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Advances in HTGR Wastewater Treatment System Design

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Abstract – *The source terms of radioactive wastewater from HTR-PM were introduced. Concentration process should be used to reduce volume. A radioactive wastewater treatment system was designed by using Disc tubular reverse osmosis (DTRO) membrane system. The pretreatment system was simplify by using a cartridge filter. A three-stage membrane system was built. The operated characters to treat low and intermediate radioactive waste water were studied. A concentration rates of 25-50 is reached. The decontamination factor of the membrane system can reach 30-100.*

I. INTRODUCTION

The sources of radioactive wastewater of HTGR are mainly from (1) Decontamination during the repair processes. The main radionuclides are neutron activation products. (2) Floor flush. (3) Laboratory drainage. The radioactive wastewater from lab will be collected for further treatment. The possible radionuclides in the wastewater are corrosion products and fission products. The estimated radioactive level is <37000 Bq/L. The major radionuclides are Sr-90, Cs-137 etc. The estimated volume is 180 m^3 per year.

The wastewater from laundry facilities should be collected for further monitoring or treatment. This kind of wastewater is collected separately. The estimated volume of this category is 1200 m^3 per year. The estimated radioactive level is <7.4 Bq/L.

According to regulation for environmental radiation protection of nuclear power plant, the radioactive of the effluent from the power plant must lower than 1000 Bq/L [1] .

Many technologies can be used in the treatment of radioactive wastewater. The conventional methods include precipitation, evaporation, ion exchange, adsorption, membrane distillation, microfiltration, ultrafiltration, nano-filtration and reverse osmosis (RO) [2-14]. Among all the above processes, RO process has been proved to be a competent one for radioactive wastewater treatment with high decontamination factor. Because of its economical during operation and outstanding performance, RO tech has been applied by many nuclear related departments to treat low and intermediate liquid radioactive wastes (LRWs) [15-18] .Conventional RO systems are easily to be blocked and fouled by the sediment and colloids in the solution [19] .

II. THE TREATMENT SYSTEM DESIGN

A new radioactive wastewater treatment system was designed for HTGR. The main purpose of the system is to obtain a high and stable decontamination factor (DF). Meanwhile, in order to minimize the waste volume, a high concentrate ratio (CR) is pursued.

II.A. Selection of the membrane

In order to simplify the treatment system, Disc tubular reverse osmosis (DTRO) was selected. Compared with conventional RO types, DTRO system possesses many merits in the treatment of low and intermediate LRWs. Firstly, the solution passageway of DTRO reaches 2mm while conventional tubular one only 0.2mm. Secondly, DTRO system can be operated under nearly 7MPa which is much higher than RO system. This ensures the high velocity of the feed. Once pumped into the system, the high-speed flow will impact with the salient points on the guide plate and form the turbulence. The turbulence prevents the blockage and fouling of sediments to the membrane. In a nutshell, combined with all characteristics above, DTRO system can get rid of the dependence on the pretreatment and trouble of the fouling. The pretreatment system was simplify by using a cartridge filter.

II.B. Flow chart of the system

The membrane system contain three stages. The feed is firstly directed into the first stage membrane. Then the permeate and concentrate of the first stage are transported into the second and third stage respectively. For the second stage, only DF of the permeate is focused on. For the third stage, only CR of the concentrate is concerned. During the operation, only the permeate of second stage and the concentrate of the third stage are discharged from the system ultimately. All the rest is recycled in the system. The permeate of second stage is treated by resin beds. Via this design, the system can obtain both high DF permeate and high CR simultaneously. The designed flow chart of the system is given out in Figure 1. The simulated sketch of the treatment system is showed in figure2.

II.C. Design parameters

The influent of the system is 400L/h. The intake of the first stage is 600L/h; the permeate of the first stage, which is also the input of the second stage, is 480L/h. The concentrate of the first stage, which is also the input of the third stage, is 120L/h. The permeate of the second stage is 392L/h. The concentrate output of the third stage is 8L/h.

The design operation pressure of the membrane system is 7MPa. The design concentrate ratio is 50. The design decontamination factor of the system is 5000-10000.

