Research on the current situation of ultrafiltration combined process in treatment of micro-polluted surface water

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Abstract: At present, most of the source water of domestic urban water supply treatment plants is taken from micro-polluted surface water. With the further improvement of drinking water sanitation standards, the traditional "coagulation-sedimentation-filtration-disinfection" process cannot meet the requirements of the new standards. Ultrafiltration, as the core technology in the field of water treatment in the 21st century, is increasingly applied to water treatment due to its advantages of green efficiency, simple operation, small footprint, and high degree of automation. However, the use of ultrafiltration membrane alone has some problems such as substandard water quality and serious membrane pollution. Therefore, the combination of ultrafiltration and traditional water treatment technology to treat micro-polluted surface water has become the mainstream choice for treatment plants. This article mainly introduces the current research status of domestic ultrafiltration combined technology, trying to explore more reasonable and effective ways to apply ultrafiltration membranes in actual projects.

1 Preface

On July 1, 2007, the "Sanitary Standards for Drinking Water" (GB5749-2006) was officially implemented, increasing the original 35 drinking water quality indicators to 106. At the same time, according to the 2018 "China Environmental Bulletin" [1] shows that the overall surface water in the country is lightly polluted, and more and more water supply treatment plants source water from slightly polluted surface water. Therefore, the traditional "coagulation-sedimentation-filtration-disinfection" water supply treatment process is difficult to meet the requirements of the new standard when treating micro-polluted surface water.

In recent years, with the continuous development of ultrafiltration membrane technology, the membrane cost has been gradually reduced, and the anti-pollution ability has gradually increased. In addition, because of small footprint, good treatment effect, strong effluent stability, and high degree of automation, ultrafiltration membrane technology is used in water supply treatment[2]. However, when the ultrafiltration membrane is used alone, some of the effluent water quality is not up to standard and the membrane is seriously polluted[3], which affects the service life and increases the operating cost, which seriously affects the wide application of ultrafiltration technology. Therefore, various ultrafiltration combined processes have emerged as the times require, providing new ideas for water treatment.

2 Fouling mechanism of ultrafiltration membrane

Micro-polluted surface water contains suspended particulate matter, colloidal matter, algae, organic matter and bacteria and other microorganisms. These substances have different physical and chemical properties such as particle size, molecular weight, hydrophobicity, and chargeability. An inseparable and complex system is formed under the interaction of ion exchange and other interactions, which pollutes the ultrafiltration membrane during the filtration process [4].

At present, it is generally believed that membrane fouling is mainly divided into three parts: concentration polarization, membrane surface fouling (formation and compression of filter cake layer), adsorption and blockage in membrane pores. In the process of membrane separation, impurities in water form a concentration gradient on the membrane surface, and then form a stable concentration polarization boundary layer, and finally a filter cake layer. This membrane fouling caused by concentration polarization and filter cake layer can be passed through hydraulic power. Backwash removal is reversible; if impurities in the water have a strong affinity with the membrane, the membrane will adsorb these substances, causing irreversible pollution of the membrane. Reversible pollution and irreversible pollution exist at the same time and influence each other.

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The classic membrane filtration pollution model is proposed by Hermia in the constant pressure filtration[5], and the form is shown in formula (1)

$$\frac{d^2t}{dV^2}=k(\frac{dt}{dV})^n \quad (1)$$

Complete clogging model, n=2: all particles reaching the membrane surface completely block a membrane pore during the filtration process. There is no overlapping accumulation of particles on the membrane surface but an ideal state of monolayer particle coverage. The membrane pore clogging rate is proportional to Filter flux. Standard plugging model, n=3/2: Small particles of pollutants enter the membrane pores and are adsorbed on the inner wall of the membrane pore channel, reducing the effective filtration area of the membrane pores. Intermediate blockage model, n=1: As the water flow reaches the membrane surface, the particulate matter can be deposited at any position on the membrane surface, including unblocked membrane pores and deposited particles, allowing overlapping accumulation. Filter cake layer filtration model, n=0: Pollutants are deposited on other pollutants, and there is no space on the membrane surface so that the pollutants directly block the membrane pores, and the internal structure of the membrane pores does not change. The model is shown in Figure 1.

