Treatment of Reverse Osmosis Reject Water from Desalination

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Abstract*: Water is one of the most abundant available natural resources on our planet earth, covering three-fourths of the earth's surface. However, about 97% of the earth's water is saline water in the oceans, and only a small amount accounts for about 3% is fresh water. The only inexhaustible sources of water are the oceans, which, however, are of high salinity. Reverse Osmosis (RO) process is a water purification technology which purifies drinking water, desalinate the seawater to yield potable water in the form of permeate and waste in the form of RO reject or retentate or concentrate. RO reject however cannot be further purified due to the presence of high chloride content, high suspended solids and high osmotic pressure must be treated before discharging. This paper reviews about the treatment of RO reject from the effluent of Desalination to reduce the environmental impacts on further disposal of RO concentrate.*

Keywords: Desalination, RO reject, Suspended Solids, Sea water, Water purification.

1. INTRODUCTION:

As water shortage has increasingly become a serious global problem, desalination using seawater reverse osmosis (SWRO) is considered as a sustainable source of potable water sources. While desalination has been widely applied, one of the main issues associated with seawater desalination is its high energy requirement. Thermal desalination such as multi-stage flash (MSF) and multi-effect distillation (MED) uses a lot of thermal energy and electricity. Membrane desalination using seawater reverse osmosis (SWRO) uses less energy than thermal desalination but its energy consumption is still substantial. By applying various modern desalination technologies, Affordable Desalination Collaboration (ADC) implies that the specific energy requirements for SWRO process with energy recovery devices range 1.8–2.1 kWh/m^3 [1].

Another issue to be addressed is the handling of SWRO Reject, which has a higher salt concentration than seawater. The amount and salt concentration of Reject depend on the recovery of the desalination process. At 40% recovery, the amount of the Reject is 1.5 times larger than that of the desalinated water and the salt concentration is approximately 1.66 times higher than that of the seawater. In most cases, the Reject is directly discharged into sea.

There are two possible ways of advanced Reject management: volume reduction and concentration reduction. The first approach is to further concentrate Reject to decrease its volume. Mechanical or thermal evaporation, forward osmosis, and membrane distillation have been considered for this purpose. The second approach is to remove salt from the Reject to reduce its environmental impact after its discharge. In addition, the salt concentration in the Reject can be reduced by utilizing osmotic power, which also allows the recovery of energy.

This paper reviews the state-of-art approaches for Reject management for seawater desalination. The Reject management techniques are presented as technologies for producing fresh water. Topics in this paper include membrane distillation (MD), forward osmosis (FO) and crystallisation as emerging tools for beneficial use of RO Reject.

2. METHODOLOGY:

Seawater with the NaCl concentration ranging from 3.0% to 4.5% (or 0.51–0.765 mol/L) results in the osmotic pressure between 25 and 37 bar at 25 °C. Assuming that the recovery of product water in SWRO processes ranges from 30% to 50%, the osmotic pressure of the Reject is between 35.7 bar and 74.2 bar. If the salt concentration of the seawater is higher, the recovery in SWRO processes becomes lower, leading the maximum osmotic pressure of the Reject less than 75 bar in most cases. Therefore, technologies for producing fresh water from RO Reject should be able to overcome such a high osmotic pressure. RO is not suitable for this purpose since a very high pressure is required to further concentrate the RO Reject.

Another approach to overcome the high osmotic pressure of the RO Reject is to apply higher pressure in osmotic processes. But it can be done in forward osmosis (FO) processes that use osmotic pressure as their driving force. The methodology is given in the Fig. 1. For example, the ammonium-carbon dioxide draws solution of 6 mol/L results in approximately 250 bar, which is enough to extract fresh water from the RO Reject.

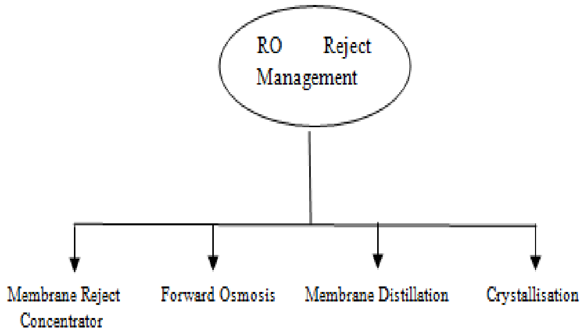

Figure 1: Technologies for RO Reject Management

3. TECHNOLOGIES FOR RO REJECT MANAGEMENT:

3.1 Membrane Reject Concentrator

The RO Reject treated from seawater desalination plants is to be applied into a specially designed RO system using hydraulic pressure called Membrane Reject concentrator. This Membrane Reject Concentrator is capable of treating high TDS feed water ranging from 70,000 mg/L to 165,000 mg/L [6]. However, membrane Reject concentrators are generally considered for industrial wastewater treatment rather than seawater desalination. The energy consumption was reported to range from 10 kWh/m^3 to 15 kWh/m^3.

