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Research Article

LAB SCALE STUDY OF ELECTRO-COAGULATION PROCESS FOR ZINC & IRON REMOVAL FROM METAL PLATING INDUSTRIAL WASTE-WATER

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ABSTRACT

Generation and discharge of industrial waste water is becoming a serious problem for our environment and water bodies. So, there is a need of some efficient waste water treatment technique. In this study waste water from a metal plating industry was collected and treated by electro-coagulation process. A lab scale model of electro-coagulation was set up using iron and aluminium electrodes. Samples were treated and analyzed at varying pH of 3, 5 and 7 at different values of current (i.e. 1 A, 1.5 A, 2 A and 2.5 A) using different combinations of iron and aluminium electrodes for a contact time of 10, 20 and 30 minutes. The optimum conditions of treatment were determined. It was observed from the experiments that Al-Al electrode pair was able to achieve 99.78 % zinc removal and 99.89 % iron removal at 1.5 A current and at optimum pH of 7 during 20 min contact time with electrical energy consumption of 12 kWh/m^3.

INTRODUCTION

India generates nearly 6.2 million m^3 of industrial waste-water and 38.354 million m^3 of domestic waste-water every day. The quantity of waste-water is increasing day by day due to rapid expansion of cities and domestic water supply. As per CPHEEO estimates about 70-80% of total water supplied for domestic use gets generated as waste-water. Electroplating operations from part of large scale manufacturing plants (e.g. automobiles, cycle, engineering and numerous other industries) or performed as job-work by small and micro units (Asselin, *et al*., 2008; Asselin, *et al*., 2008; Bensadok, *et al*., 2008). They are mainly in small scale sectors with over 3,00,000 small scale units in India. Electro-coagulation is attaining a great attention on treatment of industrial waste-water because of its versatility and environmental compatibility. The several advantages of this technique as compared to conventional methods (such as membrane filtration, ion exchange, reverse osmosis, dual media filtration, chemical precipitation, adsorption, dissolved air flotation, clariflocculator, flash mixer, secondary clarifier, sand filtration, activated carbon filter, sludge drying beds and tank stabilization) are ease in operation, less treatment time, reduction of chemicals, simple equipment and removes suspended and colloidal solids, breaks oil emulsions in water, removes fats, oil and grease, removes complex organics, destroys and removes bacteria, viruses and cyst.

Electro-coagulation (EC) is a process of destabilizing suspended, emulsified or dissolved contaminants in an aqueous medium by introducing an electrical current via parallel plates constructed of various metals that are selected to optimize the removal process. The two most common plate materials are iron and aluminium (Canizares, *et al*., 2008; Kabdash, *et al*., 2009; Kalyani, *et al*., 2009). The electrical current provides the electromotive force to drive the chemical reactions. When reactions are driven the elements

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or compounds will approach the most stable state. Generally, this state of stability produces a solid that is either less colloidal and less emulsified (or soluble) than the compound at equilibrium values. Electro-coagulation (EC) is an emerging technology that combines the functions and advantages of conventional coagulation, flotation, and electrochemistry in waste-water treatment. Electro-coagulation (EC), the passing of electric current through water, has proven very effective in the removal of contaminants from water.

There are different factors affecting electro-coagulation such as current density/charge loading, pH, treatment time, material of electrodes, temperature and power supply (Katal and Pahlavanzadeh, 2011; Kobya and Delipinar, 2008; Kobya, *et al*., 2003).

Site Selection

Waste-water sample used in this study was obtained from metal plating industry located in Sector-E, Sanwer road, Indore (M.P.). This industry produces approximately 5 kL of waste-water per day.

MATERIAL AND METHODS

Electrolysis was conducted in a batch setup to investigate the effect of pH, current density and treatment time on removal of heavy metals such as Iron and Zinc.

Experimental Set-Up

Experiments were carried out in batch mode in 3 litres capacity plastic jar for monopolar arrangement of EC technique. (Fig. 1) represents lab scale electro-coagulation set-up. Iron and Aluminium electrodes of dimensions 120 mm × 10 mm × 3 mm were used in this study. The distance between anode and cathode was kept as 1 cm. the electrical circuit consisted of DC power supply (12 V, 20 V) with a rheostat of multi-range ammeter, all connected in series. A voltmeter was connected in parallel with the cell to measure its voltage (Kobya, *et al*., 2010; Kobya, *et al*., 2006; Maghanga, *et al*., 2009).

