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DESALINATION OF BRACKISH WATER BY INTEGRATED REVERSE OSMOSIS (R.O.) AND MEMBRANE DISTILLATION (M.D.)

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ABSTRACT

The objective of the paper is to study desalination of the brackish water The term integrated membrane processes refers to the integration of one or more membrane processes with or without the conventional unit operations in order to increase the performance depending on the type of feed and product quality required. Desalination has been accepted on a large scale over the last few years to overcome water shortages issue in many areas around the world .The main objective is to desalinate Brackish water using Reverse osmosis and membrane distillation as an integrated method . Brackish water as abundantly available can be very promising source after proper treatment. Reverse Osmosis (RO) is the leading technology for desalination of brackish water because of their strong capabilities in removing dissolved salts. Membrane Distillation (MD) is an emerging technology for effective desalination process of brackish water due to its potential lower energy consumption and simplicity. Both RO and MD have a great potential for treatment of water worldwide due to its availability, low cost and high efficiency.

Keywords: Desalination, Membrane distillation (MD) Reverse osmosis (RO), Water quality

I.INTRODUCTION

Water is the source of life, the basis of human survival, and the principal material base to guarantee the economy substantial development of a country. With increasing global population. Potable water production has become a worldwide concern; for many communities, projected population growth and associated demand exceed conventional available water resources. Water is the most common element 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 environmental pollution. According to the World Health Organization (WHO), about 2.4 billion people do not have access to basic sanitation facilities, and more than one billion people do not have access to safe drinking water. Moreover, the world’s population is expected to rise to nine billion from the current six billion in the next 50 years. The US geological survey 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]. Chronic water pollution and growing economies are driving municipalities and companies to consider the desalination as a solution to their water supply problems. Generally, desalination processes can be categorized into two major types: 1) phase change/thermal and 2) membrane process separation. Some of the phase-change processes include multi-stage flash, multiple effect boiling, vapour compression, freezing and solar stills. The pressure driven membrane processes, such as reverse osmosis (RO), Nano filtration (NF), ultrafiltration (UF) and microfiltration (MF), have found a wide application in water treatment [2].Although India occupies only3.29 million km geographical area, 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, 2011 was 1,210,193,422 persons (Census, 2011)[3]. Desalination uses a large amount of energy to remove a portion of pure water from a salt water source. So it is necessary to do the process efficiency, flux performance and energy consumption for desalination of Brackish water to meet the water crisis problem and global economic challenges. RO and MD when used as an integrated process, provides more efficient results as compared to other pressure driven processes. Challenges, however still exists to produce desalination water for relatively large communities for the continuous growth, development and health, and for modern efficient agriculture, at moderate costs [4].

II. DIFFERENT PROCESSES FOR DESALINATION

Desalination is a process of removing dissolved salts from water it is also called as desalting. Various methods can be used for desalination of brackish water which are as follows;

2.1 Thermal Processes

2.1.1 Multi-stage flash (MSF):The by far most frequently used process for desalting of seawater is the Multi Stage Flash (MSF) distillation. It is a process that comprises of evaporation and condensation of water, where pressurized feed water is heated in the brine heater before entering a chamber under partial vacuum. The latent heat of evaporation is recovered for reuse by preheating the incoming water. To increase water recovery in each stage of an MSF unit operates at a successively lower pressure.

2.1.2 Multiple effect distillation (MED):Multiple Effect Distillation (MED) employs the principle of distillation that incorporates boiling of the feed water. Therefore, this method comes across problems with scaling and has in general a more complex installation and control as compared to MSF. MED also uses different pressure vessels or effects, and the feed water is evaporated in the first vessel at its boiling point [5]

2.1.3 Mechanical vapor compression (MVC): The MVC process is symbolized by being driven exclusively by electric current, which is used to drive the mechanical vapour compressor. External heating steam is required for initialization of MVC process. Vapour compression (VC) is similar to the MED principle. Feed water introduced into the column is evaporated and the produced vapour leaves by passing through a moisture separator. Instead of condensing in the next subsequent effect as the case MED, the feed water is compressed and hence its condensing temperature is elevated.[6]

