Application of Microfiltration membrane Technology in Water treatment

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Abstract. In wastewater treatment, membrane technology is called a major technology in the field of water treatment in the 21st century. With the development of membrane technology and the development of other emerging technologies in combination, microfiltration membrane technology is widely used in the treatment of various types of wastewater such as radioactive wastewater and heavy metal wastewater. The application of microfiltration technology in radioactive and heavy metal wastewater is described. It provides a solid guarantee for deepening the research and application of water treatment.

1. Introduction

The environmental problem of water pollution has become a major problem that human beings urgently need to solve. And the prevention and control of water pollution has become one of the important tasks of countries all over the world. Membrane technology has been widely used in water treatment because of its unique characteristics such as high efficiency, energy saving and applicability[1]. The application of membrane technology in the field of water purification treatment is a global development trend, including various coupling technologies, such as the coupling of reverse osmosis and positive osmosis to reduce energy consumption and water production cost, and the coupling of reverse osmosis and membrane distillation to achieve the goal of zero discharge. It has been widely used in sewage treatment[2-4].

In recent years, the development of nuclear power generation is very rapid, but nuclear energy can produce a lot of radioactive waste while bringing us economic benefits. And other industries can produce large amounts of radioactive slag, medical waste and industrial wastewater[5]. Radioactive waste water from different sources contains different radioactive substances, radioactive levels and chemical composition. Efficient treatment and disposal of radioactive wastewater has become one of the urgent problems to be solved in the development of nuclear industry and environmental pollution. How to treat radioactive wastewater safely and effectively is very important for the safe use of nuclear energy and people’s health. At the same time, with the rapid development of industry and agriculture in China, large amounts of industrial wastewater is produced, which causes serious pollution to the water body. If the water body polluted by heavy metals is discharged directly without treatment, it will not only lead to a waste of resources, but also aggravate the pollution to the environment. And it will seriously pollute surface water and groundwater, resulting in a shortage of available water resources.

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Radioactive waste water is usually accompanied by the discharge of heavy metals, which are difficult to be biodegraded and easy to be absorbed and enriched by organisms. If it is not treated, heavy metals will pose a serious threat to the ecological environment and human health[6]. After entering the human body, heavy metals can interact strongly with physiological polymers to make them inactive, and may also accumulate in the human body to cause chronic poisoning, however, it takes many years to show this cumulative risk sometimes[7]. Therefore, it is urgent to control heavy metal and radioactive pollution in order to protect human health and ecological environment.

2. Membrane separation technology

At present, low radioactive wastewater is mainly treated by adsorption, ion exchange and membrane separation[8]. As a rising technology in the treatment of radioactive wastewater, compared with conventional technology, membrane separation technology has many advantages, such as high efficiency and not easy to cause secondary pollution, and has considerable potential in the treatment of radioactive wastewater, and it has achieved good results in the field of heavy metal water treatment[9]. Membrane separation technology mainly includes microfiltration membrane (MF) and ultrafiltration membrane (UF) technology, reverse osmosis (RO) technology, but filtration cost of reverse osmosis technology is high[11], while when reverse osmosis and nanofiltration technology filtrate secondary treatment water, they can save cost[12]. Membrane technology has become one of the key technologies to control polluted water[13].

The separation or treatment process of the membrane mainly contains the three basic principles of adsorption, sieving and electrostatic phenomena[14]. Membrane is a kind of material with selective separation function, which can restrict and transfer fluid substances and separate the interface between the two parts in a specific form, either solid or liquid. Both solid and liquid membranes must have these two characteristics. One is that there must be two interfaces, and the other is that the membrane has selective permeability[15]. The adsorption mechanism in the process of membrane separation is mainly based on the hydrophobic interaction between the membrane and the solute. The interaction usually leads to more rejection, mainly because of the decrease of the pore size of the membrane[16]. Compared with other methods, the energy consumption of membrane separation is relatively low. The used device has the advantages of simple operation and easy control, convenient maintenance and high separation efficiency. Compared with conventional water treatment methods, membrane separation technology has the advantages of small area and high treatment efficiency[17]. Membrane separation technology can not only purify the wastewater but also recover some useful substances, which has been widely used in wastewater treatment and shows its broad development and application prospects[18].

3. Microfiltration technology

Microfiltration is a membrane process in which the static pressure difference is used as the driving force and the sieving separation of the membrane is used for separation. The separation mechanism of microfiltration is similar to that of ordinary filtration, but the filtration accuracy is higher, and it can intercept 0.13-15 um particles or organic macromolecules. Due to the different structure of microporous membrane, the separation mechanism of microfiltration is also different, and its mechanism is roughly divided into adsorption interception, mechanical interception and bridging, among which physical interception is the main one[19]. Generally speaking, the pore size of the microfiltration membrane is 0.1-1 um, which can allow macromolecular organic compounds and dissolved solids to pass through, but it cannot directly intercept heavy metal ions and cannot remove dissolved solid pollutants whose size is less than 1 um. In addition, microfiltration is not an absolute barrier to the virus. However, when used in combination with disinfection, microfiltration can control these microbes in water[20]. Microfiltration technology can also be combined with other processes to treat polluted water. It plays an important role in the treatment of radioactive and heavy metal wastewater.

