Journal of Research in Science, Technology, Engineering and Management (JoRSTEM)
ISSN: 2456-0197

Recovery of Hydrochloric Acid from designed Synthetic Acidic Water using Diffusion Dialysis Technique

S. Gnana Sowjanya[1], K. Srilatha[2], Ch. Sri Sai lakshmi, V. Hima bindu, C. Sarala

[1]Centre for environment, IST, JNTUH, Hyderabad, Telangana – 500085
[2]Centre for Water Resources, IST, JNTUH, Hyderabad, Telangana – 500085

Abstract— ***Large quantities of acids are required during the process for stripping, cleaning, and pickling in metal finishing and mining industries. So, to remove the acids and contaminants from this water, a diffusion dialysis technology has emerged. In this study, optimization studies of anion exchange membrane (AMI-7001) UltrexTM were carried out by varying concentrations of hydrochloric acid and different flow rates to know the maximum acid recovery. The recovery of acid was observed to be 30% at 0.1N synthetic HCl solution with a 24h retention time in a diffusion dialysis reactor at a flow rate of 375ml/min.***

Keywords: Diffusion dialysis, Anion-exchange membrane, Hydrochloric acid, Flow rate, Acid recovery.

I. INTRODUCTION

Enormous amounts of acidic waste solutions are produced from different industrial operations [1–4]. Direct disposal of these solutions not only contaminate the environment but also are the reasons for loss of economic viabilities. Diffusion dialysis is an attractive separation method which is generally useful to recover acids, heavy metals, salts and solvents from different waste solutions because of their unique benefits mainly the environmental sustainability and consumption of low energy [5–8]. Diffusion dialysis separation method using anion exchange membrane (AEM) is determined by concentration gradient, in which the solutes instinctively pass through AEM from high to low concentration side [9]. Consequently, only external power is necessary for the solution circulation. As the essential component for diffusion dialysis, AEMs shows the vital role in this method. In addition to long-period stability with high acidic resistance & thermal stability, they are required to hold high acid dialysis coefficient for pilot-scale practical application of acid recovery [10, 11].

Further, scientists and researchers reduced HCl as a potential cause of acidification in reserved ecosystems as they assumed it could not travel far from its power-plant source. This was due to the reason that the highly reactive HCl molecules attached on particulate matter and water droplets to fall out with precipitation in the immediate vicinity of the plants. As HCl is such a strong acidifier, the researchers are in the opinion that it significantly impacts the acidification of peat lands and other key ecosystems. If a large amount of hydrochloric acid is released or if other acids are present, the pH could be lowered until it is harmful for aquatic animals and plants.

So, in the present study, hydrochloric acid from the synthetic water sample was recovered through diffusion dialysis treatment technology due to its higher efficiency in purifying wastewater, low energy consumption and low installation costs. Effect of different acid concentration against varying time duration and acid concentration against varying flow rates were studied during the experiment.

II. EXPERIMENTAL INVESTIGATIONS

A. Materials

An anion exchange membrane, (AMI-7001) UltrexTM (IICT Tarnaka, Hyderabad), was procured. The feed solutions were prepared by diluting 35% assay Hcl solution and the amount of the acid extracted from the membrane was measured by acid-base titration with 0.1N NaOH standard solution. All the chemicals used for this study were of analytical grade. Deionized water was used throughout the experiment. All experiments were done at room temperature.

B. Diffusion dialysis experiments

Diffusion dialysis setup was designed and fabricated in the laboratory using ‘Perspex’ material consisting of two chambers (Deionized water and feed) with each chamber containing a volume of 600ml (total), and separated by anion exchange membrane ((AMI-7001) UltrexTM 5.5×5.5 cm) (Fig .1). The setup was fabricated using leak proof sealing along with proper inlet and outlet arrangements. Each chamber was provided with four additional ports, two ports were interconnected with silicon tubing for proper mixing of the feed using peristaltic pump.

Fig. 1 Experimental setup

C. Operation details

At the beginning of each experiment, the dialysate compartment was filled with the model HCl solutions (0.05N-0.3N) and the diffusate compartment side with deionized water. During the experiments, both compartments were intensively stirred to minimize the effect of liquid films on both sides of membrane and acid concentration in both compartments was measured with varying flow rates of 1rpm (53ml/min), 3rpm (160ml/min), 5rpm (268ml/min), 7rpm (375ml/min) and 9rpm (482ml/min) using acid-base titration method. The experiment was continued for all the synthetic acid concentrations, first initially starting from 0.05N. The reading was noted after every 6 hours. The concentration of HCl was determined by potentiometric titration using 0.1mol/L NaOH solution.

