Application of membrane separation technology in water treatment process

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Abstract. Water is the source of life. With the development of economy, China has paid more attention to water pollution and adopted a series of scientific solutions. Following the situation, membrane separation technology has made great progress in the research and application of water treatment. In this paper, the principle of membrane separation and the process of membrane separation are briefly introduced, and then the application of membrane separation technology in drinking water purification, industrial wastewater treatment and desalination engineering is introduced, and the discussion and summary are made according to the application.

1. Introduction
In recent years, the quality of water environment in China has deteriorated, and various kinds of water pollution events happen endlessly. In response to this, Li Guibai, the academician of Chinese Academy of engineering, proposed the application of ultrafiltration technology in drinking water treatment at the eighth cross strait water quality safety control technology and management meeting 2013 Water Supply Summit Forum. Ultrafiltration technology is an important kind of membrane separation technology. Membrane separation technology refers to the technology of separation, classification, purification and enrichment of two-component or multi-component mixed liquid or gas by means of the promotion of external energy or chemical potential difference and the permeation of specific membrane [1]. Membrane separation technology can effectively intercept pollutants, bacteria and pathogenic bacteria. Compared with conventional water treatment technology, it has the advantages of high quality, stability and safety. Experts even call the development of membrane separation technology "the third industrial revolution". The importance of the research and development of membrane separation technology can be seen.

2. Membrane separation principle
According to the difference of pore size (or molecular weight retained), membrane can be divided into microfiltration (MF), nanofiltration (NF), ultrafiltration (UF) and reverse osmosis (RO) [2].

2.1. Microfiltration membranes
Microfiltration belongs to precision filtration, which is also called fine filtration or screen mesh filtration. The pore diameter of microfiltration membrane is generally between 0.01-10 μ M. Under the static pressure of 0.1-0.3mpa, the particles such as solvent, salt, water and macromolecular substances which are smaller than the pore diameter of the membrane will pass through the membrane, while the micro particles and macromolecular substances such as some bacteria which are larger than the pore diameter of the membrane will be intercepted by the membrane, so as to achieve the separation effect. It is mainly used in liquid clarification, sterilization, and the capture of PM2.5 in industry.
2.2. Ultrafiltration membrane
Ultrafiltration membrane is generally asymmetric structure, the size of membrane pore size and membrane surface properties have different retention effect. The pore diameter of the membrane is generally 2-100nm. Under the pressure of 0.1-1.0mpa, solvents or substances with small molecular weight can penetrate the membrane, while macromolecules and fine particles will be intercepted, so as to achieve the separation effect. It is mainly used in the purification and separation of solutions containing macromolecules and colloidal substances.

2.3. Nanofiltration membrane
Nanofiltration is also called ultra-low pressure reverse osmosis. The pore diameter of nanofiltration membrane is about 1nm. Under the pressure of 0.5-2.5mpa, substances with molecular weight less than 200 such as water and solvent will pass through the membrane, while substances with molecular weight of 200-1000 such as solute, divalent salt, sugar and dye will be retained, so as to achieve the separation effect. The separation performance is between microfiltration and ultrafiltration, and the working principle of both is considered. It is mainly used for concentration and purification of macromolecular substances in solution.

2.4. Reverse osmosis membrane
Reverse osmosis is a membrane separation process which is driven by the pressure difference to complete the separation task through the semi permeable membrane. When the pressure (1000-10000mpa) applied on the upper side of the solution is greater than the osmotic pressure of the solution, the solvent molecules reverse the concentration gradient (opposite to the direction of natural osmosis) under the pressure difference, so as to obtain the penetrating solvent on the low-pressure side of the membrane and the concentrated solvent on the high-pressure side. Most of them are used for desalination of seawater. Fresh water is obtained at the low pressure side of the membrane and brine is obtained at the high pressure side.