Series of experiments were carried out with varying pH (i.e. 3, 5, 7), different values of current (i.e. 1 A, 1.5 A, 2 A, 2.5 A) using different combinations of Fe and Al electrodes at periodical time interval of 10 min, 20 min and 30 min respectively.

METHODOLOGY ADOPTED

The waste-water sample used in this study was collected in a closed container from the metal plating industry. Characteristics of the influent raw waste-water were determined experimentally in the laboratory and are tabulated in Table 1. pH of the sample was adjusted to 3, 5 and 7 respectively by adding 1N NaOH or 1N H_2SO_4. Then the sample was allowed to settle for 2 hrs. Two litres of this sample was taken in the reactor and electrodes were placed and the setup was completed. After passing the desired amount of current (i.e. 1 A, 1.5 A, 2 A and 2.5 A) for stipulated time, the solution was slowly stirred with a glass rod and was allowed to settle for 30 minutes. A small portion (approximately 100 ml) of the supernatent was withdrawn from it which was then filtered to remove flocs. Concentration of heavy metals (such as iron and zinc) in the filterate was then determined by Atomic Absorption Spectrophotometer.

The process was repeated for different pH,

S. No.	Characteristics	Unit	Value
1.	pH	--	1
2.	Iron	mg/l	25
3.	Zinc	mg/l	10
4.	Conductivity	μS/cm	39374
5.	TDS	mg/l	44300
6.	Colour	--	Greenish
7.	C.O.D.	mg/l	440

Table 1: Characteristics of Metal plating wastewater

Fig. 1 Lab scale electro-coagulation set-up.

current densities with respect to varying electrode combinations. Electrodes were washed with dil. H_2SO_4 and were weighed after each run.

RESULTS AND DISCUSSION

Effect of various operational parameters like material of electrode, pH, current density and operation time on removal efficiency of heavy metals such as iron (Fe) and Zinc (Zn) was investigated (Mollah, *et al.*, 2001; Sengil and Ozacar, 2006).

Effect of pH

The effects of pH of waste-water on electro-coagulation are reflected by the current efficiency as well as the solubility of metal hydroxide. Experiments were conducted to study the effect of initial pH variation on Iron removal efficiency, keeping other parameters constant and results have been depicted in (Fig. 2). Effect of initial pH was investigated using pH values 3, 5 and 7 at different current densities of 2.77 mA/cm^2, 4.16 mA/cm^2, 5.55 mA/cm^2, 6.94 mA/cm^2 and for periodic time interval of 10 min, 20 min and 30 min respectively.

From (Fig. 2) it was concluded that highest removal of iron was obtained at pH 7 at different current values. The initial concentration of Fe was 10.5 mg/L which reduced to 0.42 mg/L. with removal efficiency of 95.84% and minimum removal efficiency occured at pH 3. A considerable increase in the removal efficiency of iron was found till 20 min operating time and then it scarcely increased. The reason for this was that excess of hydroxyl ions were produced at cathode in acidic conditions which lead to continuous increase of removal efficiency (Sisodia, 2015; Solak, *et al.*, 2009; Soloman, *et al.*, 2009).

Effect of Current Densities

Current density is directly proportional to the rate of EC reactions taking place on the electrode surface and has an influence on the electrode potential, which defines the reactions taking place on electrode surface. Effect of different current densities of 2.77 mA/cm^2, 4.16 mA/cm^2, 5.55 mA/cm^2, 6.94 mA/cm^2 were studied at an optimum pH of 7 at periodic time interval of 10 min, 20 min and 30 min and have been displayed in (Fig. 3).

It was revealed from (Fig. 3) that the removal efficiency of Fe increased with the increase of current density range of 2.77 mA/cm^2, 4.16 mA/cm^2 till 20 min operating time. Further increase of current density resulted only in a small increase of the Fe removal efficiency. Since, increasing of current density increases energy and electrode consumption, therefore a current density of 4.16 mA/cm^2 was determined as the optimum current density.