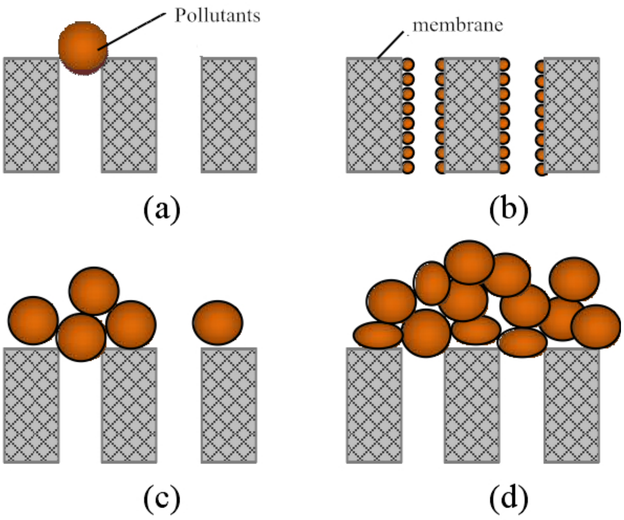

Fig. 1. Schematic diagram of membrane fouling mechanism model

(a) Complete blockage model (b) Standard blockage model (c) Intermediate blockage model (d) Filter cake layer filtration model

3 Research status of ultrafiltration combined process

2.1 Coagulation-ultrafiltration combined process

Using coagulation as a pretreatment process can complement ultrafiltration and improve the removal of pollutants such as small molecular organics, soluble salts and metal ions. Li Weiying et al[6] used the coagulation-ultrafiltration process to remove turbidity and Escherichia coli with significant removal rates of 99% and 100%, respectively, and the removal of COD_{MN}, UV_{254}, and DOC to varying degrees. Dong Bingzhi [7,8] and other studies believe that the use of coagulation as a pretreatment before the membrane can reduce membrane fouling, mainly because: coagulation can make small molecular organic matter in the water into microflocs, and ultrafiltration membranes can effectively intercept them , reducing the amount of pollutants entering the membrane pores, and at the same time changing the nature of the deposition layer on the membrane surface; the transport speed of the floc particles formed by coagulation on the membrane surface will increase with the increase of their particle size,making organic matter on the membrane surface .The adsorption deposits have been reduced.

2.2 Advanced oxidation-ultrafiltration combined process

Using ozone as a pretreatment before the membrane can slow down membrane pollution, and the effect becomes more obvious with the increase of ozone dosage. Zhu Dongliang [9] used the pre-ozone conventional ultrafiltration combined process to treat Taihu Lake water, and the results showed that the process can effectively remove the turbidity, COD_{MN}, UV_{254}, DOC and ammonia nitrogen in the water, and the removal rate of algae can reach 99.46%. At the same time, the combined process is stable, and the membrane flux can be maintained at a high level for a long time. Other studies have shown that the use of ultraviolet light and titanium dioxide powder catalysis as the pretreatment before the membrane can effectively remove TOC, and the removal rate can reach 90% [10].

2.3 Powder activated carbon-ultrafiltration combined process

Powder activated carbon-ultrafiltration is a relatively common combined process in water treatment at present, which can replace ozone oxidation or granular activated carbon adsorption technology in conventional water treatment. This is mainly because the process can effectively remove organic or trace substances in water. Powdered activated carbon can adsorb organics in water and ultrafiltration membranes can block the powdered activated carbon from passing through the membrane, and their combined action reduces the adsorption and deposition of organics on the surface of the membrane [11]. This process not only has a good removal effect on organic matter, but also removes pollutants such as pesticides, herbicides, odor-causing substances, and the generation of disinfection by-product precursors. Chen Yan [12] and other studies have shown that because powdered carbon can effectively adsorb small molecular organic matter, the powder activated carbon ultrafiltration membrane process has a better removal effect on organic matter and disinfection by-products, and after adding powdered carbon, the membrane flux is reversed. It can recover quickly after washing. Although the powdered carbon forms a filter cake layer on the membrane surface, this filter cake layer protects the membrane from membrane fouling. However, other researchers believe that membrane filtration resistance has increased due to the presence of activated carbon [13]. Therefore, the impact of powdered activated carbon on membrane fouling is related to its dosage, and the higher the better.

2.4 Biological pretreatment-ultrafiltration combined process

Biological pretreatment is to cultivate microorganisms in front of the membrane, use the degradation of microorganisms,interception and adsorption between biological fillers to improve water quality, reduce the load of organic matter in the water, and delay the rate and degree of membrane pollution. Biological filter is a commonly used biological treatment implementation at present. Fillers usually include activated carbon, ceramsite and zeolite. For example, biological aerated filter (BAF) using ceramsite as filler has excellent removal effect on ammonia nitrogen in water, and during continuous operation, the head loss changes little with time.