3.2 Forward Osmosis

The RO Reject sea water using membrane technologies for FO system uses low energy and low fouling potential [7]. This is attributed to the requirement of high osmotic pressure for FO processes for SWRO Reject treatment. The application of FO processes for high salinity feed water has been done not for RO Reject treatment but for the treatment of shale gas produced water or zero liquid discharge system [14, 15, 16].

Recently, osmotically assisted reverse osmosis (OARO), which combines RO with FO, was suggested for high salinity Reject treatment [17]. According to this study, the OARO process was found to have a 35–50% water recovery with an energy consumption of 6–19 kWh per m^3 of product water for a feed solution of 100–140 g/L NaCl.

3.3 Thermal Evaporation

Thermal process such as evaporation is a conventional technique to treat RO Reject. Evaporation ponds are natural processes that lead the evaporation of water from RO Reject by the sun [19, 20]. They are successfully used in regions with dry weather, high evaporation rates, and availability of land at low cost. Wind can also help to evaporate water from RO Reject and this systems is called a wind aided intensified evaporator.

Traditional thermal desalination such as multi-effect distillation (MED) and mechanical vapour compression (MVC) can be applied to treat RO Reject. In theory, the use of MED can significantly reduce the RO Reject. However, scale formation on heat exchanger surfaces due to the precipitation of silica and calcium salts prevents to achieve it.

3.4 Membrane Distillation

Nowadays Membrane Distillation (MD) has drawn attention as a promising technique to treat the RO Reject. MD is a thermal separation process and thus less sensitive to salt concentration than RO or FO. Moreover, MD can be operated under lower temperature than MED or MVC, allowing the use of low grade heat such as solar thermal energy and waste heat from power plants or other industrial plants. This makes MD more attractive than other thermal techniques for RO Reject treatment [31-36]. The performance of different configurations including direct contact MD, vacuum MD, and submerged MD [26] has been evaluated for the treatment of RO Reject.

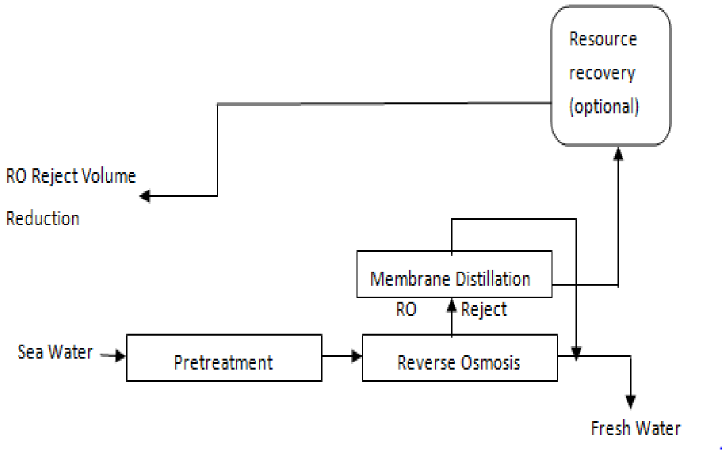

Figure 2: Water Recovery from MD process

3.5 Crystallisation

Crystallization is used for further treatment of RO Reject. There are two types of crystallization including freeze crystallization and evaporative crystallization. In the freeze crystallization, the RO Reject is cooled until its temperature becomes the eutectic temperature, which is essential for crystal formation. In the evaporative crystallization, additional thermal energy is added until the crystals are formed. In this case, vapour from the compressor increases the Reject temperature and the water is allowed to evaporate, leading to crystallization of salts from the concentrated solution [40-45].

In addition to conventional crystallization techniques, membrane crystallization is increasingly gaining interest as a Reject treatment option. Membrane crystallization allowed the operation at moderate temperature (40–50 °C) while conventional evaporation for NaCl crystallization is operated at temperature over 70 °C. However, fouling is also a critical issue in membrane crystallization of the RO Reject. One of the approaches for this problem is the control of bulk crystallization and surface crystallization in membrane crystallization, which has potential to induce crystallization and de-supersaturation without causing membrane fouling.

CONCLUSION:

This review paper concludes of all RO Reject technologies used for the reduction of water volume and salt concentration, the maximum efficiency was achieved by SWRO Reject membrane distillation (MD) technologies rather than other technologies.

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