# Application of reverse osmosis in purifying drinking water

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**Abstract.** In view of the shortage of water resources and the pollution of water environment, the development of efficient water purification technology is one of the effective ways to ensure the safety of drinking water. The technology of reverse osmosis has attracted much attention in the application of drinking water security for its advantages of no phase change and simple equipment. This paper briefly introduces the research progress at home and abroad, basic principles, process flow diagram, advantages and disadvantages and development direction of the technology.

## 1 Introduction

The status of water resources is closely related to the improvement of economic and social development and people's living standard. Therefore, the utilization of water resources, rational use, effective protection and safety supply of water resources is of great significance for promoting economic and social development. At present, the outstanding problem of water supply industry in China is water quality. On the one hand, the water source is generally polluted, on the other hand, the standard of water quality has been continuously improved. The water quality of drinking water has become an important factor restricting the further development of the economy and the influence of social stability[1].

At the same time, drinking water is the basic demand for human survival. The safety of drinking water is closely related to the health of the people and the national security, so it has always been highly valued by our country. The Action Plan for Prevention and Treatment of Water Pollution, namely "water ten item", clearly pointed out that by 2020, the quality of water environment needs to be improved step by step, and the level of drinking water safety is continuously improving in 2015. However, the current situation of drinking water safety in China is still grim. Drinking water safety incidents often occur, such as groundwater pollution incidents in Xinhe County in 2015, and sudden water pollution incidents in Xinyu County, Jiangxi Province in 2016. The safety of drinking water is still one of the focus of public concern[2].

Compared with the conventional water purification process of increasing ozone and activated carbon adsorption equipment on the traditional water purification equipment, reverse osmosis water purification technology develop rapidly in recent years, the pressure driven water molecules flow through the dense reverse osmosis membrane to separate the solute and the solvent. This technology can improve efficiency, so it has made great strides, and at the same time, the development of reverse osmosis water purification technology has matured[3]. In theory, the reverse osmosis technology can not only remove the salts and other substances in the ion state, can also remove suspended solids , organic matter, colloids, bacteria and viruses[4], only water can through reverse osmosis membrane, so as to ensure the water from being polluted. Therefore, the drinking water purification technology which can maximum possibly remove the disinfection by-products and trace organic pollutants to be recognized by more and more people[5]. And it has become an effective way to ensure the safety of drinking water, and has been widely applied to improve drinking water quality, expand drinking water sources and ensure emergency water supply[2].

## 2 Domestic and foreign research

Research data show that scholars and researchers have detected 2221 kinds of organic matter in water all over the world, and there are 765 kinds of organic matter in drinking water, of which 107 species are carcinogenic, mutagenic, and distorted substances. Chlorination and other disinfection by-products were found after adding chlorine to the drinking water in the United States in 1974. Chloroform is the most likely to be carcinogenic in the water. The reverse osmosis membrane combined equipment effectively removes the residual chlorine and organic pollutants in tap water, and it can solve the key problem of the safety of drinking water[6].

The research and application of reverse osmosis technology started earlier in the US and Japan[7]. In the early 1980s, the United States overcome the defect of cellulose materials and developed a compound polyamide membrane with high water flux and high salt interception rate, which made reverse osmosis technology widely used in the industrial field[8]. Meanwhile, its self-designed reverse osmosis membrane emergency water supply desalination and purification equipment is easy to transport and install. It can be adapted to such as high

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turbidity water, seawater, nuclear polluted water, biochemical pollution water and so on[9].

In recent years, the reverse osmosis method for purifying drinking water has also been widely used in Russia. The small and medium-sized water reverse osmosis device designed by Russia can realize the automation of work. And it can be applied to the daily living conditions[4]. At the same time, in Russia, the reverse osmosis device is also widely used in the purification of well water and removing the fluoride, nitrate and nitrite ions which are the most difficult to remove[10].

G.R.Lashkaripour and others found that the water quality of desalination of Zahedan brackish groundwater with the salt content of 2697mg/L by reverse osmosis device can reach the standard of WHO, and the energy consumption is low. In Gaza area, the first brackish water reverse osmosis desalination plant was built in 1993. Now there are many equipments. So reverse osmosis desalination technology has become a mature technology in the local area.

The research of reverse osmosis membrane in China began in 1966 and it has been widely used in recent years. Reverse osmosis technology was initially applied to seawater desalination, and gradually expanded to brackish water desalination, food processing, medical and health, beverage purification, ultra pure water preparation and so on and resulting in high economic benefits[7]. In 2000, supported by the key technology research project of the Ministry of science and technology, "the production of 1000 tons of reverse osmosis seawater desalination system and engineering technology development", the 1000 t/d reverse osmosis seawater desalination demonstration project was built in Long Island, Shandong Province and Shengsi, Zhejiang Province[8].

