

ELECTROCHEMICAL REMOVAL OF NICKEL FROM INDUSTRIAL EFFLUENTS

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Electrochemical industries, like metal finishing and electroplating industries, contribute considerably to pollution load. The pollutants include heavy metals and various organic and inorganic compounds. The most toxic pollutants are cyanides, mercury, lead, chromium, nickel, zinc, etc. Nickel, a well known heavy metal pollutant, is present in plating effluent to the tune of 10 ppm to 200 ppm. Conventional method of treatment of nickel-containing effluents, is by addition of suitable chemical precipitants and precipitating it as hydroxide after neutralising the effluent. This method is not suitable since sludge disposal becomes a problem. Electrochemical methods of treatment of industrial effluents have gained much importance in recent years. Various electrochemical techniques as well as reactors, such as, flowing system, trickle tower, bipolar rotating electrode cell, diaphragm cell and packed bed cells have been tried for effluent treatment. This paper describes the results of investigations carried out on the removal of nickel by electrodeposition using a double packed bed cell electrolyser of flow-by configuration using a synthetic effluent containing 200 ppm of nickel and sulphuric acid as supporting electrolyte. The electrolysis was carried out in a batch recirculation system. The flow rate was varied from 5 to 60 l/h. Of all the flow rates under study, 5 l/h is found to be optimum flow rate at a current efficiency of 84% and conversion efficiency of 97%. The results are discussed in detail.

Key words: Industrial effluents, nickel removal, electrodeposition

INTRODUCTION

Heavy metals, various organic and inorganic compounds are the pollutants present in the effluents generated by various electrochemical industries. Nickel, a well known heavy metal pollutant, is present in the effluent of plating industries to the tune of 20-200 ppm. Nickel salts in water produce hazardous effects and nickel is carcinogenic [1, 2]. Various methods have been proposed for treatment of the effluents. Chemical methods aim at precipitation of the nickel ions.

Electrochemical methods of treatment have gained much importance in recent years. Various electrochemical reactors, such as flowing system [3-5], trickle tower [6] bipolar rotating electrode cell [7] diaphragm cell [8], different configurations of packed bed cells [9] have been tried for effluent treatment. Packed bed electrolysers have been successfully used in the oxidative destruction of cyanide [10] as well as cathodic reduction of hexavalent chromium [11]. Different processes viz. reverse osmosis [10], ion exchange [11, 12] and electrodialysis [13] have been tried for the recovery of nickel from plating waste waters. Studies have been carried out extensively on the waste water treatment for recovery of Cu, Ni and Zn [14] from plating waste waters. Results have been reported in literature regarding the recovery of metals [15, 16] and recovery of nickel in particular [17-19]. In this work, experiments have been carried out on nickel removal using double packed bed electrolyser and results are reported.

EXPERIMENTAL

Experiments were carried out at ambient temperature employing synthetically prepared effluent containing 200 ppm of nickel and the electrolysis was carried out in a double packed bed electrolyser using graphite particles for both the electrodes. The cell belongs to flow-by configuration and details of the cell are given elsewhere [20]. Two concentrations of supporting electrolyte viz. 0.1N and 0.01N H₂SO₄ were used. The electrolysis was carried

out in a batch recirculation system for a period of 6 hours at a constant applied voltage of 30V with 2 litres of solution. The flow rate was varied from 5 to 40 l.h⁻¹. The rate of removal of nickel during electrolysis was estimated by analysing the samples drawn from the reservoir at 1 hour interval. Amount of nickel remaining after electrolysis was estimated by Atomic absorption spectrophotometry.

RESULTS AND DISCUSSION

Figure 1 shows the variation of concentration of nickel (2+) with time in 0.1N sulphuric acid as supporting electrolyte at different flow rates. In an hour's time, 70 to 80% of nickel content has been removed. The rate of further removal is considerably low. Generally, the concentration varies exponentially with time of electrolysis at all flow rates under study.

Figure 2 shows the behaviour of Ni²⁺ in 0.01N sulphuric acid as the supporting electrolyte. The variation of concentration of nickel with time is more or less similar to that in 0.1N H₂SO₄.

Figures 3 and 4 show the variation of current efficiency with concentration of Ni²⁺ in the two supporting electrolytes. The maximum current efficiency obtained is around 30% in 0.01N H₂SO₄ at a flow rate of 5 l.h⁻¹ with Ni²⁺ content of 200 ppm whereas it is only 20% in 0.1N H₂SO₄.

From the observations in Table I, it may be seen that nickel deposition occurs more effectively at low flow rates and maximum depletion is at 20 l.h⁻¹, in both the supporting electrolytes as borne out by the maximum conversion efficiency values at this flow rate. Also the average current increases with flow rate under both the conditions and the rate of conversion increases with flow rate upto 20 l.h⁻¹.