2.2 Membrane Technologies

2.2.1 Reverse osmosis (RO): Although the overall capacity of reverse osmosis is comparatively 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 solely 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 a adequate amount of water pass through a unit area of membrane.[7]

2.2.2 Electro dialysis (ED): As the name implies, this technology utilizes an electrochemical separation process in which charged membranes are applied to separate ionic species from a mixed aqueous solution of varied components and water through ion exchange membranes, which cause the concentration variations of solute in dilute and concentrated compartment. [8]

2.2.3 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.[9,10,11]

III. INTEGRATED PROCESS OF DESALINATION OF WATER

The integrated process of desalination consists of reverse osmosis followed by membrane distillation

3.1. Reverse Osmosis

Reverse osmosis is a process in which pressure is applied greater than the osmotic pressure through a semi permeable membrane so that the solute is removed from the feed solution.

3.1.1. Principle of Reverse Osmosis (RO*)*:RO is a physical process based on osmosis phenomenon. It is a pressure driven process wherein feed stream is fed into a chamber having semi permeable membrane resulting in the separation of two streams, one consisting of high concentration salt and other with less concentration. Pressure applied is higher than the osmotic pressure and the salt is retained in the feed side.

3.1.2.Various stages in RO

- Pre-treatment.
- High pressure pump (if required).
- Membrane assembly.
- PH adjustment.
- Disinfection.(if required)

3.1.2.1 Pre-treatment: It is a process in which the water is pre-treated in such a way that all the macromolecules are filtered out from the feed water solution, so that there is no deposition of solid macromolecules on the semipermeable membrane. This leads to lesser damage to the membrane and there is availability of more surface area for the process.

3.1.2.2 High pressure pump: High pressure is required when the applied pressure is less than osmotic pressure which is required for the RO. High pressure pump is generally not used when an energy recovery is combined with the RO set-up as it leads to minimum consumption of energy.

3.1.2.3 Membrane assembly: The membrane assembly consists of a pressure vessel with a membrane that allows pre-treated feed water to be pressed against it. The membrane must be strong enough 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. A part of the saline feed water pumped into the membrane assembly passes through the membrane and the salt gets removed. The remaining "concentrate" flow passes along the saline side of the membrane to flush away the concentrated salt solution. The recovery ratio varies with the variations in the salinity in the pre-treated feed water and the design parameters of the system.

3.1.2.4 pH adjustment: Sometimes it is necessary to adjust the pH value of the pre-treated water so that there is no effect on the membrane of the system. Generally liming is done to maintain the pH value of the pre-treated water to be as close to the pH value 7.

3.1.2.5 Disinfection**:** (if required)It is a post treatment process in which the bacteria and the viruses are being destroyed using UV lamps or chlorination to make it disinfected potable water.[12]

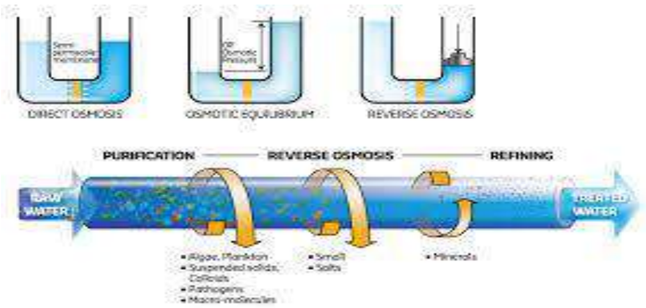

Fig.1 Reverse osmosis process

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3.2 Membrane Distillation

3.2.1 Principle Of Membrane Distillation (MD): MD is a thermal, vapour driven transportation process through hydrophobic membranes. It is a non-isothermal membrane process in which the driving force is partial pressure gradient across the membrane. Sea water is heated, its vapour pressure is increased which creates the difference between the partial pressure at both sides of membrane. Hot water evaporates through the non-wetted pores of hydrophobic membranes and only non-condensable gases are present within the membrane pores. The vapour coming out of the membrane is then condensed and fresh water is produced.

The output of the reverse osmosis process is then used as a feed to the membrane distillation. In membrane distillation unit further purification of the water occurs. The membrane distillation process is then carried out as follows.

