Analysis of Wastewater Treatment Technology Based on Bipolar Membrane Electrodialysis

Ziyi Ma [1,*], Mengyu Sun [2], Jinlei Du [2], Yao Lin [1], Qian Liu [1]

[1] Qingdao University of Technology, Water science and engineering, 266500, China
[2] Qingdao University of Technology, civil engineering, 266500, China

Abstract. Metal wastewater and saline wastewater are two major problems in the field of wastewater treatment. At present, common treatment methods include ion exchange, electrodialysis and reverse osmosis. The ion exchange method often uses chemical reagents to achieve regeneration, which is likely to cause secondary pollution after treatment. Electrodeionization technology can continuously operate to treat wastewater, and does not require the use of acid-base reagents to achieve resin regeneration, but the structure is complex and requires higher pretreatment. Bipolar membrane electro-regenerative ion exchange is a new technology that has been practically applied in water supply treatment by a certain enterprise. A considerable degree of ion exchange capacity, after reaching the exchange capacity, the bipolar membrane is used for water dissociation to achieve electrical regeneration of the membrane. On the basis of investigating the desalination and regeneration of groundwater (well water) by this technology, this paper studies its removal effect on simulated food processing salty wastewater, Cu2+ and Fe2+ containing simulated electroplating rinsing wastewater. Influence of operating conditions such as influent flow on the treatment effect.

Key words: Bipolar membrane; electric regeneration; ion exchange; metal wastewater; saline wastewater.

1. Metal wastewater and saline wastewater treatment and reuse technology

Metal wastewater and saline wastewater are important problems in the field of water treatment, and the environmental problems caused by them cannot be ignored, which has attracted extensive attention of domestic and foreign researchers[1]. At present, the most widely used methods mainly include ion exchange method, electrodialysis, electrodeionization method and reverse osmosis method. Each method has its own advantages and disadvantages and applicable conditions[2].

1.1 Ion exchange method

The ion exchange method is mainly through the exchange reaction between the exchange groups in the ion exchanger and the ions in the solution, so that the ions in the solution are removed and the wastewater is purified. Taking anion and cation exchangers as examples, the exchange process of its exchange group (R-X) and ion (Y) in water is as follows:

$$\boldsymbol{R - X^- + Y^- \rightarrow R - Y^- + X^-}$$
$$\boldsymbol{R - X^+ + Y^+ \rightarrow R - Y^+ + X^+}$$

Ion exchangers are divided into inorganic and organic types. Inorganic exchangers include various natural and artificial synthetic boiling agents. Organic exchangers include sulfonated coal and ion exchange resins[3]. Most of the ion exchange methods use ion exchange resin, which is a water-insoluble spherical electrolyte particle with a resin skeleton and an active ion exchange group. The active group makes the resin have a high exchange capacity, so it is widely used in wastewater treatment. widely[4].

1.2 Electrodialysis

Electrodialysis is an important branch of membrane separation, generally using a plate-and-frame structure, consisting of cells separated by anion and cation exchange membranes. The principle of electrodialysis is shown in Figure 1[5]. The potential difference formed under the action of a DC electric field is used as the ion driving force. Anions and cations in the wastewater pass through the alternately arranged ion exchange membranes[6]. The anode attracts anions and the cathode attracts cations. A membrane technology in which the cation exchange membrane (A) blocks the passage of anions, and the anion exchange membrane (C) blocks the passage of cations, so that the anions and cations enter the adjacent fresh water chamber and concentrated water chamber, thereby realizing the separation of solute and solution[7-9].

