Study on Ultrafiltration-Reverse Osmosis Technology in The Treatment of Deep Ocean Water

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Abstract. As a high-quality water resource, deep ocean water (DOW) has aroused widespread interest. In this study, ultrafiltration-reverse osmosis technology was used to desalinate deep ocean water to prepare pure deep ocean water. By controlling the process conditions, the ultrafiltration-reverse osmosis system obtained a desalination rate of 98.3%, and the product water met the requirement of relevant standards.

Keywords: Deep ocean water, resource, ultrafiltration, reverse osmosis, desalination.

1. Introduction
Deep ocean water is defined as the seawater below a certain depth where cannot be enlightened to sunlight [1]. Deep ocean water is one of the most promising and a unique renewable resource because it is far away from land source pollution, has the advantages of clean water quality and rich minerals and trace elements [2, 3]. Due to the advantages of simple operation process, no phase change, low energy consumption for separation, good separation effect, and no secondary pollution, membrane separation technology is widely used in the field of water treatment [4-7]. Ultrafiltration membranes have a good effect on removing particles, colloids, bacteria, heat sources and various organic substances in water [8-12]. The reverse osmosis membrane can intercept various inorganic ions, colloidal substances and macromolecular solutes in water [13, 14]. Reverse osmosis technology is usually used in the desalination of seawater and brackish water, water softening treatment, waste water treatment, and purification, concentration, and separation in the food, pharmaceutical and chemical industries [15-17].

In this work, the ultrafiltration-reverse osmosis technology was used to study the desalination process of deep ocean water. The desalination rate of reverse osmosis system and its influencing factors were studied, and the relationship between operating pressure and desalination rate was investigated. By changing the process parameters, high-quality deep-sea purified water can be obtained, which can be sold as high-grade drinking water.

2. Experiment
The experimental raw material water was taken from the seawater at a distance of 500m from the sea level in the South China Sea. The ultrafiltration membrane was purchased from GE Co. The reverse osmosis membrane was obtained from DOW Co., whose model was SWRO 4040.
The deep ocean water was pre-filtered through a precision filter to remove various suspended substances in the water. The ultrafiltration device was then used for secondary filtration. The permeate flow rate of ultrafiltration was 0.48 LPM. The deep ocean water after ultrafiltration treatment entered the reverse osmosis device for separation and concentration. In the reverse osmosis system, the pressure difference reversed the natural permeation direction of water molecules. Thus, water molecules were separated from the concentrated solution, and reverse osmosis pure water was obtained after desalination.

The rate of desalination was the overall removal rate of salt by the system, which can be used to evaluate the system's ability to filter impurities in water.

The rate of desalination (Dr) was calculated by the following Equation (1):

\[
D_r = \frac{(TDS_r - TDS_p)}{TDS_r} \times 100\%
\]

where, TDSr was the total salt content of raw water (mg/L); TDSp was the total salt content of product water (mg/L).

3. Results and Discussion

The composition of the raw water after ultrafiltration were shown in Table 1. It can be seen from Table 1 that the content of macro elements such as potassium, sodium, calcium, magnesium, sulfate, chloride and beneficial elements such as strontium and active silicate in deep ocean water at 500 m was greater than that in deep ocean water at 300 m. Therefore, the technical research experiments in this paper used the deep ocean water at 500m as the raw material water.

| Test item | DOW (300m) | DOW (500m) |
|-----------|------------|------------|
| Sr        | 7.72       | 8.08       |
| Li        | 0.184      | 0.196      |
| SiO₂      | 2.32       | 3.97       |
| K         | 333        | 364        |
| Na        | 9750       | 10600      |
| Ca        | 355        | 375        |
| Mg        | 1190       | 1270       |
| HCO₃⁻     | 136.3      | 142        |
| SO₄²⁻     | 2140       | 2200       |
| Cl        | 17630      | 19010      |
| TDS       | 31220      | 33660      |
| pH        | 7.54       | 7.67       |

Desalination rate and water production were the essential characteristics of reverse osmosis membranes, which were mainly affected by the salt content, pressure, recovery rate, temperature and pH of the raw water. In this study, the water source is deep ocean water, and the environmental temperature, water temperature, salt content of raw water and system pH are relatively stable. So we focused on the impact of system pressure on desalination rate and rate of product water.
Figure 1. The effect of pressure on rate of product water

As shown in Figure 1, the rate of product water gradually increased with the enhancement of water supply pressure, and there was an obvious linear relationship between the two.

Figure 2. The effect of pressure on desalination rate

As shown in Figure 1, the rate of product water gradually increased with the enhancement of water supply pressure, and there was an obvious linear relationship between the two. It can be seen from Fig. 2 that the rate of desalination also increased with the upsurge of pressure, but it was not a linear relationship. After the pressure reached 4.3 MPa, the rate of desalination no longer increased. This was because reverse osmosis membrane cannot completely retain all the soluble salts in the water, and there was always a small amount of salt leaking through the membrane. Within a certain range, the penetration rate of salt was slower than that of the water. However, there were limits to improving the desalination rate by enhancing the water pressure. When the pressure was too high, both water molecules and salts passed through the reverse osmosis membrane, resulting in that the increase water flux was offset by permeability of salt and the desalination rate was no longer rose. The content of
total dissolved solids in the product water was 240 mg/L. The desalination rate of the ultrafiltration-reverse osmosis system was 98.3%.

4. Conclusions
The operation results showed that the application of ultrafiltration-reverse osmosis technology to the desalination treatment of deep ocean water has a good effect, and the index of desalinated water obtained was better than the sanitary standard of drinking water. The desalination rate and water production of the system were significantly affected by the operating pressure of the system. Under the optimized process, the desalination rate of the system can reach 98.3%, the operation was stable and has broad application prospects.

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