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A CASE STUDY: REVERSE OSMOSIS WITH SOLAR ENERGY EFFICIENCY AND COST ANALYSIS.

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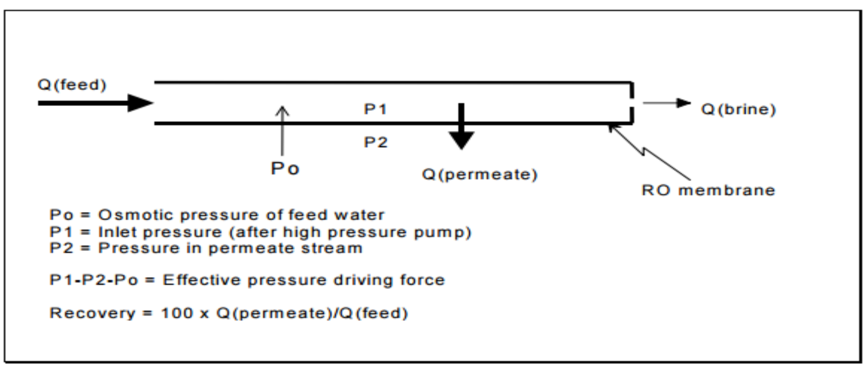
ABSTRACT

An efficiency and cost comparison is made for reverse osmosis process which used to purify the water for drinking purpose. Reverse Osmosis (RO) plants utilize selective membranes capable of separating fluids of different salinity, permitting the diffusion of preferred liquid molecules, but widely barring the penetration of solute molecules and other components. The driving force to sustain the process is pressure applied to the saline water fed into the RO system. The development and implementation of a solar powered RO unit will not only be of great benefit for communities in rural areas, but is also seen as a cost effective method of supplying potable water from brackish sources in disadvantaged and or remote areas.

Keywords: Energy Demand, Parameters, Osmosis, Solar Power, , Configuration and Operation , Conversion Systems

I INTRODUCTION

Membrane separation provides a favorable method for purification of water with moderate salinity. This method is a very low energy consumption method which used to remove the salt content of the feed water. If salt concentrations are higher, the process of Reverse Osmosis (RO) can be performed**.** In the reverse osmosis process, an external hydraulic pressure is applied to the concentrated solution, thus forcing pure water through the membrane against the osmotic pressure of the system. This external pressure obviously needs to be higher than the osmotic pressure.



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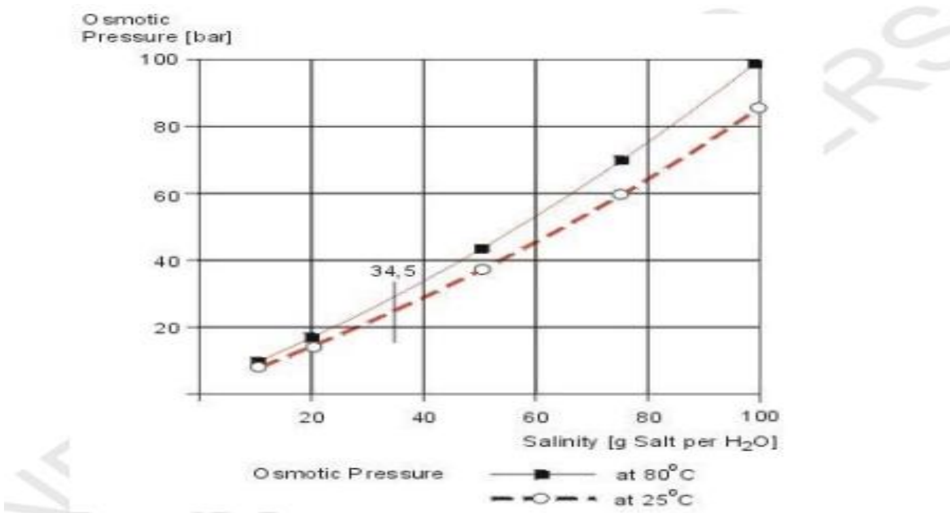
Osmotic pressure and salt concentration are directly related. Data for water qualities representative for desalination applications have been compiled, shown in figure. The process is reversible, controlled by pressure and concentration differences. As long as no state of equilibrium between the two solutions is reached, mass transfer through the membrane takes place. The process temperature exerts some influence, as do the diffusion coefficients and the material characteristics of the membranes.