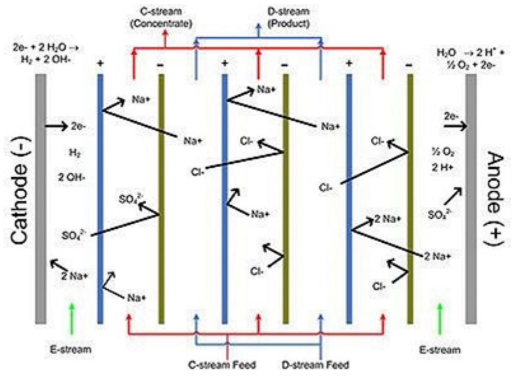

Figure 1 Working principle diagram of electrodialysis

1.3 Electrodeionization

Electrodeionization is a combined process of electrodialysis and traditional ion exchange. Electrodialysis is an uneconomical method for treating low-concentration solutions due to its high resistivity and concentration polarization. To overcome these problems, ion-exchange resins are introduced into electrodialysis units, combined with ion-exchange membranes, to achieve a continuous deionization process[10]. The working principle of electrodeionization is shown in Figure 2. Different from electrodialysis, the ions in the electrodeionization device are first mixed with the ion exchange resin. It migrates to the ion-exchange membrane through the conductive path formed by the ion-exchange resin, and the conductivity of the dilution chamber filled with the ion-exchange resin is improved by more than two orders of magnitude, thereby greatly reducing the energy consumption. Compared with the acid-base regeneration of the ion exchange method, the electrodeionization method can dissociate water under the action of a DC electric field to generate H+, OH-, and realize the regeneration of the resin[11].

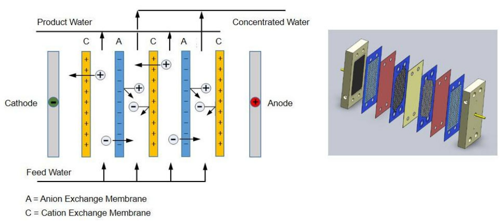

Figure 2 The working principle of electrodeionization

2. The working principle of the double membrane method

The process of bipolar membrane electric regeneration ion exchange is mainly divided into two stages: deionization stage and electric regeneration stage. The migration and exchange of ions occurs in the deionization stage, and when the ion exchange capacity is reached, the electrical regeneration of the ion exchange resin membrane is carried out[12]. Taking the removal of NaCI from water as an example, the working principles of the deionization stage and the electrical regeneration stage are shown in Figure 3 and Figure 4.

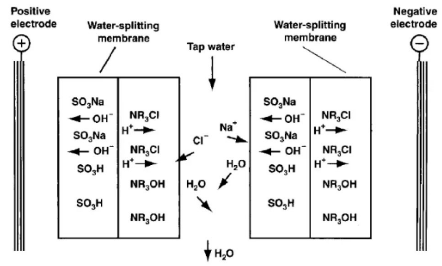

Figure 3 Working principle diagram of deionization stage

In the deionization stage, the feed water flows from the top into the gap of the membrane module. The cation exchange material (P-COON) of the bipolar membrane and the anion exchange material (P-NR2) are used to exchange cations and anions, respectively. Under the action of the DC electric field, the target removal ions migrate from the solution to the ion exchange resin on the surface of the bipolar membrane, and exchange reaction with it to replace H+ and OH-. At the same time, water dissociates in the middle catalytic layer of the bipolar membrane to generate OH^-_{W-S} and H^-_{W-S}, which react with the displaced H+ and OH- to generate water, as shown in Equations 1 and 2. The neutralization reaction can speed up the process of the exchange reaction between the metal ions and the anion and cation exchange materials, so that the metal ions are continuously removed from the solution[13].

$$P-COOH+OH^-_{W-S}+Na^+=P-COONa+H_2O \quad (1)$$

$$P-NR_2+H^+_{W-S}+Cl^-=P-NR_2Cl+H_2O \quad (2)$$

Regeneration is required when the ion exchange capacity of the device is exhausted. Regeneration is achieved through the action of an electric field, reversing the polarity of the electrodes, without the use of chemicals. At the interface of the middle catalytic layer of the bipolar membrane, the H^+_{W-S} and OH^-_{W-S} generated by water dissociation migrate through the ion-exchange layer to the electrode of opposite polarity, and H^+_{W-S} replaces the sodium ions in the cation-exchange layer , OH^-_{W-S} replaces chloride ions in the anion exchange layer, the bipolar membrane is regenerated, and the exchanged ions form NaCl concentrate[14]. The regeneration process of weak acid type cation exchange membrane and weak base anion exchange membrane is shown in formulas 3 and 4.

