International Journal of Chemical Sciences and Applications
ISSN 0976-2590, Online ISSN 2278 – 6015
Vol 4, Issue 1, 2013, pp 68-72
http://www.bipublication.com

APPLICATION OF ELECTRO-DIALYSIS (ED) TO REMOVE DIVALENT METALS IONS FROM WASTEWATER

Rahul Keshav Jadhao

Analitika Ecolab Private Limited – Gwalior, India
*Corresponding Author: Email id: rahulkjadhao@yahoo.co.in; (Mobile Number: 91-9922480968)

[Received-01/03/2013, Accepted-17/03/2013]

ABSTRACT

The effect of influential factors on separation of divalent Metal ions (Cu^{2+}, Zn^{2+}, Pb^{2+}) from wastewater using AMV and CMV ion-exchange membranes were investigated. The effect of concentration (300, 600, 900 ppm), temperature (20, 40, 60°C), flow rate (0.2, 0.6, 1.2 ml/s) and voltage (15, 20, 35 V) on separation percent of the individual ions in the solution were studied. The results show that increasing concentration, voltage and temperature improves cell performance; however, the separation percent decreases with increasing flow rate. At concentrations of more than 600 ppm, dependence of separation percent on concentration diminishes. The optimum levels of influential factors, determined for all ions are: concentration 900 ppm, temperature 60°C, flow rate 0.2 ml/s and voltage 35 V. It was found that performance of an electrodialysis cell is depends on the operating conditions and cell structure. For ions of similar valence, separation percent was indicated to be restricted by molecular weight and electrochemical activation energy of the ions ($S_{Pb}<S_{Cu}<S_{Zn}$).

Keywords: Wastewater, Anion and Cation Exchange Membrane, Heavy Metals

I. INTRODUCTION

Desalination is a process that removes dissolved minerals from seawater, brackish water, or treated wastewater. About 71% of the earth surface is covered by water which is in the form of the oceans, seas and the ices in the poles. However, only about 3% of water is fresh and suitable for drinking. The water of the oceans and seas is salty and thus not directly utilizable. Therefore, some special processes are needed to desalinate these waters [1-3]. Meanwhile, copper, zinc and lead are Persistent, Bio accumulative and Toxic (PBT) chemicals. The PBT chemicals are of particular concern not only because they are toxic but also because they remain in the environment for long periods of time, are not readily destroyed, and build up or accumulate in body's tissues [4-6].

Pollution prevention has become a central part of the thinking for regulators, chemists, chemical engineers, process engineers and others in chemical manufacturing. Efforts have been undertaken to identify new processes that inherently produce less pollution to be used in tomorrow's processing plants. New technologies such as membrane technologies to recover and reuse waste process streams are enjoying interest [7, 8].

ED with ion exchange membranes represents one of the most important membrane methods. It deals with the problems of desalination of salted waters, wastewater minimization, ultra-pure water production, concentration of dilute solutions, separation of electrolytes and non-electrolytes and production of acids and alkalis from their salts.

The objectives of present study are: (1) to find the best or optimal condition for the product or process, (2) to identify the contribution of individual factors and (3) to estimate the response under optimal conditions.

II. MATERIALS AND METHOD

ED cell is packed with a pair of ion exchange membranes (cation and anion) and a pair of platinum electrodes (anode and cathode). Both electrodes are made of pure platinum. Area of each electrode is 4.4 mm × 4.4 mm. Thickness of dilution cell (center) is 5 mm and thickness of each concentrate cell (left and right) is 4 mm.

Types of membranes were used in all experiments: AMV and CMV anion and cation exchange membranes. Effective area of each membrane is 50 mm × 50 mm. Analytical grade salts (copper sulfate, zinc sulfate, lead Nitrate supplied by Merck) were used in all experiments to produce solutions with wastewater qualities. Concentration of metal ions in the dilute product was measured using a conduct meter, when separation of individual ions was investigated. When separation of mixture of ions was investigated atomic absorption was utilized.

In this study, the quality characteristic was SP which was calculated as follows:

$$SP = \frac{C_0 - C}{C_0} \times 100$$

where, C_0 and C are feed and dilute concentrations, respectively.

Four factors each with three levels (low, medium and high) were chosen based on previous results in related works and qualitative experiments [4, 5]. The matrix experiment was designed by selecting appropriate control parameters. Controllable factors and their levels in the L9 array are presented in Table 2.