3. Application of membrane separation technology in water treatment
The contradiction between the improvement of drinking water quality standard and the sewage discharge standard of urban factories and the shortage of water resources has been intensified. The traditional water treatment process is difficult to meet the increasingly strict requirements. Since the membrane separation technology was applied in the field of water treatment, it has the advantages of effective retention of pollutants, bacteria and pathogens, high-quality and stable effluent, small footprint, easy to automatic control and High security has become one of the most potential technologies in the field of water treatment. The following will introduce the application of membrane separation technology from drinking water purification, industrial wastewater treatment and desalination:

3.1. Drinking water purification process
In the traditional water production process, chlorine is often used for disinfection. Research shows that chlorine can cause problems such as difficult to kill chlorine resistant pathogens, increase the possibility of carcinogen trihalomethane (THMs) formation, and produce chemical sludge. However, ultrafiltration technology can effectively overcome the limitations of the traditional process, provide high-quality drinking water, reduce turbidity and reduce the use of flocculants. However, when it is used alone, it is easy to cause membrane pollution and insufficient ability to deal with ammonia nitrogen, metal ions or some small molecular organics. At present, people combine ultrafiltration membrane technology with traditional technology to improve purification capacity and reduce membrane pollution. Now scholars at home and abroad focus on the combination process of powdered activated carbon ultrafiltration and coagulation ultrafiltration.

Coagulation ultrafiltration combined with pre membrane coagulation can form flocs from small molecular organics, and then use ultrafiltration membrane to intercept flocs and remove small molecules and macromolecular compounds in water. Wang Xiaochang's Experimental Study on the removal of
humic acid by coagulation ultrafiltration shows that [3], the efficiency of coagulation ultrafiltration technology in the removal of macromolecular organic matters in humic acid is significantly higher than that of ultrafiltration alone, and the removal effect of natural small molecular weight organic matters is also significantly improved. Coincidentally, park and others abroad have studied the influence of coagulation steps on subsequent ultrafiltration (UF) in the process of drinking water treatment [4]. In this paper, it is proposed that choosing appropriate membrane and appropriate flocculant can effectively remove colloidal substances and harmful pollutants in water, and in practical operation, using automatic dosing flocculation device can reduce membrane pollution.

The combined process of PAC-CF is the combination of adsorption and ultrafiltration, which can improve the removal rate of organic matter and reduce membrane pollution to a certain extent. In the experiment of Xia Shengji’s powdered activated carbon ultrafiltration membrane process to purify Songhua River water [5], it was found that: (1) the turbidity of membrane effluent was very low when the amount of powdered activated carbon was changed (10, 30, 50mg / L); (2) the removal rate of organic matter (UV254) was about 10% when the membrane was treated alone. The removal efficiency of "powdered activated carbon ultrafiltration" can reach 63%. It can be seen that (1) ultrafiltration membrane is the control factor of effluent turbidity and an important guarantee to ensure the quality of drinking water. (2) The combination of powdered activated carbon and ultrafiltration has obvious effect on the removal of organic matters in natural water.

3.2. Treatment of industrial wastewater

Industrial wastewater has the characteristics of complex composition, great change of water quality and strong toxic effect. The purpose of wastewater treatment is to remove the pollutants and make them meet the requirements of discharge or recovery. Meanwhile, the separated wastewater should be fully resourced or properly treated. In the face of complex composition and clear treatment objectives, single membrane method or traditional technology is difficult to meet the treatment requirements, and the integrated membrane method combining traditional treatment methods and membrane method is often used [6]. The research direction of integrated membrane technology includes ceramic microfiltration membrane technology and nanofiltration membrane technology.

Ceramic microfiltration membrane has good heat resistance and can be used stably at 400 °C [7]; it has high chemical stability and can resist organic solvent and acid-base corrosion; it has stable mechanical structure and strong anti pollution performance, can be cleaned and regenerated, and can adapt to the harsh environment of industrial wastewater treatment. Taking the removal of chroma and COD from printing and dyeing wastewater [8] as an example: Zhang Yi et al. Treated PVA desizing wastewater with dynamic ceramic membrane with pore diameter < 1 μ m, and finally obtained the water quality meeting the secondary standard of discharge standard of water pollutants for textile dyeing and finishing industry (GB 4287-92).

Nanofiltration technology has the advantages of low operating pressure, easy operation and management, and no need for additional chemical reagents in the treatment process, which will not cause secondary pollution. Take the textile industry wastewater treatment as an example: Zheng Yue [9] and others used nanofiltration membrane (Dow n90) to treat the textile wastewater treated by activated sludge. Compared with ozone oxidation method, it shows that the combination of nanofiltration method and ozone oxidation method can get ideal results and solve the problem of high cost of ozone oxidation method alone.

