

The advantages and future development trends of reverse seawater osmosis compared with other desalination methods

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Abstract. Global freshwater resources are not evenly distributed in regions and time, and with economic development and population growth, the world's water consumption is also increasing year by year. The world is facing a crisis of insufficient freshwater resources, which will become more and more serious in the future. In order to solve this problem, various countries are vigorously developing seawater desalination technology. Seawater reverse osmosis is one of the important methods of seawater desalination. The advantages and disadvantages of the seawater reverse osmosis method were obtained by comparing it with other desalination methods. Find references to list the views of some countries on seawater reverse osmosis. Combined with the different needs of some regions and countries, this paper summarizes the corresponding progress of seawater reverse osmosis technology, analyzes the application of seawater reverse osmosis, and understands the specific technologies to be developed in the future. The future development trend and challenges of seawater reverse osmosis were predicted.

Keywords: Seawater reverse osmosis; advanced seawater reverse osmosis technology; global seawater reverse osmosis application.

1. Introduction

The world's water reserves are abundant, at 1.45 billion cubic kilometers, but freshwater accounts for only 2.5 percent of them. Of this tiny amount, more than 70 percent is locked up in Antarctic and Arctic ice caps, and with inaccessible mountain glaciers and frozen snow cover, 87 percent is unusable. Humans can use only freshwater resources rivers, lakes, and groundwater, which account for 0.26% of the earth's total water volume. The freshwater resources in the world are not only in short supply but also extremely unbalanced in regional distribution. By region, nine countries -- Brazil, Russia, Canada, China, the United States, Indonesia, India, Colombia, and Congo -- account for 60 percent of the world's freshwater resources. About 1.5 billion people in 80 countries and regions, representing 40 percent of the world's population, are short of fresh water, and about 300 million people in 26 countries are critically short of water. It is estimated that by 2025, there will be 3 billion people in the world facing water shortage, and 40 countries and regions are in a serious shortage of fresh water. To solve the global water shortage problem, instead of only focusing on saving water, converting other types of water resources into freshwater should also be considered as a long-term open source plan. So one of the powerful ways to solve this problem is reverse seawater osmosis. This paper is divided into four parts, from the basic introduction of the seawater reverse osmosis method to the comparison of the seawater reverse osmosis method with other seawater desalination methods, to the study of seawater desalination technology and application in some countries and regions, and finally, the development trend of the seawater reverse osmosis method. The necessity of the development of a seawater reverse osmosis method is analyzed reasonably and carefully [1].

2. Advantages of seawater reverse osmosis and advanced improvements in RO technology

2.1. Advantages of seawater reverse osmosis

The demand and market for freshwater resources are huge. Reverse osmosis is one of the methods of seawater desalination. Seawater cannot be used to irrigate farmland, is difficult to use as industrial water, and cannot be used directly as drinking water for people. The reverse osmosis desalination membrane has a high-pressure capacity, large membrane flux, and high sodium chloride and boron removal rate. It is widely used in seawater or brackish water desalination and is one of the low energy consumption desalination membrane elements in the world. Reverse osmosis desalination technology develops rapidly, the project cost and operation cost continue to reduce, the scope of application desalination scale is moderate, the project construction time is short, and many other characteristics. It can also effectively remove bacteria, viruses, inorganic salts, heavy metal ions, organic matter, and other harmful impurities in seawater, and the water quality meets the national industrial water standards. It can even reach the national drinking water standards and be trusted to drink directly.