III. RESULTSAND DISCUSSION

The matrix experiment was conducted under the limiting current density and the results for ions using two types of membranes are recorded in Tables 3. According to these tables, 8th run gives the best SP of metal ions. Selecting this run, as an optimal condition can be an erroneous decision. Since, based on Taguchi method, one-ninth (1/9) of all possible experiments are carried out, there may be a combination of levels which results in the highest SP. Taguchi approach offers a statistical model by which the results of supplemental 72 experiments as well as those of other levels are predicted (seventh step of Taguchi method) [4,10]. Based on the final step of Taguchi method, confirmation experiments are required to be conducted using the predicted optimum levels for the control parameters being studied. In this work, the optimum condition was incidentally observed in the main matrix as T_{high} (60 (C), C_{medium} (600 ppm), F_{low} (0.2 mL/s) and V_{high} (35 V).

Comparing the amounts of SN and mean response for different ions, it was found for ions of similar valence, SP was observed to vary as SPb < *S*Cu < *S*Zn. This can be attributed to the different molecular weight and electrochemical activation energy of the ions.

The following relation is used to calculate SN ratio:

$$SN = -10 \log \left(\frac{1}{n} \sum_{j=1}^{n} \frac{1}{SP_j^2} \right)$$

where, n is the number of all observations used for calculation of SN. Whatever the type of quality or cost characteristic, the transformations are such

that the SN ratio is always interpreted in the same way: the larger the SN ratio the better [9, 10].
It was verified that, temperature, concentration and voltage are directly proportional to SP and SN, while increasing flow rate decreases SP and SN. Hence, in the case of higher temperatures, voltages and concentrations electrical resistance of the feed solution decreases and subsequently ED separation performance increases. It was also approved that SP at 600 ppm is slightly greater than that at 900 ppm. Taking a closer look to Figs. 1b and 2b, it is found that SP varies inversely and SN varies proportionally with concentration level from 600 to 900 ppm.

IV. CONCLUSION

In the presentwork, separation of divalent (Cu2+, Zn2+, Pb2+) ions from wastewater was investigated using a laboratory scale ED cell. AMV and CMV anion and cation exchange membrane was used. Effect of concentration (300, 600, 900 ppm), temperature (20, 40, 60 ◦C), flow rate (0.2, 0.6, 1.2 mL/s) and voltage (15, 20, 35 V) on SP of individual ions in the solution was examined. As a result, higher temperature, higher concentration (concentrations greater than 500 ppm have almost no effect on the performance), higher voltage and fewer flow rate were recommended to modify performance of ED cell.
The results confirmed that a pair of membranes with higher IEC causes better results for ED cell. It was found that SP is dependent on molecular weight and electrochemical activation energy of the ions (*S*Pb < *S*Cu < *S*Zn). It was also found that performance of ED cell is almost independent on the type of ions and to a large extent depends on the operating conditions and the cell structure.

ACKNOWLEDGEMENT

The author expresses his deep sense of gratitude to Mr. Arun Jain, Managing Director, Mahavir Chemical Pvt.Ltd., Nagpur, India for their priceless encouragement, advice and guidance.

REFERENCES

[1] T. Mohammadi, A. Kaviani, Water shortage and seawater desalination by electrodialysis, Desalination 158 (2003) 267–270.
[2] T. Mohammadi, A. Moheb, M. Sadrzadeh, A. Razmi, Separation of copper ions by electrodialysis using Taguchi experimental design, Desalination 169 (2004) 21–31.
[3] T. Mohammadi, A. Razmi, M. Sadrzadeh, Effect of operating parameters on Pb2+ separation fromwastewater using electrodialysis, Desalination 167 (2004) 379–385.
[4] R. Klischenko, B. Kornilovich, R. Chebotaryova, V. Linkov, Purification of galvanic sewage from metals by electrodialysis, Desalination 126 (1999) 159–162.
[5] N. Kabay, M. Ardab, P. Kurucaoval, E. Ersoza, H. Kahveci, M. Can, S. Dal, Effect of feed characteristics on the separation performances of monovalent and divalent salts by electrodialysis, Desalination 158 (2003) 95–100.
[6] M.E.Vallejo, F. Persin, C. Innocent, P. Sistat, G. Pourcelly, Electrotransport of Cr(VI) through an anion exchange membrane, Sep. Purif. Technol. 21 (2000) 61–69.
[7] A. Chapotot, G. Pourcelly, C. Gavach, F. Lebon, Electrotransport of proton and divalent cations through modified cation-exchange membranes, J. Electroanal. Chem. 386 (1995) 25–37.
[8] M. Kameche, C. Innocent, F. Xu, G. Pourcelly, Z. Derriche, Electrotransport of protons, alkali metal cations and solvent molecules through a commercial cation-exchange membrane conditioned with aqueous and organic solutions, Desalination 168 (2004) 319–327.
[9] T. Mohammadi, A. Moheb, M. Sadrzadehb, A. Razmi, Modeling of metal ion removal from wastewater by electrodialysis, Sep. Purif. Technol. 41 (2005) 73–82.
[10] P. Zschocke, D. Quellmalz, Novel ion exchange membranes based on an aromatic polysulfone, J. Memb. Sci. 22 (1985) 325–332.

