by feed concentration and operating pressure. It is possible to concentrate waste water containing sodium sulphate stream up to 14.1% by use of Nano membrane. The membrane NE 1812-70 was found to be more suitable for sodium sulphate recovery at high feed concentration of 30.878gm/L compared to RE 1812-50.

6. Fundamentals of Membranes for Water Treatment, Alyson Sagle and Benny Freeman1

Water treatment processes employ several types of membranes1. They include microfiltration (MF), ultrafiltration (UF), reverse osmosis (RO), and nanofiltration (NF) membranes (Figure 1)2. RO membranes are effectively non-porous and, therefore, exclude particles and even many low molar mass species such as salt ions, organics, etc. NF membranes are relatively new and are sometimes called “loose” RO membranes. They are porous membranes, but since the pores are on the order of ten angstroms or less, they exhibit performance between that of RO and UF membranes3. One of the major considerations in desalination is the energy consumption of the process. Lower energy consumption translates into lower product cost. RO has an advantage over MSF and MED because RO does not require heating to desalinate water. For RO, the main energy costs come from the electric power needed to run the process pumps. MSF and MED require electric energy for pumps, but they also require heat for evaporation. This thermal energy often comes from steam generated from low or medium-pressure turbine lines. RO processes are more directly affected than other desalination processes by salinity content because feed osmotic pressure is directly proportional to feed salt content. economic studies of RO, MSF, and MED desalination methods have shown that RO has the lowest overall energy requirements. RO, MED, and MSF brine discharges all have high salinity and chemical additives, but when it comes to discharge temperature, RO is the least destructive to the surroundings. This fact, coupled with reduced emissions due to lower power consumption, makes RO a more environmentally friendly option.

3. CONCLUSION

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. To determine RO efficiency the priority to remove these by way of pretreatment is important.
Hence RO membrane performance can be checked to avoid the irreversible damages to the RO membrane. In fact success of RO system depends upon efficiency of the pretreatment. Post treatment of brine streams present a major problem with growing desalination capacity to minimize the damage on the ecology which depends upon the location of plant.

4. FUTURE SCOPE

RO provides a cost-effective solution that has the potential to improve the lives of people drinking water with high levels of contaminants. Overall, the membrane field has advanced immensely. Being economical, environmentally friendly, versatile, and easy to use, membranes are a leading choice for water purification applications and should continue to be for many years to come. This type of device will be used in the petrochemical industry, with very different membranes, for dehydrogenation processes or the partial oxidation of methane. Such applications could be much more important, but the development of suitable membranes poses a number of very challenging technical problems.

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