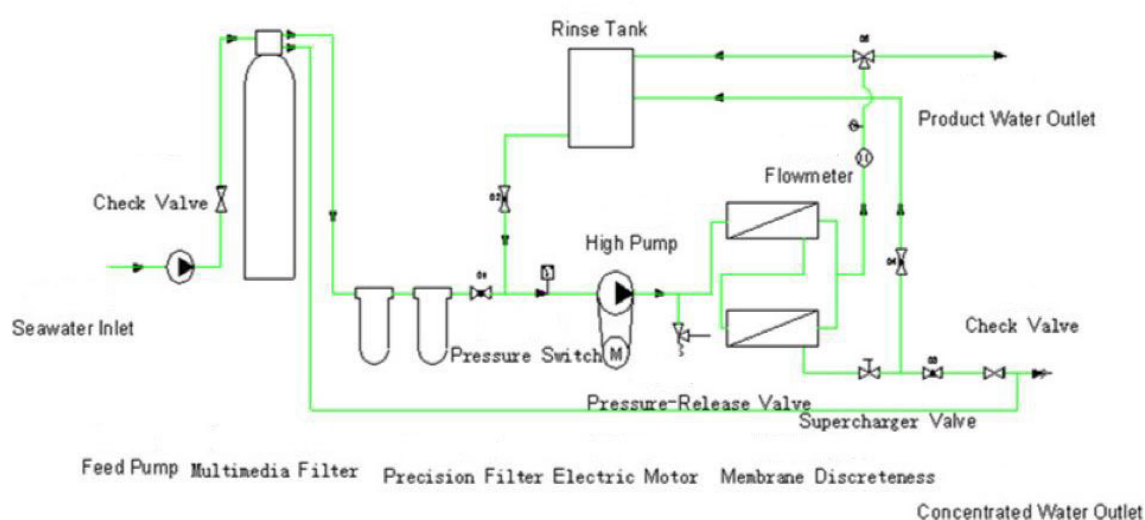


Fig. 1 The schematic graph of the seawater osmosis desalination [2]

The main advantages of reverse osmosis desalination equipment are discussed as follows. First, the filter element used has the characteristics of good filtration effect, large flow, strong anti-pollution ability, strong anti-pressure ability, and can effectively intercept different sizes of impurities particles. Second, because of the resistance to pressure, it can continue to operate at a high water flux under low pressure, and the desalination can reach 99%. Third, the whole set of equipment saves the manufacturing cost and investment cost, the same inch operation period also greatly reduces the operation cost, the high operation ring uses water resources, saves energy. Fourth, the equipment adopts anti-pollution membrane elements, improves the service life of the system, prolongs the maintenance cycle, equipment maintenance is simple, easy to operate, and the whole set of equipment occupies a small area and has a good energy-saving effect.

Besides, seawater desalination is a new energy technology and conforms to the development of The Times Materials, energy, and information are the three pillars of industry in the 21st century. New materials and new energy play an important role in promoting the development of seawater desalination in terms of improving efficiency, cost savings, and environmental friendliness. The emergence of new technologies means that the use of seawater desalination is diverse, and energy consumption is economical. The various technologies of desalination of seawater coexist and complement one another. The seawater desalination technology is essentially mature but improving process technology and using new materials and processes are still unprecedentedly active.

Overcoming the trade-off between permeability and selectivity as well as enhancing membrane stability against chlorine and soil assaults have both seen significant advancements in recent years. Recent research has concentrated on the development of water-loving membrane surfaces and brushstroke-like surface topology to reduce the consequences of a filth attack since dirt is one of the primary limits in the saltwater desalination process. It is strongly advised to have a deeper understanding of the types of pollutants found in water bodies with reference to the creation of surfaces for anti-fouling membranes. Given that the desalination industry requires pre-treatment of dechlorination, the creation of a chlorine-tolerant technology may be the most advantageous response to future industrial demands by reducing the cost of desalinated water [3].

The least expensive practical wind energy alternative, as determined by the optimization results, entails a single FL 30 kW wind turbine, ten batteries, and ten converters. This alternative has a cost of around \$0.17/kWh and a capacity shortfall of roughly 51%. As a result, our RO system will operate at maximum efficiency for roughly 4000 hours per year, generating about 30,000 m². Since the majority of severe wind gusts occur during the day, the system must run for more than 8 to 12 hours every day for the whole year to provide the anticipated 4000 hours. It could be essential to construct a water storage tank in order to store water for usage during times of low wind speed in order to handle increases in water output during high temperature and wind speed seasons [4].

Until 2004, the market for SWRO was dominated by small and medium-sized desalination plants. After 2004 there was a peak in the online and expanded capacity of both the large and the very large SWRO factories. This is reflected in a sudden decline in average global capital expenditure from USD 3,074 /(m³/day) in 2003 to USD 1,160 /(m³/day) in 2005. The cost of a reverse osmosis installation is more influenced by its economic size than that of a thermal desalination plant. Voutchkov explains that a milestone in membrane desalination occurred in 2004, when large-diameter membranes, suitable for large and extra large volumes, were developed and commercialized. This is to meet the growing demand for large desalination capacity. Using a 16" membrane instead of a standard 8" membrane means a compact physical structure and reverse osmosis training. Other components of the SWRO system, such as high-pressure pumps, energy recovery systems, and membrane cleaning systems, also benefit from the advantages. These factors explain the expansion of the capacity of SWRO's large installations after 2004, which reduces the average capital expenditure worldwide. These technological advances are the driving force behind the learning curve[5].

