Removal of zinc from effluents by electrodeposition

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In view of very low concentrations of metal ions present in effluents and streams, special types of electrolysers have been tried for the purpose. Investigations have been carried out using zinc containing effluent (160 ppm of zinc) under alkaline condition in a packed-bed electrolyzer and in batch recirculation system. Effect of flow rate and concentration of sodium hydroxide have been studied. It was observed that maximum removal efficiency of 98.75% was obtained at a flow rate of 180 l. hr^{-1} $hr.^{-1}$ with 0.1N sodium hydroxide as supporting electrolyte. At higher concentration of sodium hydroxide both the current and the removal efficiency is considerably reduced due to partial redissolution of zinc.

Key words: Zinc removal, packed bed electrolyser, metal pollution

INTRODUCTION

In view of the strong effects of the heavy metal pollution, considerable importance has been given for the removal of these ions from the effluents. In recent years electrodeposition of heavy metal ions has been under development. A review of various technologies for recovery and removal of metal ions from plating effluent was made by Olathof [1]. Normally, the plating industry effluents contain 20-200 ppm of zinc which has to be necessarily removed from the effluent prior to disposal. Owing to very low concentration conditions involved, special types of electrochemical reactors with three dimensional electrodes such as packed bed fluidised bed, have been under development [2]. With the particle bed electrodes it has been reported that 75% of an initial 55 ppm zinc could be removed [3]. In the present investigation, removal of zinc from an alkaline solution using a packed bed electrolyzer is reported.

EXPERIMENTAL

Investigations have been carried out with synthetic effluent containing 160 ppm of zinc and a supporting electrolyte of sodium hydroxide using graphite packed bed electrodes with batch recirculation system. The details of the reactors are given elsewhere [4]. The electrolysis was carried out at a constant applied voltage of 20V for 5 hrs. Experiments were carried out at different flow rates namely 30 to 200 $1.hr^{-1}$ and with 0.1N and 1N sodium hydroxide as supporting electrolyte. The rate of depletion of zinc was determined using atomic absorption spectra AAS.

RESULTS AND DISCUSSION

The results are presented in Table I. The variation of

concentration with electrloysis are plotted in Figs. 1 and 2 for the two concentrations of supporting electrolyte.
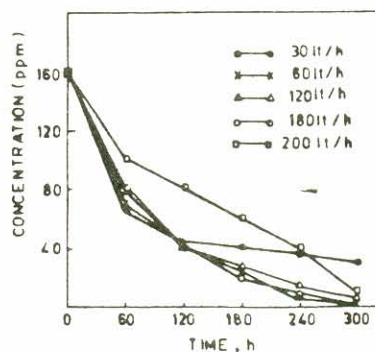

Fig. 1: Concentration vs time plot for the electrolytic removal of zinc in presence of 0.1N NaOH as supporting electrolyte
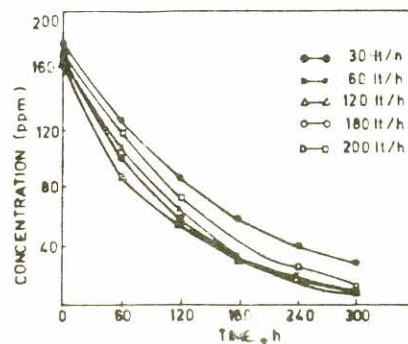

Fig. 2: Concentration vs time plot for the electrolytic removal of zinc in presence of 1N NaOH as supporting electrolyte

As can be expected, the concentration of zinc varies exponentially with time. Within the first hour of electrolysis, the fall in concentration has been steep; 50-

TABLE—I: Removal of zinc using graphite packed bed electrodes with batch recirculation

Conc. of NaOH (N)	Flow rate (l.hr^{-1})	Average current at 20V (A)	Conc. of zinc (ppm)		Overall current efficiency (%)	Overall removal efficiency (%)	Mass transfer co-efficient (K $\times 10^2$ cm/min.)
			Initial	Final			
0.1	30	2.4	162	30	13.5	81.48	2.35
	60	2.5	160	3	13.55	98.12	4.12
	120	2.8	162	6	13.71	96.30	4.43
	180	2.94	162	2	13.04	98.75	4.53
	200	2.98	164	10	12.71	93.90	1.22
1.0	30	9.7	180	20	4.1	88.9	2.7
	60	8.3	168	14	4.8	91.57	3.75
	120	8.35	166	14	5.1	91.56	4.07
	180	8.25	164	10	5.6	93.5	4.19
	200	8.35	162	12	5.1	92.4	3.06

60% of the initial concentration of 160 ppm of zinc in both the cases at all flow rates under the conditions of study. Towards the end of electrolysis, the removal of zinc ion has become difficult. With the flow rate ranging between 60-180 l.hr.$^{-1}$, the rate of depletion of zinc has been more or less constant and further increase or decrease in flow rate results in the reduction of depletion rate. The data during electrolysis with 0.1N and 1N NaOH as supporting electrolyte are presented in Table I. Due to the improved mass transfer conditions, the current increases with increase in flow rate in both the conditions. With the tenfold increase in concentration of sodium hydroxide, there is nearly 2.5 to 3 times increase in current flow. With 0.1N NaOH, the minimum concentration in solution that could be achieved in 5 hrs of electrolysis has been 2-3 ppm whereas at 1N NaOH the same has been 8-10 ppm. The overall current efficiency has been considerably reduced by increase in concentration of NaOH from 10-15% to 4-5%.

The overall conversion efficiency is slightly higher at 0.1N NaOH and a maximum conversion of 98.25% can be obtained at a flow rate of 180 l.hr.$^{-1}$. The same efficiency could be achieved by further electrolysis of one hour. Applying the plug flow model to the reactor, the values of the mass transfer coefficient (K) are calculated and found to increase with increase in flow rate in both the cases.

The electrolyte being lean in zinc ion concentration, the predominant reaction at the cathode is discharge of hydrogen ions. Simultaneously, the deposition of zinc also takes place at the cathode in a very fine powdery form. This deposit being very loosely attached to the cathode, particles are liable for dislodgement due to either vigorous gassing or by fast flow of the electrolyte through the electrode. In such an event, the fine zinc particles redissolve in the electrolyte NaOH to form zincate. The latter reaction is accelerated by increase in temperature and thorough mixing of the electrolyte and higher concentration of NaOH. Such a situation arises during electrolysis with 1N sodium hydroxide as the supporting electrolyte. The temperature rise has been around 294-296K under the various conditions of electrolysis. This increase in temperature could have been caused by high current concentration prevailing in the cathode chamber and/or exothermic dissolution of zinc. These have led to low current efficiency as well as removal efficiency.

CONCLUSION

Removal of zinc can be effectively carried out from an alkaline solution in a packed bed reactor. Low alkali concentration, lower flow rates and low current density have been found to be beneficial for this reaction.

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