## 3 Application progress

For a long time, reverse osmosis technology was considered less economical than other traditional methods of purification-coagulation and sedimentation, aeration, adsorption, etc. Most experts think this is a special and expensive method, and only limited to medicine, electronics, food and industry, etc. That is because of the high energy consumption (7.5~10kW/m$^3$), high investment of membrane components and pump equipment, and complex pretreatment system.

In recent years, because of its compact , simple and better effluent quality, the application of reverse osmosis has been considered as a good choice for small and medium-sized water treatment stations (50-1000m$^3$/d) in the selection of purifying surface water with toxic contaminant and underground hard water with higher iron content,.

Reverse osmosis technology can effectively remove water pollutants.At present, this technology can guarantee drinking water safety from many aspects such as water quality, water volume and emergency water supply[2].

### 3.1 Improve drinking water quality

In general, we believe that the membrane pore size of 1nm or less for reverse osmosis technology, it can effectively remove dissolved salts, colloids, microorganisms and organic compounds in water so as to ensure the safety of drinking water.

#### *3.1.1 Removal of salt and hardness.*

Salinity is an important component of healthy drinking water. But salty water, such as sea water in coastal areas and brackish water in inland areas, is not suitable for drinking. In addition, the high level of divalent ion concentration will cause water hardness. Hard water can easily cause calculi or other diseases. The toxic and harmful ions, such as fluorine and arsenic, can also lead to pathological changes and damage of human viscera. Reverse osmosis technology can effectively remove salt and hardness. Researches show that the removal rates of fluoride and arsenic in most of the commercial reverse osmosis membranes in high-fluoride water and high-arsenic water can reach more than 95%[11,12].

#### *3.1.2 Removal of organics.*

The concentration of organics in water is in a low level, but its composition is complex and it has potential harm to human health. Reverse osmosis technology helps to remove water traces of organic matter, thus ensuring the safety of drinking water. Studies have shown that reverse osmosis technology can successfully remove small molecule organic, such as emulsifiers[13], alkylphenol polyoxyethylene acid[14], etc. In addition, reverse osmosis technology is also quite complete for the removal of non-volatile dissolved organic carbon[15], total organic carbon[16] and assimilable organic carbon[17].

#### *3.1.3 Removal of micro-organisms.*

Micro-organisms are the common and widespread over-standard items in rural drinking water and secondary water supply in urban areas, mainly including protozoa and bacteria. Reverse osmosis membrane on a variety of microorganisms has a very high removal rate, up to 99.9% or more[18].

### 3.2 Increase the source of drinking water

#### *3.2.1 Desalination of sea water.*

The Earth's seawater reserves are about 1.35 billion km$^3$, providing a stable and reliable source of water for seawater desalination. Therefore, desalination is regarded as one of the important strategies to solve the global water shortage. Our country is a large marine country with a coastline of 18,000 km and provides convenient geographical conditions for desalination. In 2011, the largest seawater desalination project, using RO method, which independently designed and contracted by domestic

enterprises was put into operation in Caofeidian, Hebei Province, marking the new stage of technological capability of membrane desalination project in China[19]. As of the end of 2015, the scale of nationwide reverse osmosis desalination water production reached 654, 535$m^3$/d[20], greatly alleviated the problem of insufficient drinking water in the coastal areas of our country. At present, the membrane desalination process with reverse osmosis technology as the core has made important progress. Among the installed capacity of seawater desalination, reverse osmosis accounts for 64.88%, accounting for the highest proportion[20].

#### *3.2.2 Desalination of brackish water.*

China has 1.6 million $km^2$ of land is brackish water distribution area, accounting for 16.7% of the country's land area, with a total of about 20 billion $m^3$ per year. However, there are only 1.066 billion $m^3$ of brackish water could be used for freshwater production each year in our country, accounting for only 4.99% of the total amount of brackish water that can be developed[21]. Water desalination of brackish water is an important supplement to freshwater resources and an effective way to alleviate the water crisis in inland areas of China. In view of the excellent desalination effect of reverse osmosis technology, it has gradually become the preferred technology for desalination of brackish water. In the brackish water treatment process design, reverse osmosis and other technologies can be combined flexibly, which is suitable for different salinities brackish water.