2.2. Energy consumption of reverse osmosis (RO) system

Energy consumption in the RO systems accounts for about 70% of operating costs, so the efficiency and reliability of the energy recovery devices in the system are particularly important. Conventional energy recovery equipment includes impact turbines and mixed-current turbines. In preliminary tests, Bermudez-Contreras and Thomson Modified the Clark Pump to reverse the effect of the two Pairs of Chambers and achieve An Energy consumption of 3.5 to 4.5 kW h/m³ [6].

Sun et al. developed an energy recovery device from a fluid switcher. The hydraulic recovery efficiency of the fluid mixer can reach 76.83% when water is used as the working medium in the experiment. Preliminary experiments on a simulated RO desalination system show that the energy recovery rate is up to 95.9%. Song et al. developed a piston-shaped shear and achieved energy recovery of up to 98% under the experimental conditions of a 6.5 mph and a 30 m³/h RO system. Al Hawaj conducted a theoretical analysis of a new energy recovery device, the slide slider work exchanger, which combines a positive displacement pump and a positive displacement turbine. By examining the influence of geometric parameters, physical parameters, and operating parameters on device performance, it is determined that the functionality of the slide valve operating exchanger strongly depends on the friction and leakage of the blade end.

The key component of the RO system is the semi-permeable RO membrane. Therefore, the development of a semi-permeable membrane with a continuous high pass, low pressure, and low energy consumption and the application of the organic anti-pollution active coating to reduce the formation of fouling on the membrane are the challenges for the development of the RO desalination

method. McCloskey et al. applied polydopamine deposition on the surface of an RO semi-permeable membrane to improve the fouling resistance of the membrane without greatly reducing the pure water permeability. Azari S, and Zou L. created a grim-resistant zwitterionic surface on a commercial RO membrane by incorporating a redox functional amino acid onto SW 30 XLE. Fujiwara and Matsuyama used chlorine-resistant cellulose triacetate (CTA) RO membranes to eliminate biofouling problems through direct chlorine sterilization and intermittent chlorine injection. Yang et al. proposed using a nano-silver coating to modify the surface of the RO film and separator and proved through experiments that this technology can effectively control the biological fouling on the film. In recent years, the progress of nanotechnology has promoted the development of RO membranes. A variety of semi-permeable membranes with hydrophilic properties, high throughput, and low osmotic pressure have been developed by using nanotechnology. In addition, effective pretreatment methods can also control biological fouling. Placement of solubilized aerosols before ultrafiltration membranes can increase the flux (water recovery) of RO. It also reduces dirt. Aerosols are used as a pretreatment step in RO to effectively remove oil and algae. In order to improve the recovery rate of RO membranes, Japan has developed a seawater RO system with a high recovery rate, which is mainly achieved by improving the pressure resistance of the RO membrane and module and controlling the concentration polarization on the membrane surface. It is found that seawater with different TDS is tested in RO desalination plants in Japan and Saudi Arabia. The system can increase recovery from 40% to 60% for standard seawater (a TDS of 35,000 mg/L) and from 35% to 50% for Middle Eastern seawater (a TDS of 43,000 mg/L) [7].

The advancements in distillation technology are also necessary. The origins of multifaceted distillation can be traced back to the 1830s. Early MED was limited by the easy scaling of the heat exchanger surface. It was not until the 1960s that the development of low-temperature multifunctional cut technology, reduced scalable and Corrosion problems using a horizontal tube that falls into the film evaporator, which eliminates the effect of stationary pressure on the evaporation surface, Operation at low temperatures (the maximum salt-water temperature is 65 to 70 °C) also limits the calibration of the tube wall. The horizontal tube that fits the film evaporator has become the industry standard.