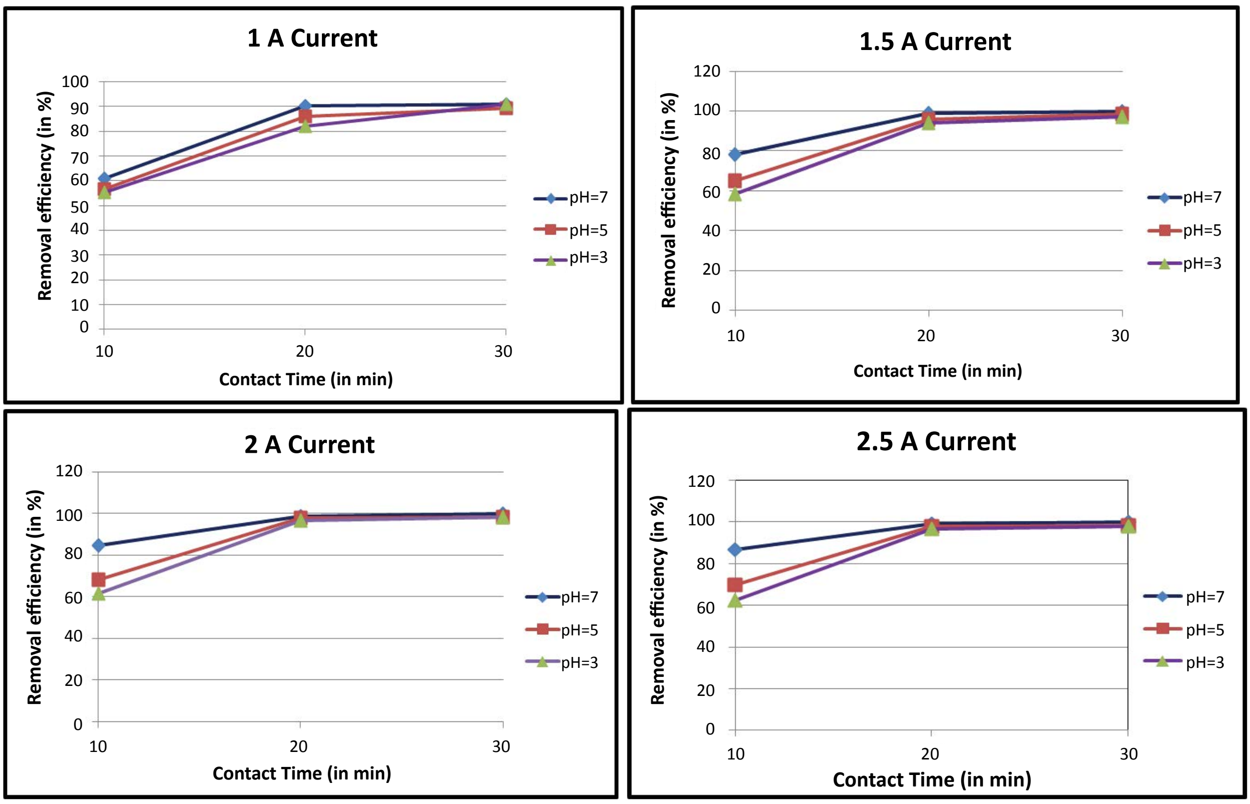

Fig. 2 Iron removal efficiency v/s time at different pH and different current values.

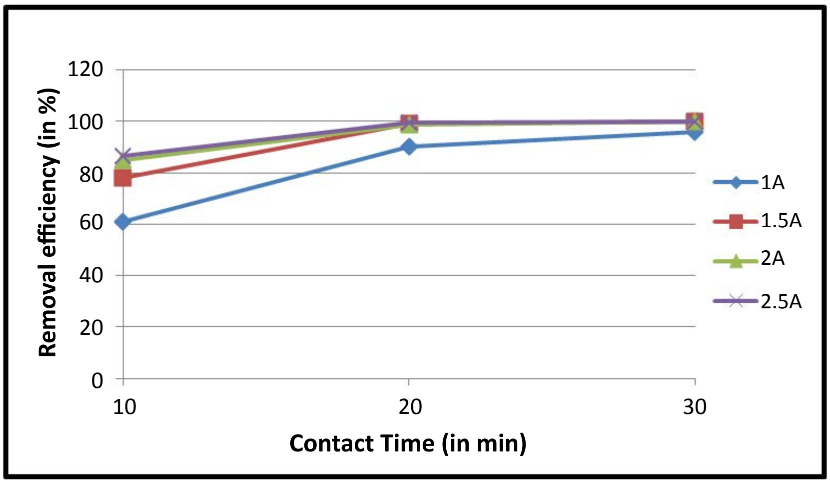

Fig. 3 Effect of current density on Iron removal efficiency at optimum pH=7.