#### *3.2.3 Reuse of rainwater.*

The average annual total amount of rainwater in China exceeds 6 trillion $m^3$, most of the rainfall is lost and rainwater utilization is less than 1%. Rainwater, as an abundant freshwater resource, has simpler treatment process. It is of great practical significance to improve the water supply by rational exploitation and utilization. The rain water is collected by natural biological treatment at first and then treated by the membrane system, finally chlorinated and reused[22]. Among them, the reverse osmosis technology is mainly used for desalination, in order to keep the water with low salt. At the same time, it can be used as the depth of rain treatment process, for protecting the safety of rainwater utilization. In addition, reverse osmosis technology can ensure that the treated rainwater reaches the standard of living water[23].

#### *3.2.4 Recycling of wastewater.*

In recent years, the discharge of waste water which has reached 3.8 billion $m^3$ in 2015 in our country has continued to increase. Some rural non-point source wastewater and industrial wastewater were directly discharged without any treatment, which not only seriously polluted the environment but also caused waste of resources. It will open up a new stable source of water if the wastewater can be treated in depth. At present, due to the variety of waste water and complicated composition, the single membrane technology can not completely solve the problems of various waste water treatment. However, reverse osmosis technology has become the core technology of the advanced treatment technology of membrane regeneration water. There have corresponding research and engineering examples in the treatment of electroplating wastewater, printing[24] and dyeing[25] wastewater and papermaking wastewater, etc. It's both to reduce the discharge of a large number of waste water, and save a lot of groundwater, tap water, indirectly supporting the safety of drinking water.

#### *3.2.5 Treatment of unconventional polluted water.*

Unconventional pollutants are directly related to drinking water safety and public health and require more rigorous treatment. Reverse osmosis is considered as one of the most effective treatments[26]. An experimental study on the high natural radioactive content in drinking water compared the effects of ultrafiltration, reverse osmosis and electrodialysis on natural radioactivity[27]. The results showed that reverse osmosis has the best removal efficiency and it can effectively remove 95 % of total alpha activity and 93% of total beta activity.

### 3.3 Safeguard emergency water supply

The water supply system would be easily threatened by water pollution, pipeline rupture and sewage leakage when heavy natural disasters such as heavy rainfall happened, resulting in the excessive concentration of pollutants such as organic substances, heavy metals and microorganisms in water, seriously affecting the safety of drinking water. In recent years, sudden pollution incidents have occurred in urban water sources in China, so establishing and improving emergency water supply systems has important practical significance for ensuring drinking water safety and maintaining social stability. However, the emergency water supply is confronted with the requirements of complex water pollution components, urgent processing time and convenient equipment operation. Conventional water purification technology cannot meet the needs of emergency water supply. The application of reverse osmosis technology in emergency water supply has drawn more and more attention.

In view of the fact that domestic drinking water near residents in a nuclear power plant accident may be contaminated by radionuclides, the results[28] show that the reverse osmosis process puts up good stability in removing radionuclides from simulated wastewater.

For the problem of high concentrations of organic matter contaminated drinking water caused by sudden accidents, the results show[29] that the removal rate of trace benzene series and trichloroethylene by the osmotic membrane process is above 95%, and the removal rate of higher concentrations of organics is achieved more than 99%, effluent organic matter concentration is far lower than the drinking water quality standards limit, which can

effectively ensure the safety of drinking water in sudden accidents.

## 4 Basic principles

Reverse osmosis technology is a membrane separation technology for pure water that makes use of reverse osmosis membrane to selectively pass through the solvent in the solution (usually water)[5]. It takes pressure as the driving force to overcome the osmotic pressure of water[8]. The process is a permeation process that is contrary to the natural infiltration[3].

In order to produce reverse osmosis pressure, a water pump is required to exert pressure on a saline solution or waste water[8]. When the pressure is equal to the natural osmotic pressure of the solution, the flow of the solvent will not occur. If the pressure is less than the natural osmotic pressure of the solution, the solvent flows from the dilute solution to the concentrated solution, and if not, the solvent will flow through the reverse osmosis membrane, so as to form dilute solution on the opposite side, and form a more concentrated solution on the side of pressure. All these will achieve solute separation and effectively remove salt, colloid, microorganism, heat source, organic matter and so on. In other words, the principle of desalination by using reverse osmosis membrane is to apply more pressure than natural osmosis pressure in water with salt (such as raw water). This will make the permeation go in the opposite direction, and press the water molecules in the raw water to the other side of the membrane, so as to achieve the purpose of removing the salt in the water. Reverse osmosis is also one of the most advanced membrane separation technologies in the world[3].

The principles are detailed in Figure 1[30].