Table 1 : IEC value of applied membranes

Membrane type	IEC
AMV	4.0
CMV	5.0

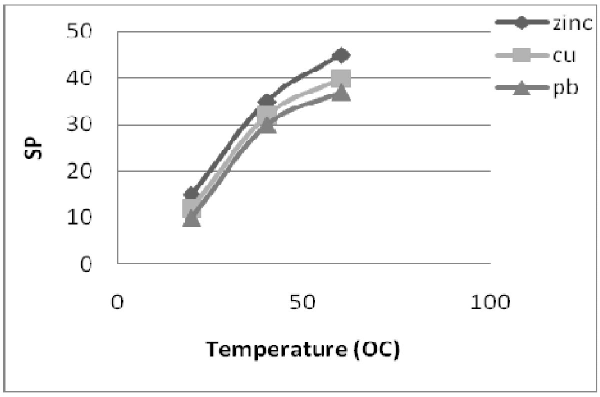
Table 2: Control factors and their levels

RUN	Control Factors			
	T(^{O}C)	C(ppm)	F(mL/s)	V(V)
1	20	300	0.2	15
2	20	600	0.6	20
3	20	900	1.2	35
4	40	300	0.6	35

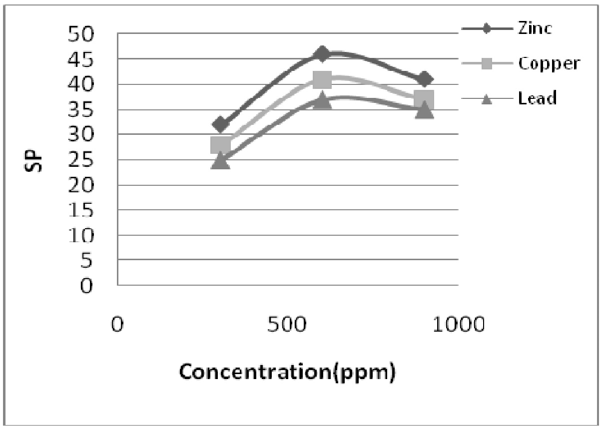
5	40	600	1.2	15
6	40	900	0.2	20
7	60	300	1.2	20
8	60	600	0.2	30
9	60	900	0.6	10

Table 3: SP & SN values for three types of ions using anion(AMV) and cation(CMV) exchange membrane

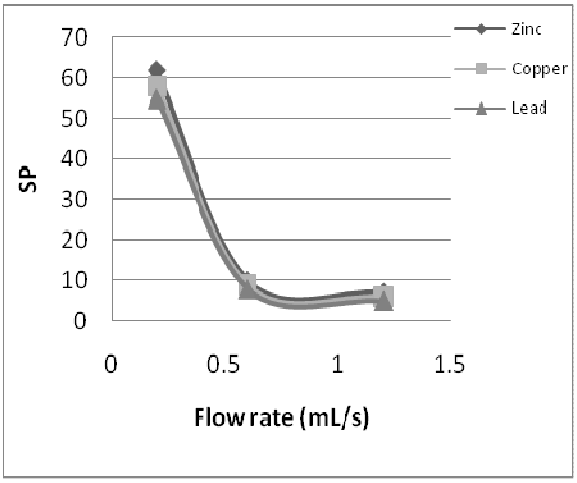
RUN	Mean response(SP)			Signal to Noise ratio(SN)		
	Zn	**Cu**	**Pb**	**Zn**	**Cu**	**Pb**
1	26.97	22.32	20.98	28.81	26.11	26.30
2	11.52	13.21	11.02	22.03	22.98	18.00
3	12.20	11.35	11.87	22.13	21.37	21.12
4	20.05	15.11	13.75	26.57	23.18	23.28
5	7.22	8.33	7.88	18.09	18.72	18.11
6	82.31	81.43	79.21	38.55	38.06	37.50
7	14.27	8.76	8.01	22.81	19.05	18.53
8	98.23	97.10	92.35	39.17	39.01	38.56
9	16.32	16.07	15.55	23.63	22.88	23.03



