Natural Treatment of Desalination Process for Brackish Water

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Abstract. Brackish water has a salt content between 500 to 17000 mg/l. If people consumption of brackish water, it impacts health problems and making plants wither or die. Groundwater become brackish is caused by sea water intrusion. Therefore, desalination technology is needed to process brackish water into fresh water. Natural material is predicted to be an alternative for desalination process. Natural zeolite is more used because they have abundant excess availability, lower operational costs, and have a high adsorption. More research is needed to determine the right activation method for zeolite so that the effectiveness of decreasing salinity can increase. In the initial study using natural zeolites with chemically activated, the reduction efficiency (ɳ) reached ~ 99.54%. From the results of these natural treatment, zeolite have the ability to reduce of salinity. This article is a review of several previous studies.

1. Introduction

In the coastal area there are many problems with limited fresh water. That was caused by the transfer of sea water intrusion. Sea water intrusion (SWI) is the main negative factor affecting groundwater exploitation in coastal areas [1]. Intake of ground water can cause changes in the direction of groundwater flow so that the hydrostatic pressure will increase and seawater intrusion will occur. Sea water intrusion is a phenomenon where seawater penetrates the aquifer layer of ground water (fresh water) so that the condition of ground water becomes brackish or salty like sea water [1]–[3]. Brackish water is water with salinity reaching 500 mg / L to 17000 mg / L. Brackish water cannot be used as drinking, cooking or washing water because the maximum salinity level for this purpose is less than 500 mg / L [4].

Therefore, desalination technology is needed to process brackish water into fresh water. Various desalination technologies have been developed such as multi-stage flash distillation (MSF), dual effect distillation (MED), steam compression distillation (VCD), reverse osmosis (RO), and electro dialysis (ED). This technology can reduce salinity until it reaches a high level of fresh water purity [5]–[7]. However, the operational costs of these technologies are still relatively high, requiring other alternative technologies that can reduce salinity levels with affordable operational costs.
Natural material is predicted to be an alternative in the alternative desalination process [7]. In addition, the availability of various sorbent materials makes the adsorption and ion exchange method potentially be developed as a cost-effective model[6], [8]–[11].

This paper is the result of a review of several previous studies.

2. Objectives

The objective of this work is to present an overview of current and future technologies applied to the desalination of brackish to produce freshwater for supplementing drinking water supplies to the common people in smaller quantity and find a cheaper, cleaner and more energy-efficient way of desalinating brackish water.

3. Desalination technology for brackish water

Desalination is generally a process of removing excess salt levels in water to obtain fresh water that can be utilized by humans, animals and plants. Some desalination methods used include electrodialysis (ED), reverse osmosis (RO), multi-stage flash distillation (MSF), multiple effect distillation (MED), vapor compression distillation (VCD).

3.1. Multi-Stage Flash Distillation (MSF)

MSF’s work process is first feed water will be flowed into the pretreatment system with the addition of chemicals and acids, to suppress the formation of scale in the heat exchanger pipe. Then aerated to reduce dissolved oxygen and carbon dioxide to minimize corrosion and improve the heat exchanger system. The water to be treated is then heated (preheated) in a heat exchanger module. Furthermore, it is heated to the maximum brine temperature in the brine heater and then the flashing process is performed in a flash evaporator [5], [12]

The advantage of using MSF for desalination is the quality of the water produced contains less than 10 mg / L of TDS. Feedwater salinity does not have much impact on MSF processes or costs. Can be combined with other processes, such as using heat energy from power plants. In addition, the MSF method has several disadvantages such as high installation and operating costs. A low recovery ratio where more feed water is needed for the production of the same amount of water. Crust and corrosion are serious problems with this method because the evaporator components are directly exposed to feed water [5], [12], [13]

3.2. Multiple Effect Distillation (MED)

MED is a desalination method that also requires heat energy in the form of steam and a small amount of electrical energy to drive the pump. Steam is obtained from turbines which after generating heat for heat exchangers will return to the secondary system [14]. The MED process consists of several stages, the first stage being obtained from the steam generating system, while the second stage and so on each gets steam from the results of the previous stage. Steam flows into the pipes in each evaporator effect and sea water is sprayed to the outside of the horizontal evaporator pipes. Steam that flows in the pipes will condense, and release the latent heat to the seawater film layer that occurs on the outer walls of the pipes, so that the seawater film layer partially boils and evaporates, while the rest falls to the bottom of the evaporator and is called a brine (salt concentrate) [15], [16].

Better thermal performance compared to the MSF method is the main advantage of using the MED method for desalination. MED requires lower operational costs on the use of heat for the refining process. The feed water used requires lower quality than the reverse osmosis (RO) method. The disadvantages of the MED method are the high operational costs when heat dissipation is not available for the distillation process and the formation of scale and corrosion [13].
3.3. Vapor Compression Distillation (VCD)

The steam compression distillation process is used in combination with other processes such as MED and single effect steam compression. In this process, heat to evaporate seawater comes from steam compression [17]. The VC generator utilizes the principle of reducing boiling point temperature by reducing pressure. Two devices, mechanical compressors (mechanical steam compression) and steam jets (thermal steam compression), are used to condense water vapor to produce enough heat to vaporize incoming sea water [12].