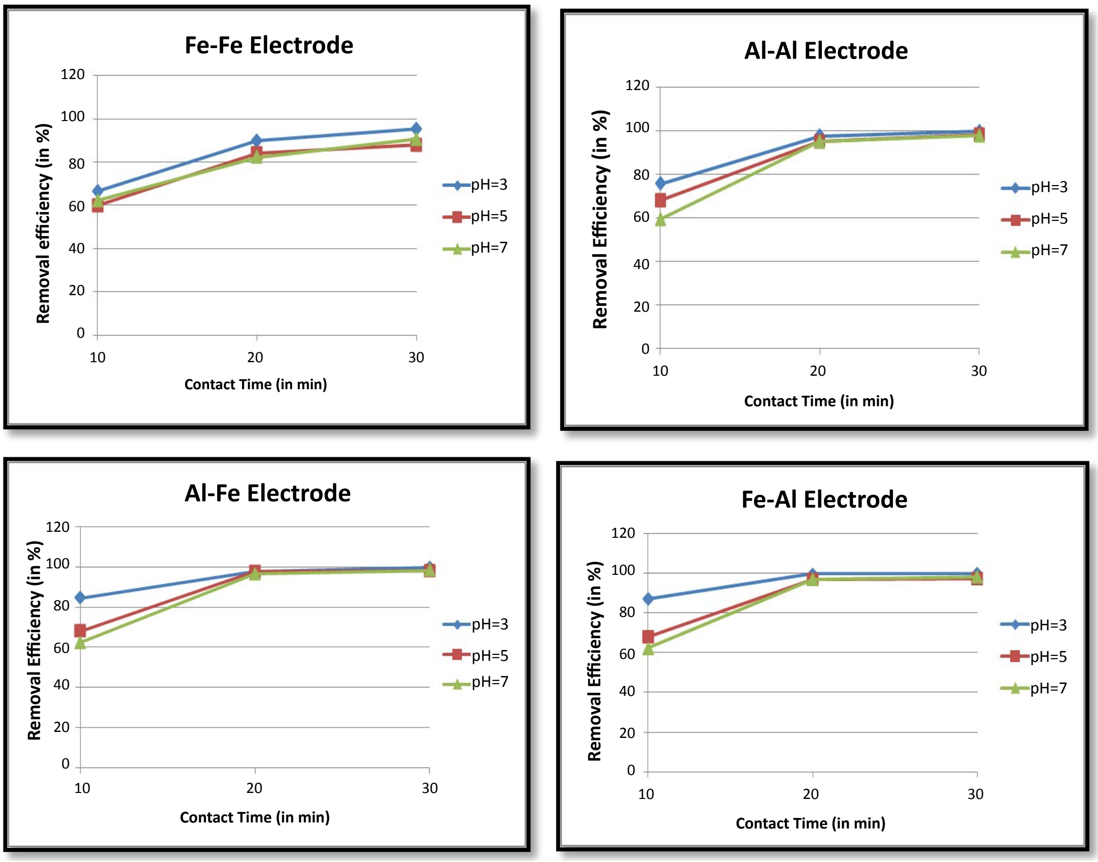

Fig. 4 Graph between zinc removal efficiency v/s operating times using different electrode combination.

Effect of Material of Electrode

The effect of electrode material was investigated using four different combinations of electrode i.e. Fe-Fe, Al-Al, Al-Fe, Fe-Al. The effect of electrode material on Zinc removal was explored at pH 3, 5, 7 at current 1 A, 1.5 A, 2 A and 2.5 A using different combinations of iron and aluminum electrode at time 10 min, 20 min and 30 min (Fig. 4).