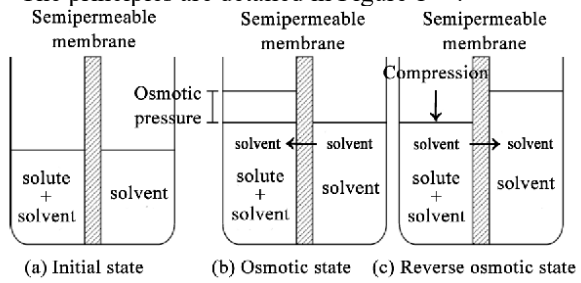


**Figure 1.** Principle of Reverse Osmosis

The process of reverse osmosis separation can remove the organic matter with molecular weight of more than 150, and the rate of desalination is over 95% one time. At the same time, as a special "filtration" process, microorganisms such as bacteria and viruses in water can be removed effectively to achieve aseptic water[5].

## 5 Process flow

The process flow is as follows:
Tap water→ raw water tank→ raw water pump→ mechanical filter→ activated carbon filter→ softener→ intermediate water tank→ booster pump→ 5μ security filter→ RO high-pressure pump → reverse osmosis system→ pure water tank→ pure water pump→ ozone generator→ 0.2μ fine filter→ outlet[5].

## 6 Advantages and disadvantages

### 6.1. Advantages

Reverse osmosis membrane technology is the most advanced and most energy-saving separation technology. It is a physical method. It has many advantages[31]:

- The operation of reverse osmosis only relies on pressure as a driving force. It has the lowest energy consumption compared with other traditional physical processing means, and it saves energy.
- Reverse osmosis can be carried out at room temperature without phase change.
- Reverse osmosis does not use chemical treatment reagents and it does not discharge chemical waste liquid. So it hardly pollute the environment.
- The space of operation equipment is small and the operation is simple.
- The water quality is excellent and the efficiency is high.

### 6.2. Disadvantages

In the process of continuous application, the shortcomings of reverse osmosis are increasingly revealed. For example, the operation and management is not strict. When the system is running, the pressure must be in the pressure range that the membrane can bear. In addition, the film materials and models can not be selected for the water quality of the original water[33].

On the other hand, the application of reverse osmosis device to improve well water and tap water has many advantages, but there is a serious contradiction between the purified water quality and the guidelines established by health institutions. Because the reverse osmosis device removes essential trace elements of human body at the same time[10].

## 7 Prospect of application

The application of reverse osmosis membrane technology in drinking water quality improvement plays an important role in solving the problems of imperfect water resources management system, poor drinking water quality, ecological environment investigation, ecological environment change, detailed management of water resources science and improvement of ecological environment. The technology of reverse osmosis membrane separation indicates the direction for the improvement of drinking water quality. Through a series of successful application in the water source, the water quality improvement project of drinking water has been pushed to a new height. In recent years, the technology has been implemented and operated frequently. So it is very mature now.

With the quickening of the pace of modernization, on the one hand, the water resources are lacking and the water sources with lower quality are constantly used. On the other hand, the pressure imposed by the government's

environmental protection department and the public's demand for high quality drinking water ask the process to update and improve the degree of processing, this has brought great market potential and space for the membrane separation technology, especially the reverse osmosis membrane technology[8]. At the same time, from the development of membrane processing technology, it has a wide application prospect in environmental engineering, especially in the field of wastewater treatment and water reuse[32].

## 8 Direction of development

Nowadays, the world's water treatment industry is developing towards the dual goal of wastewater reuse and environmental protection. Because of its excellent separation performance, reverse osmosis membrane technology will be widely applied. In the future, the direction of its development is mainly focused on the following：

- Reverse osmosis membrane components of low energy consumption, anti pollution, high temperature resistance, high pressure and special separation.
- A polymer film which can remove small chlorinated organic molecules.
- Inorganic reverse osmosis membrane that can separate hydrocarbon mixtures[34].
- New membrane materials with acid alkali resistance, oxidation resistance and high water permeability.
- Combination of reverse osmosis membrane components and components of ultrafiltration, microfiltration, nanofiltration and EDI[8].

## 9 Conclusion

The application of reverse osmosis membrane separation technology in drinking water can effectively alleviate partial pressure caused by the pollution of water environment and the shortage of water resources. It also ensures the safety of drinking water and improves the quality of drinking water by its advantages. At present, in the process of applying the technology, some problems have also been encountered. However, the technology will become more and more mature with the promotion of technological innovation and the development of new components in the future. At the same time, it will applied to other fields gradually. This is of great significance to the sustainable utilization of water resources and the development of society.

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