Since the reactive species is present at very low concentration, the main controlling factor is diffusion process. Hence adequate mass transfer conditions play a vital role in the study of packed bed reactors. The mass transfer coefficient is an important parameter

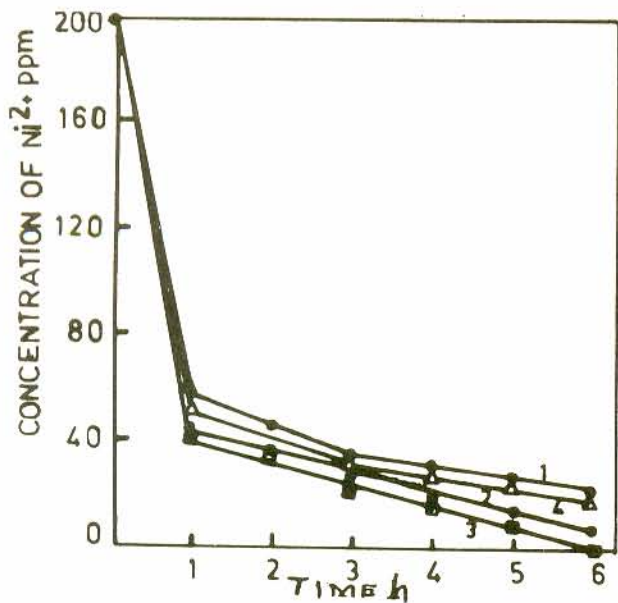


Fig. 1: Variation of concentration of Ni^{2+} with time, h- in $0.1\text{N H}_2\text{SO}_4$ (1) 5 Lh^{-1} (2) 10 Lh^{-1} (3) 20 Lh^{-1} (4) 40 Lh^{-1}

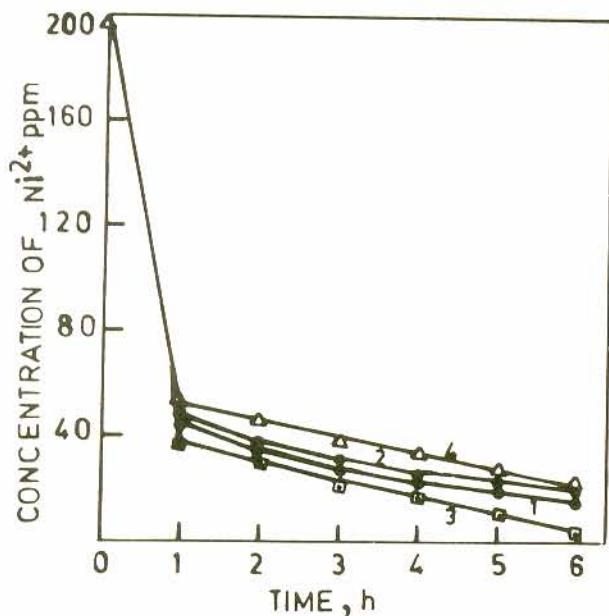


Fig. 2: Variation of concentration of Ni^{2+} with time in $0.01\text{N H}_2\text{SO}_4$ (1) 5 Lh^{-1} (2) 10 Lh^{-1} (3) 20 Lh^{-1} (4) 40 Lh^{-1}

and it is dependent on various factors like volumetric flow rate, porosity of the bed, specific surface area etc. The mass transfer coefficient K changes with flow velocity of the solution and is related to Reynold's number. The correlation between the mass transfer coefficient Reynold's number Re is given by $\log K$ vs $\log \text{Re}$ plot in Fig. 5. This shows that there is an increase in K upto 20 Lh^{-1} and then a decrease in K . Hence 20 Lh^{-1} is found to be the optimum flow rate for this reaction.

CONCLUSION

Use of three dimensional electrode system has resulted in improved efficiencies while treating solutions containing very low concentration of ions. In this study, it has been found out that it