$$P-COOM+H^+_{W-S}=P-COOH+M^+ \quad (3)$$

$$P-NR_2HX+OH^-_{W-S}=P-NR_2+H_2O+X^- \quad (4)$$

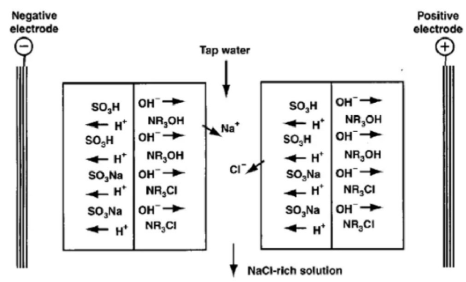

Figure 4 Working principal diagram of regeneration stage

3. Research on the effect and influencing factors of brine and wastewater treatment

3.1 Groundwater desalination effect

The change of effluent conductivity under different working voltage conditions was investigated, as shown in Figure 5. It can be seen that with the increase of the treated water volume, the effluent conductivity increases[15]. When the treated water volume is less than 50L, the effluent conductivity does not change much or increases slowly; when the effluent volume increases to 50L, the effluent conductivity increases rapidly; when treating the same water volume, the higher the working voltage, the lower the effluent conductivity, and the desalination The better the effect. For example, when the water output is 40L, when the working voltage is 70V, the conductivity of the water is 239μs/cm; when the voltage is 150V, the conductivity of the water is 145.4μs/cm; when the voltage is 300V, the conductivity of the water is 133.3μs/cm; The conductivity of the effluent reaches the level of local tap water, that is, about 230-240 μs/cm, which is the end point of the treatment, and the amount of treated water is different under different working voltages. The working voltage is 70V, the treated water is 80L, the voltage is 150V, the treated water is 110L, the voltage is 300V, and the treated water is 120L; under the three working voltages of 70V, 150V and 300V, when the treated water is 150L, the effluent conductivity is close to, 350μs/cm, 340μs/cm and 326μs/cm, respectively [16-17].

It can be analyzed that the desalination efficiency of this device increases as the voltage increases, because increasing the voltage not only helps to increase the migration speed of ions in water, but also accelerates the dissociation speed of water in the bipolar membrane to promote the forward progress of the desalination reaction, as shown in the formula 2.1 in the previous chapter. and shown in 2.2. As the amount of treated water increases, the ion exchange capacity in the device is gradually utilized in an increasing proportion.

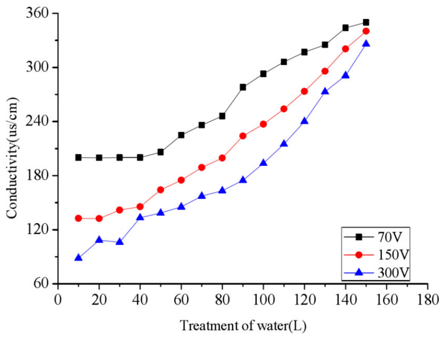

Figure 5 Variation of effluent conductivity under different working voltage conditions

As shown in Fig. 6, in the process of groundwater desalination, due to the occurrence of water dissociation reaction, the pH fluctuated between 6.7-7.25. The main reason for the pH drop at the initial stage of the reaction was the reaction process of partial conversion of influent bicarbonate into carbonic acid and carbon dioxide. obvious.