3. Global advances in seawater desalination technology

The project's growing social needs and technological advancements have led to the development of a global seawater smelting project in a broader and broader direction. The rate of herbs has risen from a few hundred tonnes a day to a hundred thousand tons. Water production in one part of the device has also increased rapidly. Technological advances, large-scale balances, and innovations in construction and operation have gradually led to lower spice mixing prices. Seawater smelting and resource exploitation gradually created an industrial chain. A combination of seawater smelting engineering and power plants, using heat waste from power plants for clean water and fully utilizing salt, is becoming a global hotspot. Seawater from the ocean has the properties of extraction and purification, which takes place about twice a year, and the temperature and liquidity of the water are stable throughout the year.

Since pressure exchange systems have been used in desalination plants for more than ten years, this technology has reached a point of maturity that enables a steady decrease in the process's specific energy consumption. New systems with superior components occasionally enter the market, providing improved efficiency and extending the operating life. Minimize the barrier by 2,00 KWH/m³ at medium and high capacity stations during the decalcification of navigation is the challenge with these devices. Currently, only small and medium capacity plants are able to break through this barrier, and only if additional highly efficient components are installed in addition to the energy recovery device, such as high-pressure pumps with throughputs of more than 90% and contemporary variable frequency propulsion systems [7].

Europe, the United States, Japan, and other countries and regions are not only exporters of desalination technology but also countries with great demand for salt water. It can be said that the United States is a water-rich country, but the west, south, and southeast are known globally for their areas of seawater, desalination, and reuse of wastewater. In the United States, the idea is not to involve any specific technologies but to combine them with water treatment. Therefore, it attaches great importance to various membrane technologies for treating water. Reverse osmosis of brine since the 1970s, thin film/nanofiltration (M/N F) in the early 1980s, and low-pressure thin film water treatment (microfiltration and excess filtration, MF/UF) in the late 1990s have played an important role in water treatment, while distillation is no longer mainly due to economic weakness.

In Southern California, the Metropolitan Water District (MWD) also provides a financial grant (\$0.2/m³) to a number of local water agencies to facilitate desalination projects. The Japanese government has invested 85% in the construction of two large reverse osmosis demonstration plants in Okinawa and Fukuoka. With the engineering demonstration, Japan's Toray, Ildong Electric, Andyo Textile, and other reverse osmosis membranes, as well as auxiliary equipment manufacturing companies and engineering companies, have become global. The Israeli government promotes the construction of offshore desalination plants by controlling the BOOT (Build-Operate-Own-Transfer) or BOO (Build-Operate-Own) models; provides financial support to local enterprises; and explains the minimum purchase amount and price of desalinated water purchased by the government in a contract to cultivate local enterprises and improve their competitiveness [8].

In October 2007, the South Korean government launched support for Doosan Heavy Industries with a construction scale of 2. A standalone experimental 7x10⁴ m³/d reverse osmosis desalination plan that invests \$76 million, of which \$32 million is funded by the government, will be completed in 2010, with an expected return on export contracts of \$10.9 billion by 2020 [9].

The establishment of a Middle Eastern Desalination Research Center (MEDRC) shows that desalination testing has become an international issue of concern to the world, and competition cooperation has become a consensus among developed countries.

Electricity is produced, transported, and distributed in Israel by the Israel Electric Company, the country's only integrated power company that is 99.85% owned by the state. In the decade between 1999 and 2009, the country's cumulative demand for electricity grew by an average of 3.6 percent. Coal accounted for 64.7 percent of IEC electricity in 2009, while fuel oil accounted for 1.2 percent, natural gas 32.6 percent, and diesel 1.5 percent. All the fuel used is imported from outside Israel, and part of the natural gas comes from Egypt (Israel Electric Power Company 2010). The volatility of obtaining gas from Egypt cannot be underestimated, especially since Egypt provides 43 percent of Israel's gas and 40 percent of its electricity. In 2011, Sinai Bedouin and terrorists blocked the flow of natural gas from Sinai to Israel eight times to protest exports, resulting in a loss of \$1.5 million a day. Israel's lack of control over the availability of fuel and reliance on a national network of desalination plants means that any disruption to the delivery (due to political or other reasons) will affect the ability of the state to provide water to residents and industry [10].