Four basic types of RO module designs are in commercial use: tubular, plate and frame, spiral wound, and hollow fiber modules. Comparisons between the four basic module designs on their energy requirements, it is concluded that spiral reverse osmosis is the appropriate module to link with a solar powered water supply.

1.1 Factors Influencing Reverse Osmosis Performance

Permeate flux and salt rejection is the key performance parameters of a reverse osmosis process. They are mainly influenced by variable parameters as indicated in the table below. The effect on both flux and passage is also indicated.

INCREASING	PERMEATE FLOW	SALT PASSAGE
Effective Pressure	Increase	Decrease
Temperature	Increase	Increase
Recovery	Decrease	Increase
Feed Salt Concentration	Decrease	Increase

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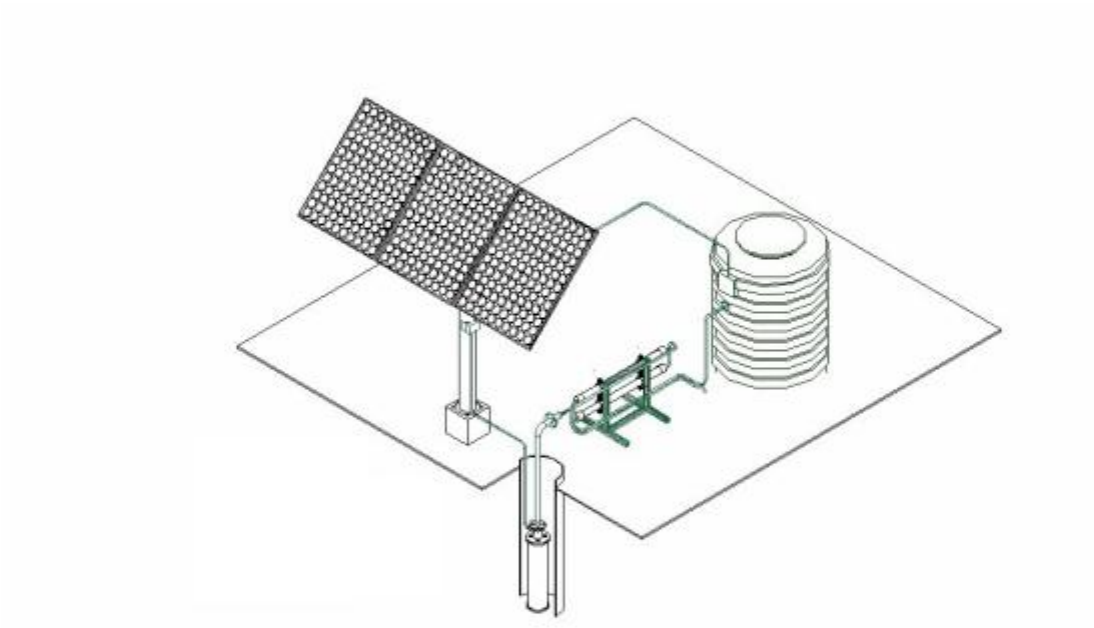
Solar Energy

There are a variety of technologies that have been developed to take advantage of solar energy. These include:

1. Photovoltaic (solar cell) systems: Producing electricity directly from sunlight.
2. Concentrating solar systems: Using the sun's heat to produce electricity.
3. Passive solar heating and day lighting: Using solar energy to heat and light buildings.
4. Solar hot water: Heating water with solar energy.
5. Solar process heat and space heating and cooling: Industrial and commercial uses of the sun's heat.