There are various methods to carry out the membrane distillation process as mentioned as follows [13,14,15]:

- Direct contact membrane distillation
- Air gap membrane distillation
- Vacuum membrane distillation
- Sweeping gas distillation
- Vacuum multi effect membrane distillation

Out of these, DCMD process is generally use due to its easy construction and better comparative efficiency than the other methods. In DCMD basically there are two chambers for the flow of the fluids with membrane at the centre of the container. The fluids flow in counter current fashion. Hot fluid flows through the right chamber whereas the cold fluid flows through the right chamber. The output of the RO process is the input to MD process. The input to the MD is first preheated and then passed through the left chamber of the MD apparatus. The vapours are formed due to the preheating; these vapours then diffuse through the membrane. The membrane is hydrophobic in nature. The diffused vapours are then condensed on the right chamber and thus potable water is achieved as product.

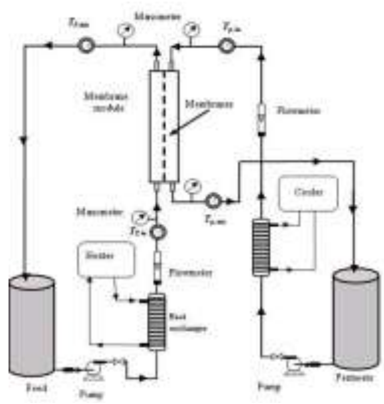

Fig.2 Membrane Distillation process

3.2.2 Effects Of Operating Parameters

3.2.2.1.Feed temperature :The effect of the feed temperature on permeate flux has been widely analysed. The feed temperature typically ranges between 60'C and 90'C.Generally, there is exponential increase in flux with feed temperature. The driving force for membrane distillation is the difference in vapour pressure across the membrane. As the feed temperature is increased, the vapour pressure in the feed solution channel also increases which results in the increment in the trans-membrane vapour pressure. it is better to work under high feed temperature, according to several researchers, as the evaporation efficiency and the total heat from the feed to the permeate/cooling side is high. The temperature polarization effect increases with the increase in feed temperature. However, if the operation is carried out at very high temperatures i.e. 90'C it may lead to reduction of membrane selectivity and severe scaling problems. [13, 14, 15]

3.2.2.2. Coolant temperature :Due to the exponential increase of the vapour pressure with feed temperature, the general effect of increasing the coolant temperature is less influential than the feed temperature. [13, 15, 16]

3.2.2.3. Feed Concentration: Feed concentration cause trans-membrane flux to decrease. This is due to several reasons as follows

- Vapour pressure reduction due to the salt concentration.
- Formation of concentration boundary layer at the membrane surface.
- Increased temperature polarization. [14,15,17]

3.2.2.4. Feed flow rate: In most of the studies, the effect of the feed flow rate results in the increase of permeates flux. This is due to decrease in temperature and concentration polarization effects by the mixing effect caused due to higher turbulence inside the feed channel. Such turbulence brings the temperature at the membrane surface closer to the bulk feed temperature. The effect of flow rate on yield is less than half of the influence of feed temperature; and its significance is obvious at higher temperatures especially associated with higher trans-membrane temperature drop. In general, the relationship between the trans-membrane flux and feed flow rate is linear to a certain limit, after which it has no effect on the trans membrane flux.[15,16]

3.2.2.5. Coolant flow rate :In the case of DCMD configurations, an increase of the permeate flow velocity increases the heat transfer in the permeate side of the membrane module by reducing the temperature and concentration polarization effect. This will tend to increase the permeate flux as the temperature difference increases. [15,16]

3.2.2.6. Trans-membrane temperature difference :The driving force in MD is the trans-membrane vapour pressure, as a result of temperature difference between the feed and permeate/cooling side of the membrane module. Flux increases linearly with hot to cold side temperature difference and increases slightly when coupled with a rise in feed concentration, as the boundary layer increases and contribute to the temperature polarization effect. Moreover, the slope at which flux increases with temperature drop tends to decrease at higher values. Such tendencies are related to temperature and concentration polarization effects which are affected by feed flow rates.[15,18,19]