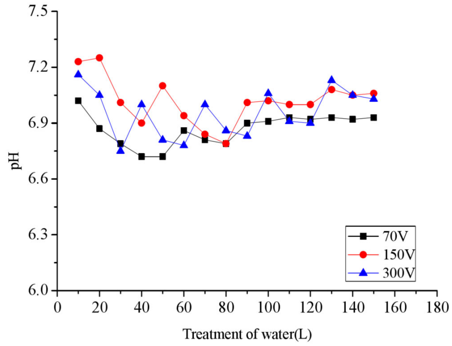

Figure 6 Variation of pH of treated water at different voltages

3.2 Effect of food processing wastewater treatment

The removal and desalination effects of NH_4-N and PO_4-P in food processing wastewater were investigated at operating voltages of 150V and 300V, as shown in Figures 7 and 8. It can be seen from Figure 7 that the NH_4-N concentration in the effluent increases with the increase of the treated water volume. Under the same effluent volume, the higher the working voltage, the lower the effluent concentration, because the higher the voltage, the faster the NH_4+migration speed, This also shows that the potential gradient is the main factor causing ion electromigration. When the influent concentration of NH_4-N is 40mg/L and the treated water volume is 10L, the effluent concentration is 9.25mg/L under the condition of 150V working voltage, and the effluent concentration is 6.9mg/L under 300V working voltage; when the treated water volume is increased from 10L to 30L , under the two working voltages, the effluent concentration increased to 15.15mg/L and 11.08mg/L respectively; when the treated water volume increased from 30L to 60L, the NH4-N concentration in the effluent increased sharply under the two working voltage conditions, and when the voltage was 150V , the effluent concentration increased to 30.2mg/L, and when the voltage was 300V, the effluent concentration increased to 25.08mg/L.

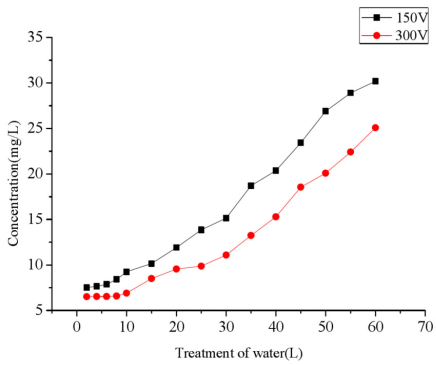

Figure 7 Variation of NH4-N concentration in effluent under different working voltages

The magnitude of the conductivity reflects the change of the salt content in the water. When the working voltage is 150V and the treated water volume is less than 15L, the effluent conductivity is maintained at 519µs/cm; when the working voltage is 300V, when the treated water volume is less than 20L, the effluent conductivity is basically Stable at 438 µs/cm. With the increase of the treated water, the conductivity increased significantly. It can be seen that the removal effect of NH_4-N and other salts in water is better when the voltage is higher, because the higher the voltage, the greater the ion mobility provided, and the water dissociation ability of the intermediate catalytic layer is enhanced, which promotes the exchange reaction, as above. Chapter Equations 2.1 and 2.2 are shown.

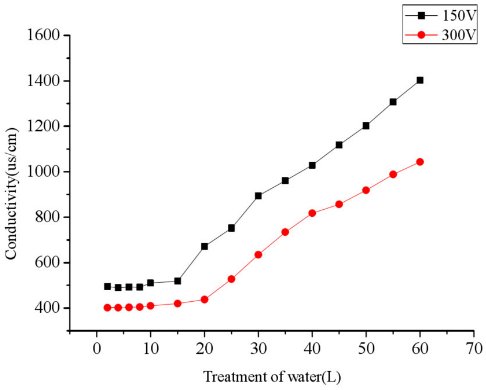

Figure 8 Variation of effluent conductivity under different working voltages

4. Conclusion

The treatment of metal wastewater and saline wastewater has always been two major difficulties in the field of water treatment. In this paper, the effectiveness and influencing factors of the two types of wastewater treatment were studied by using bipolar membrane electro-regenerative ion exchange technology, and the optimal operating conditions were determined. draw the following conclusions:

(1) Under certain working voltage conditions, when treating groundwater, if the effluent conductivity reaches the local tap water level as the reaction end point, the effluent conductivity increases with the increase of the treated water volume. Under the three working voltages of 70V, 150V and 300V, a single cycle The cumulative treated water volume is 80L, 110L and 120L respectively, and the desalination water production rate can reach 93.75%. The technology has good regeneration reproducibility, the higher the voltage, the more thorough the working exchange reaction.