III RESULTS AND DISCUSSION

A. Effect of different flow rates on the diffusion dialysis performance

Generally, the increase in flow rate leads to increased acid recovery for any synthetic acid solutions. This can be ascribed to the increased concentration gradient across the membrane created by intense mixing of the acid and water therefore leading to the enhanced ionic mobility of H+ and Cl- and their diffusion coefficients in the membrane [12].

To optimize the operating conditions, various initial tests were performed using synthetic HCl acid solution at room temperature and the higher acid recovery efficiency of 19.6% was observed with 0.1NHCl at a flow rate of 7rpm (375ml/min). A standard time interval of 24hrs has been taken as constant for this experiment to know the effect of different flow rates (fig 2). From the figure2, it was clear that with increasing flow rates from 1 to 7 rpm the acid recovery efficiency increased. This was due to the reason that with increasing flow rates the input acid concentrations increased causing the ionic strength increase which therefore increased the acid recovery efficiency. On the other hand, with increasing concentration of input synthetic HCl solutions the acid recovery efficiency has been decreased. This might be due to the reason that the diffusion coefficient of HCl is such that it will increase at low acid concentration but decrease at a relatively high concentration. At low acid concentration, the concentration gradient effect is dominant and an increase in permeability is observed, while at high concentration ionic strength effect is dominant and the permeability of the ions is decreased [13].

Categorically, the decreased HCl recovery was observed at 0.3N even with increased flow rates is attributed to less retention time as the ions had no sufficient time to permeate the anion exchange membrane to the dialysate end, observed in any other synthetic samples. Therefore, it is essential to choose a proper retention time to make the permeability completely and have a good acid recovery in a practical industrial operation [14].

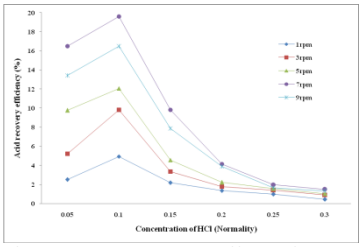

Fig. 2 Acid recovery efficiency of synthetic solutions at different flowrates and concentrations

B. Effect of different time intervals on the acid recovery efficiency of synthetic HCl solution

From the result obtained from the above section (3.1) it was clear that higher acid recovery was achieved at 0.1N at 7 rpm (375 ml/min) which were considered as optimum concentration and flow rate. Also, in the above experiment a time interval of 24hrs has been selected as standard. According to few researchers [12, 15] different time intervals have shown different effects on acid recovery efficiencies of different wastewater samples. Hence, in this present study different time intervals starting from 6hrs to 72 hrs were studied for their effect on acid recovery and the higher efficiency of 30% acid recovery was noted at 48hrs of retention time (fig.3). This was due to the reason that with increasing retention time the HCl acid recovery increased linearly

first and then gradually levelled off due to the decreased concentration difference and increased resistances in liquid films [12]. It was also propounded by [15] that the acid recovery increased with the increasing retention time, but not linearly at greater concentrations due to decreased concentration difference because even when the specific retention time was increased, the resistances in liquid films and membrane increases simultaneously.

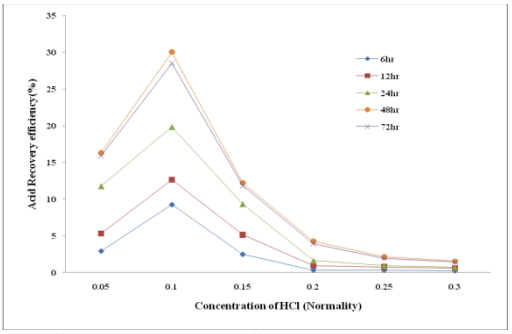

Fig.3 Acid recovery efficiency obtained at different time intervals and concentrations.

IV. CONCLUSIONS

From the present study results it was clear that the diffusion dialysis carried out to recover HCl from its synthetic solution ranging from 0.05N to 0.3N solution was effective in acid recovery. The HCl recovery increased with increasing retention time from 24 hours to 48 hours when the flow rate was maintained constant at 375ml/min which can be ascribed to the increased concentration gradient across the membrane, the enhanced ionic mobility of and their diffusion coefficients in the membrane.