1.2 Graphical representation of the typical site arrangement.



Salt concentration on the high pressure side of the membrane increases due to extraction of permeate also the equilibrium conditions between the solutions change with the coordinate temperature (λ) . At a surface element ΔA the amount of water ΔM transgressing the membrane in a time interval Δt is given by the condition:

$$\Delta M_{(\lambda)} = K_w \cdot \Delta p \cdot \Delta A \cdot \delta^{-1} \cdot \Delta t$$

K_w can be assumed as a constant, summarizing the diffusion characteristics of water across the membrane, which includes the influences of the physical coefficients within the membrane (diffusion) and the related effects at the membrane surfaces (adsorption; desorption). The dominant pressure difference Δp is characterized by the external pressure applied by the high pressure pump minus the osmotic pressure difference for the two solutions (πF - πP).

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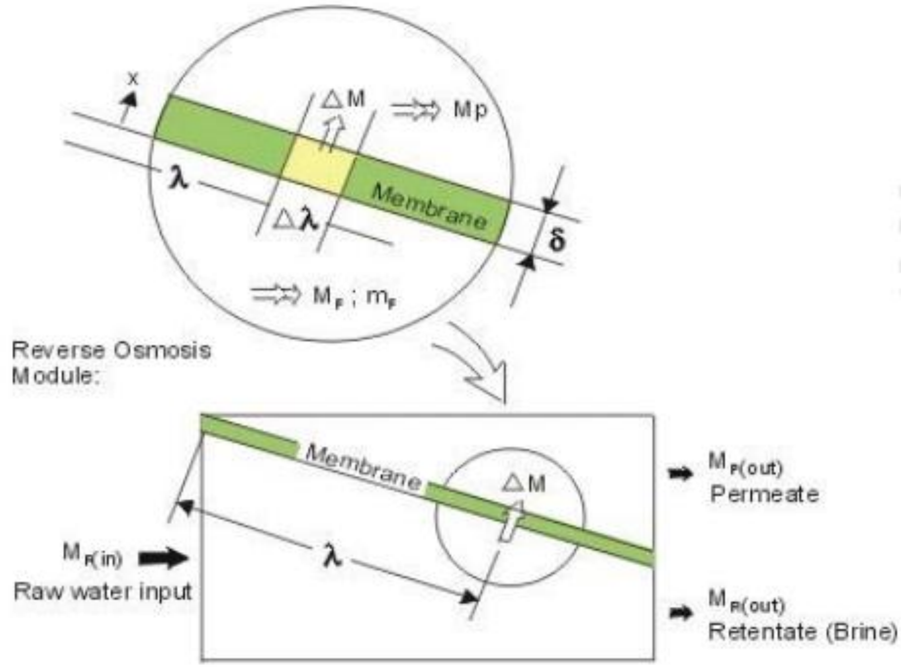
With changing salinity the local osmotic pressure difference increases as compared to the initial process conditions. Accordingly, the specific quantity of water passing per surface element of the membrane is variable.



The amount of salt Δm penetrating the membrane can be derived by a very similar expression as presented above. Here the dominant role is exerted by the concentration gradient (with Ks denominating the diffusion parameters of salt).

$$\Delta m_{(\lambda)} = K_s \cdot \Delta c \cdot \Delta A \cdot \delta^{-1} \cdot \Delta t$$

For technical application and assuming steady-state conditions the definition of a retention factor R is common to characterize the quality of the process in separating solutions of different salt concentration.

$$R = (1 - c_F / c_p) \cdot 100\%$$

With common salinity levels of the raw water ranging from 35 000 ppm, values of R between 98 and 99.5 per cent are necessary for seawater desalination plants, lower values may be admitted for brackish water treatment.