(2) When treating salt-containing food processing wastewater at different voltages, the concentration of NH-N and PO-P in the effluent increases with the increase of the treated water. Under the same effluent, the higher the working voltage, the lower the effluent concentration. When the influent flow is 0.6L/min, the working voltage is 300V, and the influent NH_4-N, PO_4-P and chloride concentrations are divided into 40mg/L, 10mg/L and 500mg/L, the effluent NH_4-N, $P0_4$- The P concentration can meet the requirements of sewage discharge standards.

References

1. Treatment of industrial high-salt perfume wastewater by bipolar membrane electrodialysis[J]. Zhang Jian, Niu Dongfang, Hu Shuozhen, Zhang Xinsheng. Electrochemistry. 2019(06)
2. Research progress of high-salt wastewater treatment technology [J]. Chen Hao, Zhang Feng, Wang Zhongzheng, Zou Junbo, Xiong Guangcheng. Guangzhou Chemical Industry. 2017(22)
3. Research status and review of electroplating wastewater treatment technology [J]. Wang Tianxing, Liu Xiaodong, Yu Xuemin. Electroplating and Finishing. 2017(09)
4. Research progress of forward osmosis separation technology and its application in high brine treatment Tian Caiyun, Li Zongshuo, Wang Chunli, Cheng Yan, Zhao Chenxi. Xinjiang Environmental Protection. 2016(04)
5. Research status and development trend of ion exchange membrane modification [J]. Wei Hui, Wu Xuehao, Guan Jia, Chen Yongxing, Guo Jingjing, Liu Lijuan, Ren Xiulian. Inorganic Salt Industry. 2016(06)
6. New technology of printing and dyeing wastewater treatment "reduces the burden" on the environment [J]. Zheng Xiuliang. Environment. 2016(03)
7. Research progress of electroplating wastewater treatment technology [J]. Jiang Yujuan, Chen Zhiqiang. Environmental Science and Management. 2015(03)
8. Research on the status quo and countermeasures of copper ions on environmental hazards [J]. Wang Xiafang. Research on Land and Natural Resources. 2015(01)
9. Treatment of simulated low-concentration nickel-containing wastewater by bipolar membrane electrodeionization technology [J]. Shang Guanghao, Zhang Guiqing, Gao Congjie. Chinese Journal of Nonferrous Metals. 2014(10)
10. Research on the problem of heavy metal pollution in electroplating industry and its prevention countermeasures [J]. Tian Jun, Zhang Xinhua, Chen Hua, Xu Jing. Pollution Prevention and Control Technology. 2014 (04)
11. Research progress of heavy metal wastewater treatment methods [J]. Zhou Xiaoyong, Tian Yayun, Li Huiyu, Zhang Gang. Henan Chemical Industry. 2014(04)
12. Problems and countermeasures of drinking water safety in rural areas in my country [J]. Chen Jianwu. Science and Technology Innovation and Application. 2014(02)
13. Toxicity and bioavailability of heavy metals in freshwater sediments to benthic organisms [J]. Shen Hongyan, Zhang Hongyan, Liu Li, Zhang Yanfeng,

Zhou Yu, Zheng Jun, Zhu Lingyan. Journal of Environmental Science. 2014(01)

14. Research progress of ion exchange resin treatment of heavy metals in wastewater [J]. Cao Ke, Min Tian, Wang Lin, Che Xuan, Cheng Gang. Applied Chemical Industry. 2013(08)
15. The relationship between water chemical environment and arsenic poisoning in drinking-water arsenic poisoning areas in China [J]. Tang Jie, Bian Jianmin, Li Zhaoyang, Wang Nong, Zhang Nan, Zhang Hao. Chinese Journal of Ecotoxicology. 2013(02)
16. Research status and progress of biological treatment of high-salt wastewater [J]. Yang Jing, Jin Xiaoli, Zheng Tiantian. Liaoning Chemical Industry. 2013(01)
17. Discussion on water-saving and energy-saving ways of cooling water recycling and utilization in thermal power enterprises [J]. Zhao Shilei. Science and Technology Entrepreneur. 2012(13)