3.2.2.7. Effect of non-condensable gases :Non-condensable gases evolve with the vapour, including dissolved. These gases get trapped in the membrane pores resulting in additional mass transfer resistance which leads to decline in the flux. When feed and permeate are degassed, the partial pressure of air within the pores becomes lower, hence, the molecular diffusion resistance decreases. De-aeration could significantly increase the permeate flux when large pore size membrane is used.[13,16,19,20]

IV.MEMBRANE MATERIALS USED FOR RO AND MD

Membranes used for RO process are hydrophilic in nature. Usually the fabric base is made up of polyester. A layer of polysulfone are used for coatings. The top layer is made up of polyamide. Membranes manufactured from hydrophobic polymers such as polypropylene (PP), polytetrafluoroethylene (PTFE) and polyvinylidene fluoride (PVDF) are used in the MD process. . The surface energies of PTFE and PVDF are 9.1 and 30.3 kN/m, respectively. They also have thermal conductivities as low as 0.22– 0.45 W/m-K and good chemical stability at the operating temperature of membrane distillation. Their pore sizes are in general in the Range of 0.2–1.0 µm and thicknesses are in the range of 0.06–0.25 mm.

The highest permeation flux and salt rejection was achieved when the membranes with a pore size of 0.22 µm were used in the cross-current follow arrangement of hot and cold streams. (For PTFE)

Name	Material	Porosity (%)	Nominal pore size	LEP_w(bar)	Thickness(µm)
TE 35	PTFE supported on polyester	75	0.2	4	120
TE 36	PTFE supported on polyester	75	0.45	1.8	120
-	PTFE	50	0.02	24	80
-	PTFE	78	0.2	2.75	60
-	PTFE	91	1	0.48	80
-	PTFE	84	0.45	1.35	80
-	PTFE	91	1	0.48	80
-	PTFE	95	3	0.13	25
-	PTFE	95	5	0.07	25

AP-20	Borosilicate with acrylic glue	50	-	-	300
GVHP	PVDF	75	0.22	-	125
HVHP	PVDF	70	0.45	-	125
LCWP	PTFE	68	5	2	125
LSWP	PTFE	60	10	-	125
FSLW	PTFE supported on polyester	75	3	-	200
FALP	PTFE supported on polyester	75	1	-	145
FHLP	PTFE supported on polyester	75	0.5	-	175
FHLP	PTFE	75	0.5	-	60
FGLP	PTFE supported on polyester	70	0.2	-	175
TF 200	PTFE supported on polyester	80	0.2	2.70	175
TF 450	PTFE supported on polyester	80	0.45	1.40	175
TF 1000	PTFE supported on polyester	80	1	0.50	150
TF 5000	PTFE supported on polyester	80	5	0.14	150
P5PQ	PTFE supported on PTFE	80	0.5	2	178
P5PL	PTFE	80	1	-	165

	supported on PTFE				
P5PJ	PTFE supported on PTFE	-	2	-	152
P5PI	PTFE supported on PTFE	-	3	-	152
P4PH	PTFE	-	5	-	127
R2PQ	PTFE	80	0.5	-	76
R2PL	PTFE	80	1	-	76
R2PJ	PTFE	-	2	-	25
R2I	PTFE	-	3	-	25

Table no 1: Main performance characteristics of flat membrane used for MD[22]

Name	material	Number of capillaries	N4minal pore size (µm)	Inner diameter in mm
LM-2P 1 2	polypropylene	22	0.2	1.2
LM-2P06	polypropylene	85	0.2	0.6
MD020TP2N	polypropylene	3	0.2	5.5
MD020CP2N	polypropylene	40	0.2	1.8

Table no 2. Main performance characteristics of tubular membrane[22]

V.TEMPERATURE POLARIZATION IN MEMBRANE DISTILLATION (MD)

The thermal boundary layer at feed side of the membrane imposes a resistance to heat transfer and creates a temperature difference between the membrane surface and the bulk liquid which creates heat transfer. The influence of this thermal layer in the feed channel (and cooling channel) is known as temperature polarization effect. Temperature polarization coefficient