Studies have shown that the removal rates of COD, TN, and ammonia nitrogen in water bodies using 800-grade clay ceramsites reach 79%, 56.8%, and 71.5%, respectively [14]. Li Fa Station and others have used contact oxidation as biological pretreatment and found that biological treatment has the highest removal rate of organic matter with a molecular weight of less than 500. Combined with ultrafiltration membrane, it forms complementary advantages and improves the removal effect of organic matter [15]. Peldszus S, Huck PM et al. [16,17] studied the impact of fast biofilters on ultrafiltration membrane fouling, and the results showed that pretreatment of biofilters can remove part of the biopolymers, delay the growth rate of irreversible pollution, and the longer contact time , the more significant effect, this green pretreatment process is particularly suitable for small water treatment systems. Biological pretreatment and ultrafiltration combined compared with other pretreatment methods, biological pretreatment uses the growth of organisms to remove pollutants, has less energy and chemical consumption, and is more in line with the concept of low carbon and green. The process is a sustainable pretreatment.It is not only green, clean, and pollution-free, but also complementary to the advantages and disadvantages, improves water purification efficiency [18].

4 Outlook

At present, ultrafiltration technology has gradually matured, and the water treatment process combining traditional technology and modern membrane technology will be more and more used in the treatment of micro-polluted surface water. Pretreatment + ultrafiltration is currently the mainstream combined process form of membrane treatment used in water treatment plants. In addition, membrane bioreactor (MBR), biological activated carbon-ultrafiltration (BAC-UF), aerated biological filter -Ultrafiltration (BAF-UF) and other combined ultrafiltration processes have also been carried out in related research. In the future, ultrafiltration membranes will occupy a more important position in water supply treatment.

References

1. Ministry of Environmental Protection of the People's Republic of China. Bulletin of the State of the Environment in China, 2018.
2. Yuan Bo. Application of membrane technology in water supply treatment[J]. Energy and Environment, 2015, 1: 73-74.
3. Bu Yanrui. On the application of ultrafiltration membrane technology in environmental engineering water treatment[J]. Engineering Technology, 2016(11): 00031-00032.
4. Huang H, Spinett R, O'Melia C R. Direct-flow microfiltration of aquasols-I. Impacts of particle stabilities and size[J]. Journal of Membrane Science, 2008,314(1-2):90- 100.
5. Ma Lin, Qin Guotong. Research progress on the mechanism and mathematical model of membrane fouling[J]. Water Treatment Technology, 2007(06):1-4.
6. Li Weiying, Tan Zhangrong, Dong Bingzhi, etc. Coagulation and ultrafiltration combined technology to treat the Yangtze River raw water experimental research, Tongji University Journal Natural Science Edition, 207-211,:
7. Dong Bingzhi, Xia Lihua, Chen Yan et al. Research on improving the filtration performance of ultrafiltration membrane by powdered zeolite. Water Treatment Technology, 2016, 32(6): 8-11
8. Dong Bingzhi, Chen Yan, Gao Naiyun, etc. The preventive effect of coagulation on membrane fouling. Environmental Science, 2015, 26(1): 90-93.
9. Zhu Dongliang, Sun Cheng Pre-ozone conventional ultrafiltration combined process to purify Taihu Lake Water Research China Water Supply and Drainage, 2012, 28 (3): 40-43
10. Yuan W, Zydney A L. Humic acid fouling during ultrafiltration[J]. Environmental Science & Technology, 2000,34(23):5043-5050
11. Fan L H, Harris J L, Roddick F A, et al. Influence of the characteristics of natural organic matter on the fouling of microfiltration membranes [J]. Water Research,2001, 35(18):4455-4463.
12. Chen Yan, Gao Naiyun, etc. Experimental study on the treatment of micro-polluted raw water with powder activated carbon ultrafiltration membrane. Journal of Tongji University Natural Science Edition, 2005, 33(6): 777-780

13. Koros W J, Ma Y H, Shimidzu T. Terminology for membranes and membrane processes [J]. Journal of Membrane Science, 2006,120(2):149-159.
14. Yuan W, Zydney A L. Humic acid fouling during ultrafiltration[J]. Environmental Science & Technology, 2000,34(23):5043-5050.
15. Li Fazhan, Lu Xiwu, Shao Jian. Biological pretreatment-ultrafiltration water purification process to remove organic matter of different molecular weights[J]. Water Treatment Technology, 2007(10): 64-66.
16. Peldszus S, Benecke J, Jekel M, et al. Direct biofiltration pretreatment for fouling control of ultrafiltration membranes[J]. Journal-American Water Works Association, 2012,104:E430-E445.
17. Huck P M, Peldszus S, Hallé C, et al. Pilot scale evaluation of biofiltration as an innovative pre-treatment for ultrafiltration membranes for drinking water treatment[J].Water Science & Technology: Water Supply, 2011,11(1):23.
18. He Qing, Lv Mou, Chen Chao, et al. The influence of operating conditions and operating flux on ultrafiltration membrane fouling[J]. Journal of Qingdao Technological University, 2014, 35(3): 94-99