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Recovery of Zinc from Zinc Waste By-adsorption Process

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Abstract: The zinc present in the dead tank wash water of plating industry is of about 300 ppm approximately. The aim of the experiment was to reduce the zinc content in the effluent. Treatment by ion exchange produces reusable water. Generally dead tank wash water contains about 1% of the plating bath concentration. If this water is sent as waste the zinc present will be left unused and it pollutes the environment, so the recovery of zinc from dead tank wash water is more important.For this process the synthetic ion exchange resin Amberlite (IR-120) was used and the resin was regenerated using acid as regenerant. Mass transfer coefficient has been derived for adsorption and desorption, adsorption mass transfer coefficient has been calculated and breakthrough curve have been drawn for experimental values. The result shows that the zinc - recovery process is feasible and effective in ion exchange process.

Key words: Zinc, effluent, ion exchange method

INTRODUCTION

Zinc is widely distributed in nature and used mainly as a replacement for iron due to its non corrosive nature. It occurs in nearly all igneous rocks and commercial minerals sources are sphalerite, cubic zinc sulphide (zinc blend or blend wurzite). These above compounds are abundant in nature and exhibit hexagonal form, stable above 1020°C. Zinc metal finds extensive use in variety of application such as galvanizing of iron and steel structures, in the pigment industry also for the production of organic and inorganic chemicals (Basha *et al*., 1980 and 1981). In it zinc metal is largely consumed by galvanizing industry and accounts for nearly 55-60% of total zinc produced during the galvanizing process considerable quantity of the zinc metal gets lost as skimming, ash and dross. These waste contain ash takes away approximately 5-10% of the metal consumed in the industry. The second major use of the zinc being chemical industries of 13% of production (Alagusundarm *et al*., 1975). The wastes materials produced by pigments, pharmaceuticals and paints industries also contain zinc, which are subjected to treatment before discharge due to environmental regulations. According to environmental legislation, the concentration of zinc waste in any discharge stream should not >5 ppm (Tolerance limits for industrial effluents prescribed by Indian standards institution IS 2490 (1981)).

In these circumstances, recovery of zinc from the zinc provides an opportunity to protect the environment and reduce dependence on new zinc. The two process, usually used for the recovery of zinc in the present day are Pyrometallurgical process and Hydrometallurgical process (Jha *et al*., 2000). The main advantages of Hydrometallurgical process, it can be operated at room temperature and treat even waste containing low concentration of zinc; the higher percentage recovery of zinc and capacity of lower volumes making economically more viable; ability to process secondary wastes containing different impurities and availability of adequate knowledge about operation on all scales (bench scale, pilot plant scale and commercial scale). The present study aims at the betterment of recovery of zinc from waste using the ion exchange process.

MATERIALS AND METHODS

Ion exchange process: A properly selected ion exchange resin can enable efficient operation, minimize running cost and provide maximum life time (more than 60 cycles). Hence proper selection of resin plays an important role in the success of an ion exchange process (Kirk and Othmer, 1995).

Ion exchange resin: The ion exchange column consisted of a glass column of length 0.6 m and diameter 0.012 m.

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Table1: Properties of cationic exchange resin

Property	Range
Ionic group	$-SO_3$, H^+
Particle size	0.45 to 0.6 (effective size)
Capacity (meq g^{-1}) dry resin	4.25
Capacity (meq g^{-1}) wet resin	1.9
Moisture content (wt.%)	44 to 48
Maximum temperature (°C)	120
pH range	0 to 14
Physical form	Spherical beads
Remarks	Standard resin, ca 8% DVB
Nominal diameter	40 microns
Density	0.77 (g L^{-1})
Moisture content	35 to 45 (%)
Screen grading	16 to 50 mesh
Effective size	0.45 to 0.6 (mL)

Trade name: Amberlite IR- 120
Manufacturer: Rohm and Haas Co., Washington Square, Philadelphia

The column consisted of cation exchange resin Amberlite IR 120 up to a height of 0.35 m.In the present study, to remove zinc ions, a cation exchange resin viz., sulphonated cross-linked polystyrene bead resin commercially known as Amberlite IR-120 was used. Amberlite IR-120 resin posses strong acidic nature with exceptionally high exchange capacity and unusual stability at elevated temperature. It has excellent chemical resistance over entire pH range. The resin in bead form, had sodium which become moist and swollen after regeneration. The complete characteristics of Amberlite IR-120 resin are given in Table 1.

Experimental procedure: The column was packed with cation exchange resin (Amberlite IR 120). The influent containing 300 ppm of zinc concentration was pumped in to the column. The zinc ions get adsorbed into the resin, the sample was collected at regular time intervals and it was analyzed using complexometric titration to find out the amount of zinc adsorbed in the resin. The used resin after each cycle was regenerated using 3N-hydrochloric acid and procedure followed for adsorption cycle. The constant flow rate through the column was maintained with the help of a peristaltic pump. The whole procedure was repeated for different flow rate of the effluent through the column. The results obtained were utilized to estimate mass transfer coefficients and break through curve.

Break through curve: Cation exchange resin columns were run using synthetic rinse water containing 250 ppm of zinc as Zn^{2+}. It is a continuous process to find out the break-even point of the resin. The results obtained from the column study are represented through curves, from the experimental data 20g of cation exchange resin have the capacity to treat 10.5 L of the rinsing water containing 250 ppm of Zn^{2+} effectively and the treated water can reuse for same purpose.