(TPC) is used to quantify this phenomena by following equation:

$$TPC = \frac{T_{me} - T_{cf}}{T_h - T_c}$$

Where,

T_{me} is temperature at the membrane,

T_{cf} is temperature at condensation film,

$T_h$is temperature at hot/feed bulk solution and T_c is the temperature at the cooling bulk liquid. Lower the TPC value, higher the temperature polarization effect, and vice versa. The temperature polarization effect increases with increase in feed temperature The thermal boundary layers depend on fluid properties, operation condition and hydrodynamic conditions[14,15,21]

VI. MEMBRANE FOULING

Fouling is recognized as a decrease of the membrane permeability (permeate flux) due to deposition of suspended or dissolved substances on the membrane surface and/or within its pores. Various types of fouling can occur in the membrane systems, e.g., organic fouling,particulate and colloidal fouling, inorganic fouling or scaling and biological fouling. Scaling occurs in a membrane process when the ionic product of sparingly soluble salt in the concentrate feed exceeds its equilibrium solubility product. The term scaling is commonly used when the hard scales are formed (e.g. $CaCO3$, $CaSO4$).

Fouling is also one of the major hindrances in MD process because the deposit layer formed on the membrane surface may cause wetting of the membrane. This phenomenon will occur swiftly if the salt crystals were formed inside the pores.

The possible origins of fouling in MD process as follows: chemical reaction of solutes at the membrane boundary layer (e.g. formation of ferric hydroxides from soluble forms of iron), precipitation of compounds which solubility product was exceeded (scaling), adsorption of organic compounds by membrane-forming polymer, irreversible gel formation of macromolecular substances and colonization by bacteria and fungi.[23,24,25,26]

VII.ADVANTAGES AND DISADVANTAGES OF INTEGRATED METHOD

7.1. Advantages:

- The degree of purity of the product obtained by this integrated method is very high.
- The energy can be easily recovered in this process.
- Low space requirement as the equipment is compact.
- Fouling of hydrophobic membrane used in MD is less when used as an integrated method.

7.2. Disadvantages:

- The commercial membrane modules are expensive.
- This method requires higher power consumption.
- Pre-treatment of water is must for free of pathogens and suspended particles for feed water.
- Non-condensable gases evolve impose additional mass transfer resistance during the process.

VIII. CONCLUSION

Desalination technologies create new sources of fresh water from seawater or brackish water. This review paper focuses on the fundamental aspects of combined RO and MD units for desalination process. This novel technology of coupling of Reverse Osmosis with membrane distillation (MD) shows a greater scope for the good quality of product flow, high rejection of salts. The field of RO has become the primary choice for water purification over the past 40 years. Though the MD is known since 1963 and is still being developed at laboratory stage for different purposes and not fully implemented in industry. Due to the compactness and ease of operation in reverse osmosis process and low pressure and temperature requirements in membrane distillation process, forms a very effective method for desalination/purification of seawater and /or brackish water. It reduces dependency on conventional and depleting energy sources. This integrated process provides easy access of drinking water for the people in rural and remote areas hence this integrated method will be a boon for long run operation with less energy consumption, easy maintenance and one time capital investment, which is more effective and economic.

REFERENCES

[1] L.F.Greenlee,D.F.Lawler,B.D.Freeman,B.Marrot, and P. Moulin, “Reverse osmosis desalination: water sources, technology, and today’s challenges,” Water Research, vol. 43,no. 9, pp. 2317–2348, 2009.

[2] A. M’nif, S. Bouguecha, B. Hamrouni, and M. Dhahbi, “Coupling of membrane processes for brackish water desalination,”Desalination, vol. 203, no. 1–3, pp. 331–336, 2007.

[3] R. Kumar, R. D. Singh, and K. D. Sharma, “Water resources of India,”Current Science, vol. 89, no. 5, pp. 794–811, 2005.

[4] S. Otles and S. Otles, “Desalination techniques,” Electronic Journal of Environmental, Agricultural and Food Chemistry,vol. 4, no. 4, pp. 963–969, 2004.

[5] El-Dessouky, Ettouney, H; Al-Fulaij, H.; Mandani, F.;Multistage flash desalination combined with thermal vapor compression Chemical Engineering and Processing, 39 343-356,2000.

[6] Mandani, F; Ettouney, H; El-Dessouky, H; 2000―LiBrî—¸H2O absorption heat pump for single-effect evaporation desalination process‖ Desalination 128, 161-76,2000.