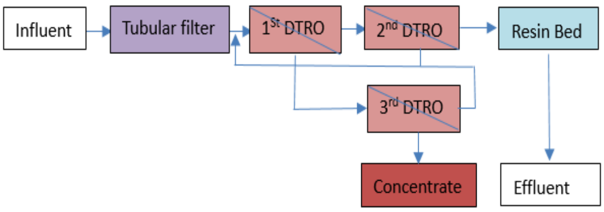

Fig.1. Flow chat of the treatment system

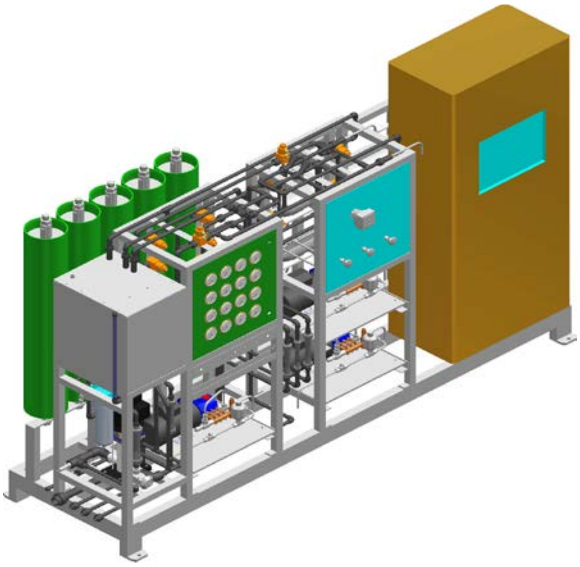

Fig. 2. Simulated sketch of the treatment system

III. EXPERIMENTS

The objective of the present research was to verify the feasibility of the three-stage DTRO system in the treatment. The pressures of different stage were compared. The electrical conductivity (ED) of the different influent, permeate of the first stage permeate of the second stage, and concentration of the third stage were showed. The DF of influents were given out. All the results were in the condition that the concentrate output of the third stage was adjusted to 8L/h. The CR of the treatment system was 50.

As a pilot plant test, 4000L solution of each group was prepared. The de-ionized water was the exclusive solvent during the preparation.

Parameters of permeate and retentate consisting of flux, pH, conductivity were detected. The flux of permeate and concentrate from each stage was measured by flow meter. pH was probed by pH meter. The component and concentration of ions in the solution was detected by Atomic absorption spectrometer.

IV. RESULTS AND DISCUSSION

IV.A. Pressures of different stages

The operation pressures of different stages were given out in figure 3. The figure showed that the pressure of the first stage was about 2.2MPa. The pressure of the second stage was about 1.8MPa. The pressure of the third stage was steadily increasing. The pressure showed out that the operation pressure was in proportion to the salt concentration of the intake water. The pressure and concentration of the the third stage could reach a stable level in about 300 minutes. The stable pressure was about 3.1MPa.

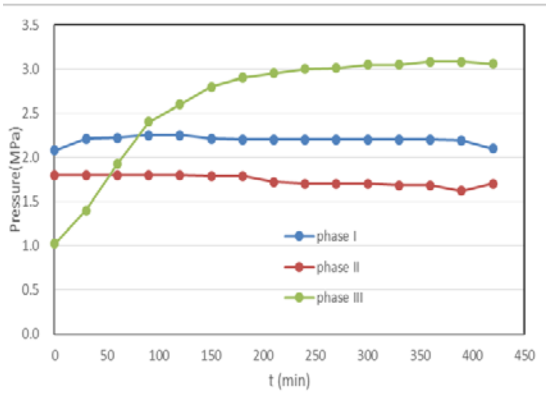

Fig. 3. Operation pressure of different stages

IV.B. Concentrations of different stages

The concentration of different stages were studied by measuring the ED of the samples. The concentration of the salt could be deemed as in corporation to ED. The ED of the different stages were given out in figure 4. The concentrations of the the first and second stage permeate could reach a stable level in about 2 hours. The concentration of the third (concentrate) stage needed about 300 minutes to reach stable.

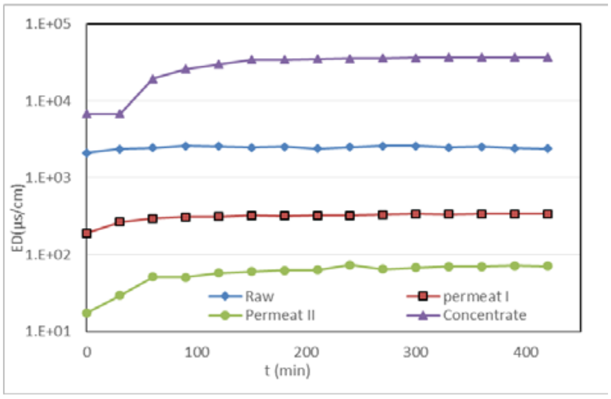

Fig. 4. *The ED of different stages*

IV.C. The influence of the salt concentration

The DFs of the membrane system in different NaCl concentration were studied. The result showed out that the DFs would decrease as the concentration of the circulation increased. The DFs of 500mg/l and 1000mg/l feed water were compared and given out in figure 5. The concentration of the salts in the wastewater will not affect the decontamination factor greatly. The DF of the membrane is greater than 30. Normally, the DF of the

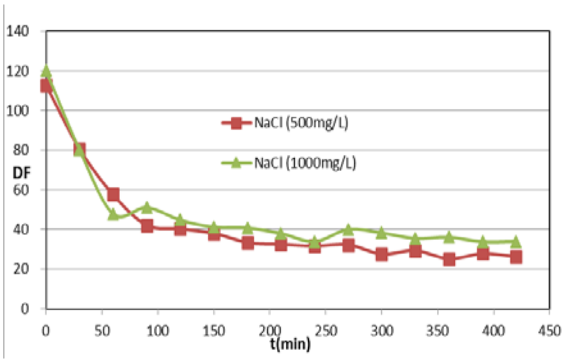

Fig. 5. *The DFs of different salt concentration*

IV.D. Variations of pH

In order to avoid fouling from calcium and magnesium, pH of the raw water should be adjusted to below 6.5. The pH variation of the raw water and permeate of the 2nd stage were given out in figure 6. The figure showed out that pH of permeate from the 2nd stage is lower than the raw water. That is because most of the calcium and magnesium ions are filtrated out. However, hydrogen ion, which will induced the decrease of pH, can pass through the membrane.