4. Analysis of seawater reverse osmosis technology in various countries and regions of the world

In the salt industry, the direct use of bottled seawater for halogen production could shorten the halogen production cycle and save land resources. On this basis, new technology will be used to extract bromine, magnesium, potassium, and calcium salts in a combination of seawater. The Senate has approved a policy of HR 1071 and HR 3834 (\$200 million over 10 years) and a \$0.16 subsidy for freshwater produced and sold by cubic meters since 2004. In the next 5–10 years, China's seawater desalination technology and industry will be greatly improved in terms of new environmental creation, innovation ability, technology and equipment level, equipment domestication rate, and application scale, and the overall level of technology and industry will enter the world's advanced ranks. Seawater

desalination, as an incremental technology of water resources, has significantly improved the contribution of new water supply to the water shortage areas in China's islands and coastal areas. At the same time, the next 10 years will also be a golden time to promote China's desalination equipment overseas to build a global competitive advantage [10].

In fact, most of these places are not water-scarce. Their starting point in developing desalination technology is to make money from the oil giants of the Middle East. Therefore, the development of the degrease industry is to solve the local water shortage problem but should not be limited by the national or regional water shortage. Even though China has plenty of water, developing desalination technology is still necessary. In fact, although desalination companies supply water, their economic benefits are low, and the payback period is long. However, if technology is exported, equipment export is not only effective, high efficiency. Therefore, our desalination entrepreneurs must be prepared to explore foreign markets. However, it will not be easy to advance in the international market if it has its own technology first, rather than staying at the current level of foreign parts assembly. For more than half a century, the countries of the Middle East have grown rapidly due to oil and trillions of dollars flowing from the developed countries of the west to the middle east in the form of oil purchases but also in the form of desalination plants.

Although this document focuses on the technical problems of reverse osmosis in seawater desalination, it is also necessary to pay attention to the technical reality of the middle east, which has the greatest demand for seawater desalination. The preferred technology is still multi-stage flash evaporation. As an international entrepreneur, this point can not be noted. Therefore, while developing membrane methods in China, researchers also need to pay attention to the development of distillation methods and large distillation units.

For a long time, many developed countries in Europe, as well as Japan and South Korea in Asia, have been in a leading position in major theoretical research on desalination in water, research and development of key technologies, nuclear equipment development, material development, material development, and engineering operations. Taking a full range of osmosis membranes as an example, due to its huge cost, long life, and high desalination rate, more than 90% of the global market share is occupied by Dupont (Dow), General Motors of the United States, Toyos of Japan and other companies; The energy recovery device developed by the United States and Switzerland has a full advantage with a high recovery rate and high stability of more than 95%. High-performance high-pressure pumps developed by Germany and Denmark (operational efficiency of about 80%), covering the global market; France, Israel, and other countries have significant advantages in heat transfer materials, vapor injection pumps, and compressors. Engineering companies from France, Israel, South Korea, Spain, and other countries occupy a large part of the international market.[10]

Although the technology and equipment of the above countries have taken a monopoly position in the world, they will continue to actively carry out the strategic schedule of science and innovation in marine and technology desalination and increase investment in research and development of new technologies, new processes, and new materials. For example, the United States and Japan conducted research and development of new materials such as carbon nanotubes, graphene, and biosynthesis, the leading research and development of international isolation; the Middle East and North Africa actively promoted large-scale desalination of water and renewable energy, and promoted the use of membrane desalination to replace a desalination project built in the 1970s.

5. Conclusion

The world is not only lacking in water resources but also unequal distribution, the water problems of the people are becoming increasingly severe, and many countries are vigorously evolving through the desalination process to utilize abundant marine resources because, in the current state of increasingly severe energy consumption, the development of nuclear energy and desalination of the sea can actively develop nuclear energy and desalination of marine combined hydrogen cooperation, there are many advantages, it benefits many people. For the state, it can not only prevent the passive

waste of state-owned assets but also increase job opportunities. For society, the development of a large-scale desalination industry can effectively leverage rich marine resources, solve population water difficulties and industrial production in water-poor areas in various countries, and basically reduce the problem of freshwater shortages in coastal areas.

Since marine desalination technology is now in the early stages of development, it has broad prospects for development. As the three pillar industries of the 21st century, materials, energy, and information have been confirmed in the development of desalination. The role of new materials and new energy in improving performance, cost savings, environmentally friendly, and other aspects of the development of marine desalination is self-evident, and the emergence of new technologies has diversified the application of marine desalination, and energy consumption has been saved. Therefore, desalination is the most promising sustainable way to access fresh water in response to the global crisis of shortages of freshwater resources.

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