[7] B. van der Bruggen, C. Vandecasteele, T. van Gestel, W.Doyen, and R. Leysen, “A review of pressure-driven membrane processes in wastewater treatment and drinking water production, ”Environmental Progress, vol. 22, no. 1, pp. 46–56, 2003

[8] Wang, Xiao-lin; Gong, Y.; Yu, Li-xin; 2004 Process simulation of desalination by electrodialysis of an aqueous solution containing a neutral solute Desalination 172 , 157-172,2005.

[9] M. Gryta, “Desalination of thermally softened water by membrane distillation process,”Desalination, vol. 257, no. 1–3, pp. 30–35, 2010.

[10] M. Khayet, “Membranes and theoretical modeling of membrane distillation: a review,”Advances in Colloid and Interface Science, vol. 164, no. 1-2, pp. 56–88, 2011.

[11] T. Mohammadi and M. Safavi, “Application of Taguchi method in optimization of desalination by vacuum membrane distillation,”Desalination, vol. 249, no. 1, pp. 83–89, 2009

[12] Sekar, Chandru. "IEEE R10 HTA Portable Autonomous Water Purification System".IEEE. Retrieved 4 March 2015.

[13] Alklaibi, A; Lior, N; 2004―Membrane-distillation desalination: status and potential Desalination 171, 111-131,2004.

[14] Lawson, K.W.; Lloyd, D.R; 1997 Membrane distillation Review Journal of Membrane Science 124 ,1997. 1–25Banat and Simandl; 1994, Alklaibi and Lior; 2006.

[15] El-Bourawi, M.S; Ding, Z; Ma, M; Khayet, M; 2006―A framework for better understanding membrane distillation separation process Journal of Membrane Science 285 ,4–29,2006.

[16] Ettouney et al, 1999―Visual basic computer package for thermal and membrane desalination processes―Desalination 165 , 393-408,2004.

[17] Criscuoli, A; DrioliE;Energetic and energetic analysis of an integrated membrane desalination Desalination 124 243–249,1999.

[18] Walton, J.; H. Lu; C. Tumer; S. Solis; H. Hein;―Solar and waste heat desalination by membrane distillation Desalination and Water Purification Research and Development Program Report No. 81, 2004.

[19] Jönsson, A.S; Wimmerstedt, R; Harrysson, AC; Membrane distillation -- A theoretical study of vaporation through micro porous membranes Desalination, 56 237-249,1985.

[20] Martinez, L; Florido-Díaz, F.J; Theoretical and experimental studies on desalination using membrane distillation Desalination 139 373-379,2001.

[21] Schofield, R; Fane, A; Fell, C; Heat and mass transfer in membrane distillation‖ Journal of Membrane Science 33 299–313,1987.

[22] Chernyshov, M.N; De-Haan, A.B; Meindersma, G.W; ―Modelling temperature and salt concentration distribution in membrane distillation feed channel Desalination 157 , 315–324,2003.

[23] Satyajit M. Deshmukh, Anil C. Ranveer, Prashant M. Ingole, Dr Sameer K. Deshmukh, “Integrated method for desalination of seawater”, ” *International Journal of Advanced Technology in Engineering and Science,* Volume 4, Special Issue (01), Page No. 22-31, May 2016 (ISSN: 2348-7550).

[24] Satyajit M. Deshmukh, , Dr Sameer K. Deshmukh, Prashant M. Ingole, “Integrated Membrane Distillation and Reverse Osmosis for Desalination of Water” International Journal of Emerging Trends in Engineering and Basic Sciences.ISSN number 2349-6967. Volume 2 Issue 2. March, “Integrated Membrane Distillation and Reverse Osmosis for Desalination of Water” International Journal of Emerging Trends in Engineering and Basic Sciences.ISSN number 2349-6967. Volume 2 Issue 2. March-April 2015

[25] Gryta, M. Direct contact membrane distillation with crystallization applied to NaCl solutions, Chem. Pap., Vol. 56, No.1, 14–19, ISSN 0366-6352,January 2002.

[26] Gryta, M. Osmotic MD and other membrane distillation variants. J. Membr. Sci., Vol.246, No.2, 45–56, ISSN 0376-7388, January 2005.