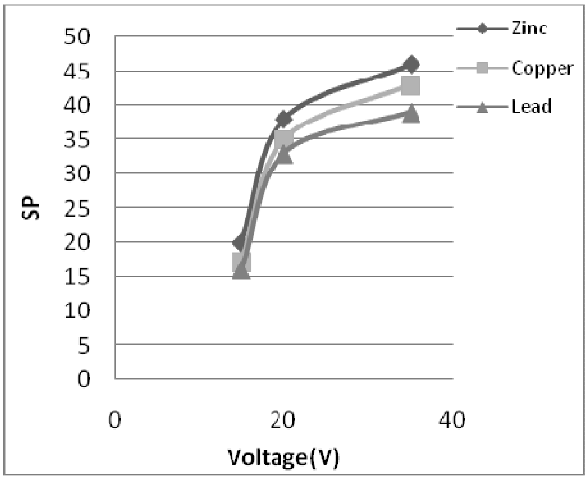
a)Temperature



b) Concentration

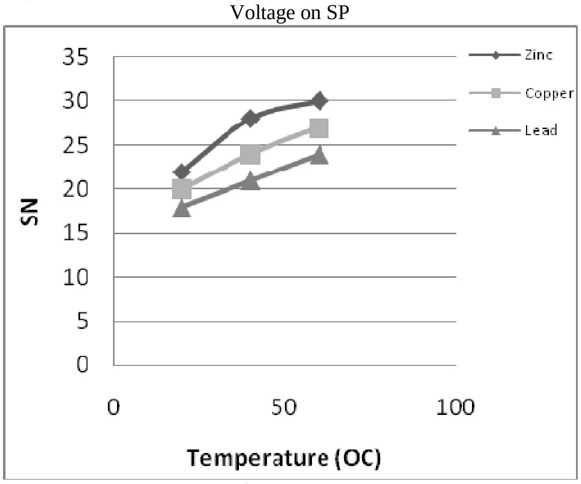


c) Flow rate

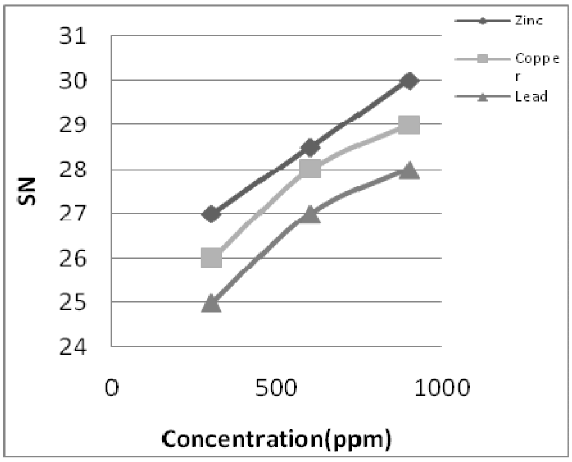


d) Voltage

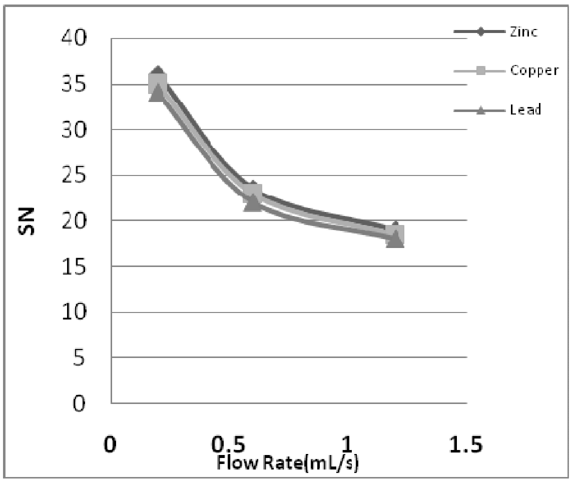
Figure 1 : Effect of a) Temperature b) Concentration c) flow rate d) Voltage on SP



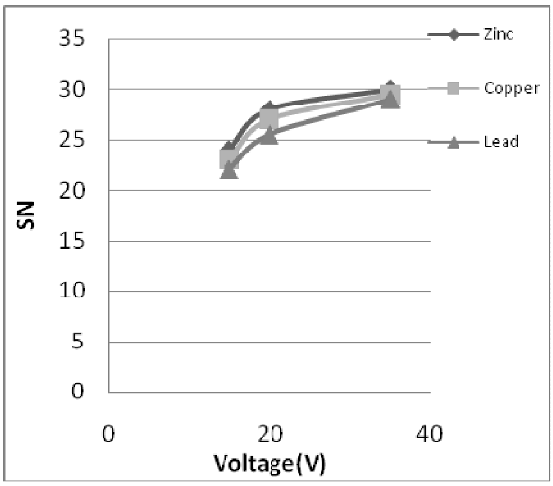
a) Temperature



b) Concentration



c) Flow rate



d) Voltage

Figure 2 : Effect of a) Temperature b) Concentration c) flow rate d) Voltage on SN