Under steady-state conditions and if the difference is sufficiently high the amount of raw water fed to the reactor separates into permeate (product) and retentate (brine), where MP(out) refers to the product water output; MF(in) to feed water input, and MR(out) to the brine rejected (retentive):

$$M_{F(in)} = M_{R(out)} + M_{P(out)}$$

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With the assumption mentioned that nearly no (or at least only a minor amount of) salt molecules will pass the membranes, and supposing that only few salt deposits are formed at the membrane surface, a compilation of the salinity increase yields for the status Sout at the brine exit:

$$S_{out} \cong S_{in} \times (1 - e_R)^{-1}$$

The term e_R represents the extraction rate as defined by:

$$e_R = M_{P(out)} / M_{F(in)}$$

It is obvious that in cases of high extraction rates specific care has to be applied to cope with the salinity increase. Still more effort may be necessary, if chemical elements are dissolved in the raw water, which are not present in common water sources. For instance, brackish water may contain elements not prevalent in standard seawater. When such molecules exist, the characteristics of the membranes need to be checked for suitability.

The Attractive Opportunity of Using Solar Energy to Power Reverse Osmosis Filtration Pressurization: Recall from above that approx. 2.5 kWh m-3 is required for the most efficient RO distillation. A system for converting this solar energy to pressurization energy, even with relatively low conversion efficiency of say 25%, would provide approximately 0.5 MWh/m2 pressurization energy per year, which would result in the production of approximately 250 m3 of desalinated water per m2 of solar collection area per year.

the energy cost is 0.86 kWh m-3 for conversion of seawater with saline content of 34,500 ppm at a temperature of 25^0 C . The cost for desalination has considerably reduced in recent years, and in india is approximately rupee30 $m^{-3}$to 60 m^{-3}.

II CONCLUSION

In this paper we compared the cost-effectiveness, energy-efficiency, and other relevant quantities of these potential solar desalination systems, and concluded that the direct solar-desalination systems using solar-thermal collectors appear to be most attractive for highly energy-efficient solar-desalination systems, although there are significant technical challenges remaining. Further, we overviewed the economics and practical issues associated with employing cost-effective solar desalination systems to provide for economic water sources for urban and also agricultural areas. We considered factors that have significant impact to these solar-desalination systems: including location, climate, and access to ocean water or brackish water sources, as well as land-use and ecological issues. We observe that the most favorable locations are those with high solar irradiance, lack of fresh water but access to large brackish water sources and/or seawater.

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REFERENCES

1. [Abdul Azis, 2000] P. K. Abdul Azis, Ibrahim Al-Tisan, Mohammad Al-Daili, Troy N. Green, Abdul, Ghani I. Dalvi and M. A. Javeed. Effects of Environment on Source Water for Desalination Plants on the Eastern Coast of Saudi Arabia. Desalination 132 (2000) 29-40.
2. [Al-Sahlawi, 1999] Al-Sahlawi MA. Sea water desalination in Saudia Arabia: economic review and demand projection. Elsever Desalination 1999;123:143–7
3. [Al-sofi, 2011] Al-sofi MAK. Sea water desalination—SWCC experience and vision. Desalination 2001;135:121–39. ElSadek A. Water desalination: an imperative measure for water security in Egypt. Elsever Desalination 2010;250:876–84.
4. [Alawaji, 2007] Alawaji SH, Kutubkhanah IK, Wie JM. Advances in seawater desalination technologies. Desalination 2007;221:47–69.
5. Dow Liquid Separations, Filmtec Membranes, Technical Manual, 1999 3)
6. Van Duuren FA (Editor), Water Purification Works Design, Water Research Commission, 1997
7. Al-Karaghouli A.A., Alnaser W.E. (2004), Experimental comparative study of the performance of single and double basin solar-stills. Appl Energy 77(3), pp. 317-25.
8. Al-Karaghouli A.A., Alnaser W.E. (2004), Performances of single and double basin solar-stills. Solar Energy 78(3), pp. 347-54.
9. Al-Shammiri M., Safar M(1999). Multi-effect distillation plants: state of the art. Desalination , 126:45-59.