RESULTS AND DISCUSSION

Detailed studies on effect of flow rate in the range of 23-31 mL min^{-1} of effluent through the ion exchange column were carried out using a cationic resin (Commercially known as AMBERLITE IR-120) with the peristaltic pump to re-circulate the effluent during the process. Initial zinc concentration in the effluent was maintained at 300 mg L^{-1}. During the process, samples of zinc taken out at regular intervals were tested for zinc concentration.

Flow rates of 23, 27, 31 mL min^{-1} adsorb 300 mg L^{-1} of zinc from the effluent takes a durationof 150, 150, 90 min respectively and the adsorption percentage of zinc from the effluent are 97.8, 98.2, 97.2, respectively (Table 2).

Table 2: Effect of flow rate on adsorption using Ion exchange column

Time (min)	Concentration of zinc C (ppm)	C/C_0	Adsorption (%)
Flow rate: 23 mL min^{-1}			
30	122	0.4067	97.8
45	89.89	0.2996	
60	57.20	0.1907	
75	40.86	0.1362	
90	28.60	0.0953	
105	20.43	0.0681	
120	12.25	0.0408	
135	6.5	0.02167	
150	6.5	0.02167	
Flow rate: 27 mL min^{-1}			
30	163.35	0.5445	98.2
60	98.01	0.3267	
90	32.66	0.1088	
120	5.445	0.01815	
150	5.445	0.01815	
Flow rate: 31 mL min^{-1}			
20	130.68	0.4356	97.2
30	98.01	0.32673	
40	57.17	0.1906	
50	32.61	0.1087	
60	24.7	0.0823	
70	16.33	0.05445	
80	8.1675	0.02725	
90	8.1675	0.02725	
Flow rate: 27 mL min^{-1}			
30	32.69	0.13076	
60	32.69	0.13076	
90	32.69	0.13076	
120	32.69	0.13076	
150	32.69	0.13076	
180	32.69	0.13076	
210	57.682	0.23072	
240	77.20	0.3088	
270	138.932	0.5557	
300	179.795	0.7191	
330	223.651	0.8946	
360	246.785	0.9871	
390	250.00	1.00	

Table 3: Mass transfer coefficients for adsorption

Flow rate (mL min^{-1})	Mass transfer coefficient Kc (10^{-3}m min^{-1}) Adsorption
23	3.616
27	4.6498
31	6.8233

From the results flow rate of 31 mL min^{-1} adsorb zinc from the effluent in a lower time cycle compared to other flow rates but the percentage of adsorption is more in a flow rate of 27 mL min^{-1}. Hence, it can be concluded that higher flow rate of 31 mL min^{-1} adsorb zinc from the effluent can be achieved quickly in a duration of 90 min, moderate flow rate of 27 mL min^{-1}(in this study) the percentage of adsorption of zinc from the effluent is 98.2% because the effluent meets the average residential time during the process.

From the concentration values obtained at different intervals of time for an effluent flow rate of 27 mL min^{-1} has been further analyzed for development of break through curve (Table 2). From the results obtained the break even point for the column was found to after 390 min of continuous operation. Under these circumstances, the volume of effluent being treated is around 10.53 L (Table 3).

Studies on ion exchange column were carried out to estimate the mass transfer coefficient for adsorption during the process. For estimation of mass transfer coefficient, ln C_{A2} values experimentally obtained at different time intervals for flow rate ranging from 23-31 mL min^{-1} are being used. The values have been estimated by replacing the slope of the line in the equation gives the mass transfer coefficient.

The mass transfer coefficients are determined by using the following equations by McCabe *et al*., (1993)
Let

C_{A1} and C_{A2} be the inlet and outlet concentration
Q be the flow rate of effluent

$\ln C_{A2} = Q/V[e^{-N} -1] t + \ln C_{A1}$ --------- (Adsorption)
$\ln C_{A2} = Q/V[e^{N} -1] t + \ln C_{A1}$ --------- (Desorption)
$Q/V [e^{N} - 1]$ = slope, $\ln C_{A1}$ = intercept
$N = Kc\ a\ L / Uo$
$a = 6 (1-\varepsilon) / Dp$

Where,
a = Mass transfer coefficient,
N = Number of transfer units
L = Length of the packed column,
Kc = Mass transfer coefficient
Uo = Superficial velocity,
Dp = Diameter of the particle
ε = Porosity

Result shows that the flow rate of 31, 27, 23 mL min^{-1} transfers 6.8233×10^{-5}, 4.649×10^{-5}, 3.616×10^{-5} mass of zinc from the zinc effluent, in a meter of resin per minute. From these results, higher flow rate (31mL min^{-1}) provides higher transfer of zinc from the zinc effluent this is due to high volume of zinc effluent is passed through the column it covers more surface area of the adsorbent and get adsorbed in to it. At the same time more volume of effluent is also get treated in each circulation than moderate and lower flow rates of our study (27 and 23 mL min^{-1}).

CONCLUSION

In this study the recovery of zinc has been accomplished by using ion exchange method. The resin used in this ion exchange process can be regenerated at the end and can be used for subsequent treatment process. This treated discharge water would be used for some other purpose. This is one of the optimal methods for recovery of zinc from rinse water of zinc plating industries.

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