The results of the experiment indicated that when Fe-Fe electrode pair of combination was used 95.55% removal of Zn was achieved after 30 min at optimum pH 7 and when Al-Al electrode pair was used highest removal efficiency was achieved i.e. 99.78% at pH 7 after 30 min. At pH 5.0, maximum removal efficiency was 88.00% for Fe-Fe electrode and 98.24% for Al-Al electrode. At pH 3.0, maximum removal efficiency for Zn was 90.71% for Fe-Fe electrode and 97.68% for Al-Al electrode combination. At pH 7.0, maximum removal efficiency for Zn was

97.78% for Al-Fe electrode and 99.73% for Fe-Al electrode combination. At pH 5.0, maximum removal efficiency was 98.08% for Al-Fe electrode and 97.12% for Fe-Al electrode combination. At pH 3.0, maximum removal efficiency achieved for Zn was 98.37% for Al-Fe electrode and 98.14% for Fe-Al electrode combination (Tezcan, *et al.*, 2009; Tir and Moulai-Mostefa, 2008; Zaied and Bellakhal, 2009).

DISCUSSION

In this work, heavy metal removal by Electro-coagulation (EC) was evaluated and the effect of different operating conditions on heavy metal removal efficiency of iron and zinc during ECP was investigated in order to determine the optimum operating conditions. The process here presented is capable of attaining high removal efficiencies for both aluminium and iron electrodes. The experimental results proved that the removal of heavy metal ions by the developed electro-coagulation reactor could be successfully achieved. The results showed that electro-coagulation could effectively reduce metal ions to a very low level (0.011 mg/L) which is much less than the permissible limit (3 mg/l) specified by environmental protection rules 1986 (Zodi, *et al.*, 2011; Zodi, *et al.*, 2009; Zodi, *et al.*, 2010).

Using iron electrodes, the removal rate of heavy metals increased as the current density increased and the total initial heavy metal amount (either single or multiple heavy metals) decreased, suggesting that the efficiency is closely related to the flocs amount. Aluminium was selected as the electrode material because it requires less oxidation potential. Aluminium electrode does not impart any colour to waste-water.

CONCLUSION

Electro-coagulation is one of the best techniques for removal of heavy metals from industrial waste-water. Following conclusions were drawn from the work conducted under this study-

a. The results obtained for investigating the effect of varying operation conditions in order to elucidate their effects on process performance revealed that removal efficiencies were significantly affected by the initial pH, electrode material, current density and treatment time.

b. Maximum removal of Zinc and Iron was obtained at pH 7. The removal of Zn and Fe was increased with the time within 30 minutes. After that, removal efficiencies scarcely increased.

c. The removal efficiency of Zn & Fe increased with the increase of current density in the range of 2.77 to 4.66 mA/cm^2. Further increase of the current density results only in a small increase of the Zn & Fe removal efficiency. Since, increasing current density increases energy and electrode consumption, therefore a current density of 4.66 mA/cm^2 was determined as the optimum current density.

d. Optimum operation conditions is by electro-coagulation of the electroplating waste-water with an Al-Al electrode pair was able to achieve 99.78% Zn removal and 99.89% Fe removal at 1.5 A current and at pH 7 after an electro-coagulation time of 20 min with electrical energy consumption of 12 KWh/m^3.

REFERENCES

Asselin, M., Drogui, P., Benmoussa, H. and Blais, J. (2008). Effectiveness of electro-coagulation process in removing organic compounds from slaughterhouse wastewater using monopolar and bipolar electrolytic cells. Chemosphere. 72 : 1727-1733.

Asselin, M., Drogui, P., Brar, S.K., Benmoussa, H. and Blais, J. (2008). Organics removal in oily bilgewater by electro-coagulation process. Journal of Hazardous Materials. 151 : 446-455.

Bensadok, K., Benammar, S., Lapicque, F. and Nezzal, G. (2008). Electro-coagulation of cutting oil emulsions using aluminium plate electrodes. Journal of Hazardous Materials. 152 : 423-430.

Canizares, P., Martínez, F., Jiménez, C., Saez, C. and Rodrigo, M.A. (2008). Coagulation and electrocoagulation of oil-in- water emulsions. Journal of Hazardous Materials. 151 : 44-51.