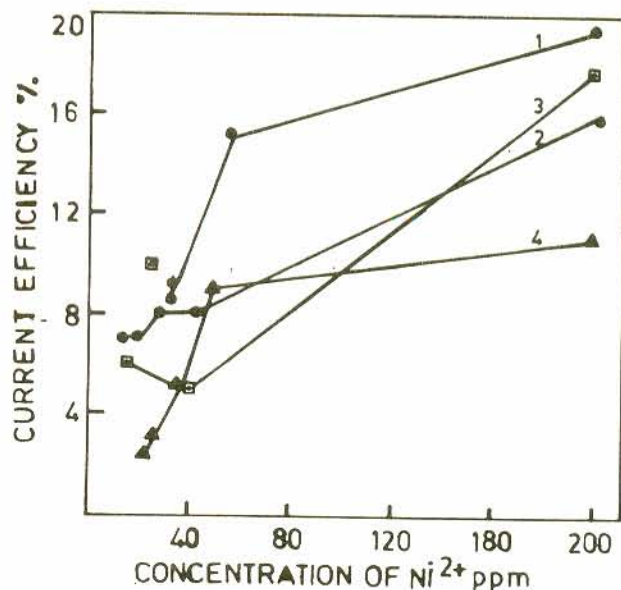


Fig. 3: Current efficiency vs concentration of Ni^{2+} (ppm) in $0.1\text{N H}_2\text{SO}_4$ (1) 5 Lh^{-1} (2) 10 Lh^{-1} (3) 20 Lh^{-1} (4) 40 Lh^{-1}

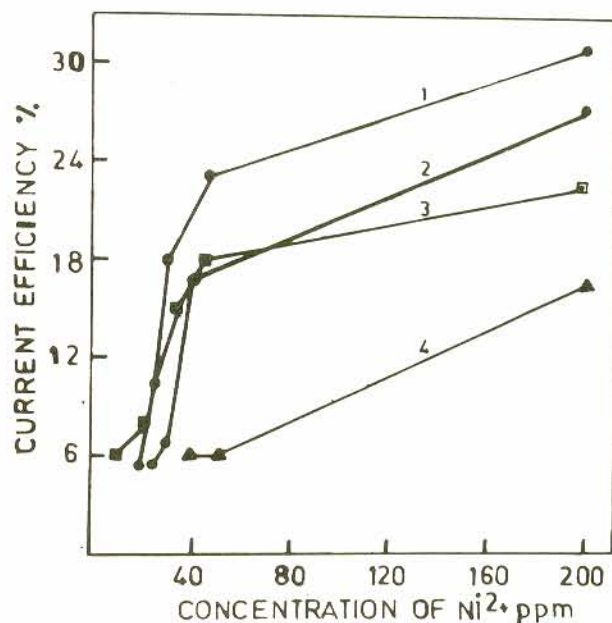


Fig. 4: Variation of current efficiency with Ni^{2+} in $0.01\text{N H}_2\text{SO}_4$ (1) 5 Lh^{-1} (2) 10 Lh^{-1} (3) 20 Lh^{-1} (4) 40 Lh^{-1}

is possible to reduce the concentration of Ni^{2+} to approximately 3 ppm from an initial concentration of 200 ppm in 6 h. of electrolysis at a packed bed electrode at an overall current efficiency of approximately 10%. It is now observed that complete removal of Ni^{2+} to very low level is possible by electrodeposition technique.

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TABLE-I: Electrochemical removal of Ni^{2+} with double packed bed electrolyser

Sl. No.	Flow rate ($l.h^{-1}$)	Average current at 30V (Amp)	Concentration (ppm)		Overall current efficiency (%)	Overall conversion efficiency (%)	Mass transfer coefficient ($K \times 10^4 \text{ cm.s}^{-1}$)
			Initial	Final			
<i>with 0.1N H₂SO₄</i>							
1.	5	1.30	200	22.5	12.6	88.8	2.1347
2.	10	1.60	200	8.3	9.3	95.9	2.3697
3.	20	1.80	200	3.3	9.8	98.4	4.4651
4.	40	2.50	200	19.2	6.0	90.4	1.1662
<i>with 0.01N H₂SO₄</i>							
1.	5	0.70	200	20.5	15.6	89.8	1.5862
2.	10	1.02	200	17.5	12.2	91.3	1.8048
3.	20	1.23	200	7.3	13.8	96.4	2.6738
4.	40	1.57	200	22.0	9.0	89.0	1.3686

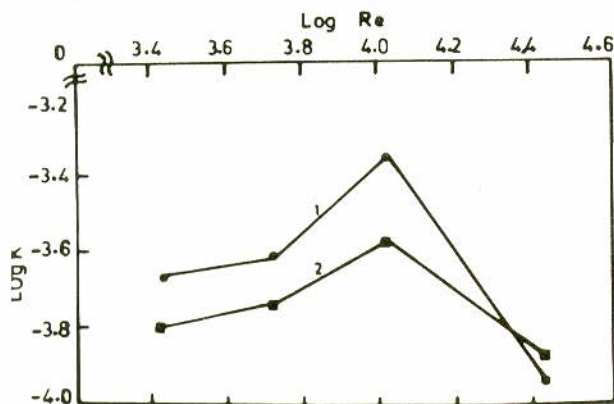


Fig. 5: $\log Re$ vs $\log K$ plot
 (1) $0.1N H_2SO_4$ (2) $0.01N H_2SO_4$

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