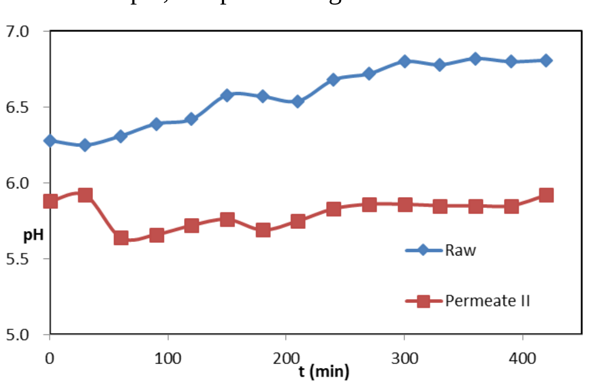

Fig. 6. *pH variations in the system*

V. CONCLUSION

The three-stage DTRO system can operate steadily. The system can reach a CF of 50, meanwhile the DF is greater than 30. The stable time for the system is about 300 minutes. The concentration of the feed water will not affect the DF greatly. pH of permeate from the second stage is lower than the raw water.

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REFERENCES

[1] National standard of People's Republic of China. Regulations for environmental radiation protection of nuclear power plant. GB 6249-2011

[2] Zakrzewska-Trznadel, G., Advances in membrane technologies for the treatment of liquid radioactive waste. Desalination, 2013. 321: p. 119-130.

[3] Rana, D., et al., Radioactive decontamination of water by membrane processes — A review. Desalination, 2013. 321: p. 77-92.

[4] Radwaste application of membrane TRS431_web.

[5] Ali, I., New Generation Adsorbents for Water Treatment. Chemical Reviews, 2012. 112(10): p. 5073-5091.

[6] Rahman, R.O.A., H.A. Ibrahium and Y. Hung, Liquid Radioactive Wastes Treatment: A Review. Water, 2011. 3(4): p. 551-565.

[7] Liu, H. and J. Wang, Treatment of radioactive wastewater using direct contact membrane distillation. Journal of Hazardous Materials, 2013. 261: p. 307-315.

[8] Harasimowicz, M., et al., Application of polyimide membranes for biogas purification and enrichment. Journal of Hazardous Materials, 2007. 144(3): p. 698-702.

[9] Cojocaru, C., G. Zakrzewska-Trznadel and A. Miskiewicz, Removal of cobalt ions from aqueous solutions by polymer assisted ultrafiltration using experimental design approach. Journal of Hazardous Materials, 2009. 169(1-3): p. 610-620.

[10] Han, F., G. Zhang and P. Gu, Removal of cesium from simulated liquid waste with countercurrent two-stage adsorption followed by microfiltration. Journal of Hazardous Materials, 2012. 225-226: p. 107-113.

[11] Removal of radionuclides by membrane permeation combined with complexation.

[12] Micellar-enhanced ultrafiltration for the removal of cadmium and zinc: Use of response surface methodology to improve understanding of process performance and optimisation.

[13] Ultrafiltration and reverse osmosis performance in the treatment of radioimmunoassay liquid wastes.

[14] The removal of zinc from synthetic wastewaters by micellar-enhanced ultrafiltration: statistical design of experiments.

[15] Sylvester, P., T. Milner and J. Jensen, Radioactive liquid waste treatment at Fukushima Daiichi. Journal of Chemical Technology & Biotechnology, 2013. 88(9): p. 1592-1596.

[16] Arnal, J.M., et al., Treatment of 137Cs liquid wastes by reverse osmosis Part I. Preliminary tests. Desalination, 2003. 154(1): p. 27 - 33.

[17] Arnal, J.M., et al., Treatment of 137Cs liquid wastes by reverse osmosis Part II. Real application. Desalination, 2003. 154(1): p. 35 - 42.

[18] Zakrzewska-Trznadel, G.Y., M. Harasimowicz and A.G. Chmielewski, Membrane processes in nuclear technology-application for liquid radioactive waste treatment. Separation and Purification Technology, 2001. 22(1-2): p. 617 - 625.

[19] Zakrzewska-Trznadel, G., et al., Reducing fouling and boundary-layer by application of helical flow in ultrafiltration module employed for radioactive wastes processing. Desalination, 2009. 240(1-3): p. 108-116.