3.1 Application in radioactive wastewater treatment

The treatment of radioactive wastewater by microfiltration process has been applied industrially in the
1980s[21]. In the treatment of radioactive wastewater, microfiltration process is usually used as pretreatment and can be used in conjunction with adsorption and flocculation processes. Under the combined process of adsorption complexation and immersion microfiltration membrane reactor, the cesium concentration can be reduced from 106.87 ug/L to 0.59 ug/L, and the removal rate can reach 99.44%[22]. The microfiltration process combined with ferric chloride as flocculant can effectively remove $^{241}$Am in the wastewater. When the radioactivity of the original wastewater is 809.2 Bq/L, the radioactivity of the effluent is less than 1 Bq/L, the removal rate can reach more than 99.9%, which proves that the process has a good effect on the treatment of radioactive wastewater[23]. In the process composed of ferrous sulfate as flocculant and combined microfiltration, when the dosage of Fe$^{2+}$ is 35-60 mg/L, the removal rate of plutonium can reach 99.9%[24]. Microfiltration technology will be better developed in the treatment of radioactive wastewater.

3.2 Application in heavy metal wastewater treatment

Due to the rapid development of industry and other industries in China, large amounts of heavy metal wastewater is discharged, which will be indirectly discharged into rivers or lakes, thus posing a great threat to people's health. The pretreatment methods for the treatment of heavy metal wastewater by microfiltration mainly include reduction, precipitation, adsorption and so on, which can convert heavy metals into insoluble particles with a particle size greater than 0.1 um. In the coprecipitation microfiltration system, the metal ions in the wastewater form coprecipitation and then removed by microfiltration technology, which has a remarkable removal effect. In the adsorption microfiltration system, when there is too much organic matter in heavy metal wastewater, ferric hydroxide is usually used as coagulant, which can not only make heavy metal ions form coprecipitation, but also adsorb some organic compounds or chelates. Coprecipitation and adsorption are usually combined to achieve a significant removal effect[25].

Wan et al use the combined process of neutralization and microfiltration to treat wastewater containing Zn$^{2+}$ and Pb$^{2+}$, after adding flocculant, the removal rate of Zn$^{2+}$, Pb$^{2+}$ can reach 99.92% and 99.77%, which has a good removal effect[26]. Song et al found that the removal rate of 0.5 mmol/L Cu$^{2+}$ could reach 75.18% when the surface modification of polyvinylidene fluoride microfiltration membrane was carried out by heat-induced polymerization and the pH value was 5[27]. Under normal circumstances, the microfiltration membrane cannot remove heavy metal ions effectively because of the small the particle size of the ions. And the related modification of microfiltration membrane still cannot achieve good results. By adopting the combined process of microfiltration membrane and microfiltration membrane, the heavy metal ions can be better removed.

| Microfiltration technology                  | wastewater type   | Pollutant | removal rate | References |
|-------------------------------------------|-------------------|-----------|--------------|------------|
| Adsorption + microfiltration              | radioactive       | Cs        | 99.4%        | [22]       |
| Flocculation + microfiltration            | radioactive       | Am        | 99.9%        | [23]       |
| Flocculation + microfiltration            | radioactive       | Pu        | 99.9%        | [24]       |
| microfiltration                           | Artificial        | Cu        | 75.18%       | [27]       |
| Microfiltration + reverse osmosis         | Landfill leachate | Fe, Cr    | >99.5%       | [28]       |
| Precipitation + microfiltration           | Ground water      | Zn        | 99.9%        | [29]       |
| Microfiltration + reverse osmosis         | Artificial        | Ca, Mn    | 76.12%, 91.61% | [30] |
| Complexation + microfiltration            | Artificial        | Zn        | 99%          | [31]       |
4. Conclusion
The membrane materials used in the treatment of radioactive wastewater should have good chemical and physical stability. The existing industrial membranes are not easy to meet the complex requirements of radioactive treatment. Therefore, it is urgently needed to develop membrane materials suitable for the disposal of radioactive contaminated wastewater in the nuclear industry system, especially in the radiation resistance of high-performance inorganic membrane materials. Because inorganic membrane material can avoid the problems that the organic membrane is easy to be brittle under alkaline conditions and decomposed by radiation in the treatment of radioactive wastewater.

In the treatment of wastewater, the use of membrane process alone, while ignoring the combination with other methods, will be difficult to achieve significant results. The cost of the microfiltration process is too high and the precision requirements for membrane preparation are also different, which affect its large-scale application. In addition, in the process of wastewater treatment, pollutants may block the pores of the membrane, which even makes the flux of the membrane unable to recover. The cleaning method with less secondary waste liquid caused by membrane cleaning and easy to deal with the waste liquid should be chosen, because of considering that the secondary waste liquid caused by membrane cleaning is very harmful. At the same time, the use of membrane pretreatment can greatly reduce the pollution and membrane flux degradation in the advanced treatment process, and improve the effect of subsequent membrane treatment process.

The preparation of membrane with high performance and wide applicability, the design of multi-membrane integrated process and the development of process coupled with membrane are the direction of membrane treatment of heavy metal wastewater in the future, which can effectively treat radioactive wastewater and heavy metal wastewater, they can also provide more remarkable effects and more choices for the development and recycling of wastewater.

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