The increasing flow rates affected increasing HCl recovery when the time was maintained constant at 24 hours, but to certain time only, following which there was no increase due to the decrease in concentration gradient. The acid recovery decreased with increasing acid concentrations in both the cases because at higher concentration, the effect of ionic strength becomes dominant leading to less permeability of ions across the membrane. But at relatively lower concentration, the effect of concentration gradient is dominant which leads to increased permeability of ions, therefore higher diffusion coefficient.

So, it is very imperative that in diffusion dialysis experiments, any operating parameters should be such that the effect of concentration gradient and ionic strength are to be carefully taken into consideration which would enhanced the diffusivity of ions and would also help in maintaining the membrane efficiency and swelling.

Acknowledgements

This work was supported by the Centre for Environment, Institute of science and technology, Jawaharlal Nehru Technological University Hyderabad, Telangana, India. The authors thank the University for providing the facilities to this work.

REFERENCES

[1] Swayze,G.A, Smith,K.S, Clark,R.N, Sutley,S.J., Pearson,R.M, Vance,J.S, Hageman,P.L, Briggs,P.H, Meier,A.L, Singleton,M.J, Roth,S.. Using imaging spectroscopy to map acidic mine waste. J. Environ.Sci.Technol 2000; 34: 47–54.
[2] Xue,M, Kendall,A, Xu,Z, Schoenung,J.M.. Waste management of printed wiring boards: a life cycle assessment of the metals recycling chain from liberation through refining. J.Environ.Sci.Technol 2015; 49: 940–947.
[3] Bramer,H.C. Pollution control in the steel industry. J.Environ.Sci.Technol 1971; 5: 1004–1008.
[4] German,M. SenGupta,A.K. Greenleaf,J. Hydrogen Ion (H^+) in waste acid as a driver for environmentally sustainable processes: opportunities and challenges, J. Environ.Sci.Technol 2013; 47: 2145–2150.
[5] Stachera,D.M, Childs,R.F, Mika,A.M., Dickson,J.M.. Acid recovery using diffusion dialysis with poly(4-vinylpyridine)-filled micro porous membranes. J. Membr.Sci 1998; 148: 119–127.
[6] Zheleznov,A, Windmöller,D, Körner,S, Böddeker,K.W. Dialytic transport of carboxylic acids through an anion exchange membrane. J.Membr.Sci 1998; 139: 137–143.
[7] Sridhar,P, Subramaniam,G. Recovery of acid from cation exchange resin Regeneration waste by diffusion dialysis. J.Membr.Sci 1989; 45: 273–280.
[8] Barnes,S, Dalhoff,R, Keller,J, Wilderer,P, Kendall,L. Investigation of membrane processes for the removal of volatile fatty acids. J. Water Sci. Technol 2003 ;47(12):191-198.
[9] Stancheva, K.A. Applications of dialysis. J. Oxid. Commun 2008; 31: 758–775.
[10]Xu, T, Yang, W. Tuning the diffusion dialysis performance by surface cross- linking of PPO anion exchange membranes – simultaneous recovery of sulphuric acid and nickel from electrolysis spent liquor of relatively low acid concentration. J.Hazard.Mater 2004; 109: 157–164.
[11]Xu, T, Yang, W. sulphuric acid recovery from titanium white(pigment)waste liquor using diffusion dialysis with a new series of anion exchange membranes-static runs. J. memb.sci 2001;183: 193-200.
[12]Luo, Jingyi, Cuiming, Wu, Yonghui, Wu and Tongwen, Xu. Diffusion dialysis-concept, principle and applications, Journal of Membrane Science 2011; 366: 1–16.

[13] Tongwen, Xu and Weihua,Yang. Sulfuric acid recovery from titanium white (pigment) waste liquor using diffusion dialysis with a new series of anion exchange membranes — static runs. Journal of Membrane Science 2001; 183: 193–200.
[14] Jing, Xu, Shuguang, Lu and Dan, Fu. Recovery of hydrochloric acid from the waste acid solution by diffusion dialysis. Journal of Hazardous Material 2009; 165: 832–837.
[15] Moon-Sung Kang, Kye-Sang Yoo, Suk-Jung Oh and Seung-Hyeon Moon. A lumped parameter model to predict hydrochloric acid recovery in diffusion dialysis. Journal of Membrane Science 2001; 188: 61–70.