The advantage of this method is the simplicity and reliability of the VC system making this unit desirable for small-scale desalination processes. VC units can be designed to be portable and require minimal pre-treatment costs. The disadvantages are the need for large and expensive steam compressors as well as the generation of corrosion and scale on the evaporator components due to direct exposure to feed water [13].

3.4. Electro Dialysis (ED)

ED provides a cost-effective way to treat brackish water and encourages great interest in all fields to use desalination technology to produce fresh water on an urban scale [12]. ED is an electrochemical separation process that uses an electrically charged ion exchange membrane with a difference in electric potential as a driving force [18].

The advantage of the ED method is that it has a high processing capability so that the fresh water produced is more and produces less salt water. ED is suitable for brackish water with a salinity of 6 g/l TDS, but it is not suitable for water with a TDS of 0.4 g/l. Desalination of water with a TDS concentration of more than 30 g/l such as seawater is possible using the ED method but is no longer economical. The main energy requirement is direct current. Energy use is proportional to the salt removed. Can treat feed water with a TDS level higher than RO. The use of chemicals for pre-treatment is low. The disadvantage is that although the ED system is suitable for separating ionic substances, it cannot remove organic, colloidal and suspended solids [13].

3.5. Reverse Osmosis (RO)

RO is a membrane separation process in which water from a pressurized salt solution is separated from a solute (solute) by flowing through a membrane without the need for heating or phase changes. The main energy needed is to put pressure on feed water [12].

The advantage of the RO method is that it cannot only eliminate the salinity of dissolved solids, but also organic matter, colloidal material, and some microorganisms. RO is usually used for brackish water with salt concentrations ranging from 100 to 10,000 ppm. The drawback is the price of RO membranes is relatively expensive and can only be used 2-5 years. Operating costs will be lower if the selection of the membrane is right so that the effectiveness is higher. The use of chemicals for cleaning is low. Pre-treatment of feed water is needed to remove particles so that the membrane can last longer [13].

**Table 1. Performance and cost of various solar desalination plants adapted from [13], [19].**

| Technology | Feed water type | Specific energy consumption (kWh/m³) | Recovery ratio (%) | Water cost (US $/m³) |
|------------|----------------|----------------------------------|-------------------|---------------------|
| MSF        | Brackish water | 81-98                            | 0.6-6             | 1-3                 |
| MED        | Brackish water | 50-100                           | 6-38              | 2-4                 |
| MD         | Brackish water | 100-250                          | 3-5               | 13-15               |
| RO         | Brackish water | 1.2-5                            | 10-51             | 3-18                |
| ED         | Brackish water | 0.6-1                            | 25-50             | 3-16                |
The recovery ratio of the five desalination processes is indeed high, but the need for operational costs is also relatively high if the technology is used by coastal residents. Therefore, further research is needed to find alternative technologies in the desalination process at a lower cost and can be applied to all coastal populations in need.

4. Alternative processes

Alternative process is needed to obtain a desalination process with affordable cost, low energy requirements, and environmental friendly that can be used for the household scale. Natural material is expected to be a water treatment material in an alternative desalination process. One of natural material that is often used for the desalination process is natural zeolite because of its abundant availability in nature, simple processing, and relatively affordable operational costs to the household scale[7].

Natural zeolite is found in many chemical structures and formulas. Clinoptilolite, mordenite, phillipsite, chabazite, stilbite, analcime and laumontite are common forms while offretite, paulingite, barrerite and mazzite are scarce types. Clinoptilolite is the most widely used for research. Zeolites exhibit interesting physicochemical properties such as cation changes, molecular sifting, catalysis and capture. The high porosity and active surface area that causes zeolites are used for desalination and diverse water treatment[20]–[22]. Some studies use natural zeolites as the main ingredients of the desalination process using ion exchange and adsorption methods.

![Flow sheet of a conventional fixed batch column](image)

**Figure 1.** Flow sheet of a conventional fixed batch column

| Reference                  | Sorbent   | Performance in Desalination                                                                 |
|----------------------------|-----------|---------------------------------------------------------------------------------------------|
| Darmawansa et.al [9]       | Clinoptilite | The optimum value of reduction in brackish water salinity reach 27.31%.                     |
| Farida N A et.al [10]      | Clinoptilite | The optimum ratio of salinity reduction is 99.54%.                                           |
| Ade Kurniawan et.al [11]   | Clinoptilite | Modified zeolite can reduce the concentration of chloride and TDS. The value of efficiency decreases in salinity reached 9.14%. Sodium ions can be reduced by desalination using natural zeolite. |
| Wibowo et.al [6]           | Clinoptilite |                                                                                             |
| Wajima T [8]               | Modernite  |                                                                                             |
5. Conclusion

Conventional desalination technologies such as MSF, MED, VCD, ED, and RO have optimal salinity reduction values very high, but this technology cannot be applied for household scale that requires a large amount of energy in the process, so the operational costs are also very expensive. Alternative processes with natural zeolites can be applied at the household scale because applying natural zeolites is abundant in nature, easy processing, low operating costs, and environmentally friendly. To be applied to coastal communities, it is necessary to develop research to get standard design criteria for brackish water desalination process.

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