Kabdash, I., Arslan, T., Olmez-Hancı, T., Alaton, I.A. and Tunay, O. (2009). Complexing agent and heavy metal removals from metal plating effluent by electro-coagulation with stainless steel electrodes. Journal of Hazardous Materials. 165 : 838-845.

Kalyani, K.S.P., Balasubramanian, N. and Srinivasakannan, C. (2009). Decolourization and COD reduction of paper industry effluent using electro-coagulation. Chem. Eng. Journal. 151 : 97-104.

Katal, R. and Pahlavanzadeh, H. (2011). Influence of different combinations of aluminium and iron electrode on electrocoagulation efficiency: Application of the treatment of paper mill wastewater. Desalination. 265 : 199-205.

Kobya, M. and Delipinar, S. (2008). Treatment of the

Baker's yeast wastewater by electro-coagulation. Journal of Hazardous Materials. 154 : 1133-1140.

Kobya, M., Can, O.T. and Bayramoglu, M. (2003). Treatment of textile wastewaters by electro-coagulation using iron and aluminium electrodes. Journal of Hazardous Materials. 100 : 163-178.

Kobya, M., Demirbas, E., Parlak, N.U. and Yigit, S. (2010). Treatment of cadmium and nickel electroplating rinse water by electrocoagulation. Journal of Environ. Technol. 31 : 1471-1481.

Kobya, M., Hiz, H., Senturk, E., Aydiner, C. and Demirbas, E. (2006). Treatment of potato chips manufacturing wastewater by electro-coagulation. Desalination. 190 : 201-211.

Maghanga, J.K., Segor, F.K., Etiegni, L. and Lusweti, J. (2009). Electro-coagulation method for colour removal in tea effluent: A case study of chemomi tea factory in Rift Valley, Kenya Bulletin of the Chemical Society of Ethiopia. 23 : 371-381.

Mollah, M.Y.A., Schennach, R., Parga, J.R. and Cocke, D.L. (2001). Electro-coagulation (EC)-Science and applications. Journal of Hazardous Materials. 84 : 29-41.

Sengil, I.A. and Ozacar, M. (2006). Treatment of dairy wastewaters by electrocoagulation using mild steel electrodes. Journal of Hazardous Materials. 137 : 1197-1205.

Sisodia, T. (2015). Lab scale study of electrocoagulation process for copper removal from electroplating industrial wastewater.

Solak, M., Kılıç. M., Huseyin. Y. and Sencan. A. (2009). Removal of suspended solids and turbidity from marble processing wastewaters by electrocoagulation: Comparison of electrode materials and electrode connection systems. Journal of Hazardous Materials. 172 : 345-335.

Soloman, P.A., Ahmed, C.B., Velan, M., Balasubramanian, N. and Marimuthu, P. (2009). Augmentation of biodegradability of pulp and paper industry wastewater by electro-chemical pretreatment and optimization by RSM. Sep. Purification technology. 9 : 109-117.

Tezcan, U., Koparal, A.S. and Ogutveren, U.B. (2009). Electrocoagulation of vegetable oil refinery wastewater using aluminium electrodes. Journal of Environmental Management. 90 : 428-433.

Tir, M. and Moulai-Mostefa, N. (2008). Optimization of oil removal from oily wastewater by electrocoagulation using response surface method. Journal of Hazardous Materials. 158 : 107-115.

Zaied, M. and Bellakhal, N. (2009) Electro-coagulation treatment of black liquor from paper industry. Journal of Hazardous material. 163 : 995-1000.

Zodi, S., Louvet, J., Michon, C., Potier, O., Pons, M., Lapicque, F. and Leclerc, J. (2011). Electro-coagulation as a tertiary treatment for paper mill wastewater: Removal of non-biodegradable organic pollution and arsenic. Journal of Separation and Purification Technology. 81 : 62-68.

Zodi, S., Potier, O., Lapicque, F. and Leclerc, J. (2009). Treatment of the textile wastewaters by electrocoagulation: Effect of operating parameters on the sludge settling characteristics. Journal of Separation and Purification Technology. 69 : 29-36.

Zodi, S., Potier, O., Lapicque, F. and Leclerc, J. (2010). Treatment of the industrial wastewaters by electrocoagulation: Optimization of coupled electrochemical and sedimentation processes. Desalination. 261 : 186-190.