3.3. Desalination

Seawater desalination is one of the important means to solve the shortage of water resources. The methods of seawater desalination include reverse osmosis (RO), multi-stage flash evaporation (MED) and compressed air distillation (VC). Among these methods, reverse osmosis technology has the advantages of low investment cost, low energy consumption and short construction period. It has become the most economical means of desalination. The reverse osmosis membrane method for
desalination in power plants can be generally divided into three processes: Seawater Pretreatment and primary and secondary reverse osmosis [10].

In the process of seawater reverse osmosis desalination, in order to make the reverse osmosis membrane fully play its role, it is necessary to meet certain water inflow requirements, so the seawater must be pretreated. Usually, coagulation sedimentation and filtration technology are used to remove suspended solids, particles, bacteria and other magazines from seawater, so as to reduce the pollution on the surface of reverse osmosis membrane and improve the service life of the system. The primary reverse osmosis system uses the characteristics of the reverse osmosis membrane to remove most of the organic matters, soluble salts, primary colloids and other substances in the sea water. Most of the fresh water obtained from the primary reverse osmosis system enters the secondary reverse osmosis system for further treatment to obtain fresh water that meets the standard of drinking water, so as to meet the daily operation needs of the power plant and the needs of people's living water. Figure 1 is the schematic diagram of seawater reverse osmosis technology:

![Seawater reverse osmosis technology](image)

**Figure 1** Seawater reverse osmosis technology

**4. Conclusion**

Membrane separation technology, as a new technology rising rapidly after 1960s, can be seen from the application of membrane separation technology in drinking water purification, industrial wastewater treatment and desalination. Compared with traditional technology and other technologies, membrane separation technology has obvious advantages and good development prospects. However, the application of membrane separation technology in water treatment is not a simple alternative to the traditional process, but a process of integrated upgrading and development. At present, a series of problems, such as high cost, membrane pollution, poor working conditions and membrane separation performance, to be improved hinder the further development and application of membrane technology. Therefore, the future development direction of membrane separation technology in water treatment should focus on the following aspects. First, this technology focus on the research of membrane pollution so as to improve the service life of the membrane. Second, this technology focus on the development of new material membrane with stable structure and strong environmental adaptability similar to ceramic microfiltration membrane to cope with water treatment in extreme conditions. Third, adhere to membrane technology and traditional treatment technology combined with traditional technology, pretreatment can reduce membrane pollution, increase membrane service life and reduce cost.
References

[1] Wang Hua, Liu Yanfei, Peng Dongming, et al. Research progress and application prospect of membrane separation technology [J]. Applied chemistry, 2013 (03): 152-154.

[2] Xu Zhenliang. Membrane water treatment technology [M]. Beijing: Chemical Industry Press, 2001.22-70.

[3] Wang Xiaochang, Wang Jin experimental study on humic acid removal by coagulation ultrafiltration [J]. China water supply and drainage, 2002 (03): 20-24.

[4] Park M N, Jang H N, Lee D S, et al. Coagulation pretreatment for drinking water treatment by membrane process of river water[A].5th IWA Conference on Membranes for Water and Waste water Treatment[C]. Beijing: IWA-MTC 2009 Organising Committee, 2009.

[5] Xia Shengji, Xu Bin, Yao JUANJUAN, Li Guibai powder activated carbon ultrafiltration membrane process for purification of Songhua River water [J] South China University of Technology Journal (NATURAL SCIENCE EDITION), 2007.

[6] Ren Songjie, Congwei, Zhang Guoliang, et al. Study on the treatment and reuse technology of printing and dyeing industrial wastewater [J]. Water treatment technology, 2009 (08): 20-24.

[7] Gao Songping. Study on Purification of emulsified suspension containing ultrafine particles by ceramic membrane [D]. Zhongbei University, 2009.

[8] Zhang Yi, Gu runnan. Technology of dynamic ceramic membrane for PVA desizing wastewater [J]. Journal of Donghua University (NATURAL SCIENCE EDITION), 2007 (02): 101-103.

[9] Zheng Yue, Yu Yaoping. Treatment of textile and dyeing industrial wastewater by nanofiltration combined with ozonization [J]. Journal of Heilongjiang Institute of Engineering (NATURAL SCIENCE EDITION), 2006, 20 (2): 56-58.

[10] Ma Shujian. On the application of desalination technology in power plants [J]. resource conservation and environmental protection, 2015 (9): 31.