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Zinc Removal from Industrial Wastewater by Electro-Coagulation Process

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Abstract

Electro coagulation treatment was used for zinc removal from electroplating wastewater of the State Company for Electrical Industries. This wastewater, here consists zinc ions with maximum concentration in solution of 90 ppm.

The parameters that influenced the wastewater treatment are: current density in the range 1–1.4 mA/cm^2, pH in the range 5-10, temperature in the range 25–45°C and time in the range 10–180 minute.

The research is a laboratory experimental type using batch system for electrical process with direct current. The cell comprised of aluminum electrode as anode and stainless steel electrode as cathode. Thirty experiments and one hundred fifty sample lab tests were carried out in this research to study the effect of the mentioned parameters on the efficiency of the removal process.

Experimental work of this research proved a higher efficiency about 95 % removal of zinc from wastewater at 1.4 mA/cm^2, in alkaline media at pH equal 10 and temperature 45°C.

Keywords: zinc, electro coagulation, wastewater.

Introduction

Increasing population, growing industry and rapidly developing technology since, the industrial revolution have sorely nature's capacity for maintaining clean water.

The increased water use and waste water discharge particularly industrial wastewater have added impurities to water which overload natural cleaning processes.

Industrial wastewater composition altered considerably with the type of industrial process, it may contain contaminants which degrade water quality and pose a threat to human health [1].

Metals, particularly heavy metals such as mercury, cadmium, cyanide and hexavalent chrome in their ionic forms belong to the category of insidious pollutants that can be toxic to human, animals, and plants due to their persistence harmful effects at low concentrations and ability to concentrated to dangerous levels by microorganisms, fish, and plants in the human food chain. They may also be accumulated in stream sediments, only to be released when such deposits are disturbed during periods of high flow [2].

Zinc is very rarely presented in natural water, but not so rare in water when it is drawn at consumers' taps because of the use of galvanized iron piping and tanks.

Zinc should not exist in water consumed in quantities in excess of 15ppm. Some waters will readily take up zinc, especially in cooking process and zinc containers for food should not be used. Another danger is the collection of drinking water from galvanized iron roofs for isolated supplies. Hard chalk waters attack the zinc of galvanized piping, forming loose deposits of zinc carbonate [3].

There are many problem associated with the presence of the trace metal in drinking water. Metal ions such as Cd^2, pb^{+2} and Hg^{+2} are serious health hazards, while Zn^{+2}, Cu^{+2} are associated with taste and staining problems. Due to pollution or natural cause, water sources exceed metal levees standards set by Environmental Protection Agencies [4].

Wastewater can be treated effectively by precipitation, membrane, leaching, coagulation / flocculation, ion exchange, electrochemical operation, cementation, evaporation and adsorption processes.

One of more common methods of treating polluted water has been to dose it with chemical coagulation agent such as aluminum sulfate and ferric chloride. The metal ions agglomerate the pollutants, causing them either to sink to the bottom or become sufficiently larger than they can be filtered out, or floated out using dissolved air floatation.

One of the difficulties associated with this progress is that the ionic contents of the water are increased by the addition of these salts. Although the metal ions are removed during the process, the salt content of the water has been greatly increased, often preventing the ability to use water in recycling or other application. One method of overcoming, it has been to use a process known as electro coagulation in which the metal ions are added electrolytically.

In electro coagulation, sacrificial electrodes are used and the passage of an electric current through the water from electrodes causes the metal to go into solutions as ions via the anode reaction.

A current is passed through a metal electrode, oxidizing the metal (M) to its cation (M^{n+}) at the anode.

$$M \rightarrow M^{n+} + ne^- \quad (1)$$

Simultaneously, water is reduced to hydrogen gas and the hydroxyl ion (OH^-) at the cathode.

$$2H_2O + 2e^- \rightarrow 2OH^- + H_2 \quad (2)$$

Electro coagulation thus introduces metal cations in situ, electrochemically, using sacrificial anodes, (usually aluminum or iron) inside a processing tank [5].

The cation hydrolyzes in water forming a hydroxyl with the dominate species determined by solution pH.

The metal ions combine with OH^- ions from the water to from highly charged coagulation which adsorb pollutants form insoluble floc particles; so that AL(III) reacts with H_2O to form $Al(OH)_3$.

Electro coagulation has proven its viability by removing a wide range of pollutants. The approach to reactor design has been haphazard, however, with little or no reference to previous designs or underlying principles [6].

Experimental Work

The standard solution of the maximum concentration of zinc ion 90 mg/l was prepared by dissolving ($ZnSO_4.7H_2O$) in distilled water. The needed amount of $ZnSO_4.7H_2O$ was calculated as follow:

$$W_{ZnSO_4\cdot 7H_2O} = V_{Solution} C_{Zn^{2+}} \frac{Mwt_{ZnSO_4\cdot 7H_2O}}{At.wt_{Zn^{2+}}}$$

$$= 1.5l \times 0.09\frac{g}{l} \times \frac{287.54}{65.37} = 0.6g$$

The experiments were conducted by introducing 1.5 liter of zinc solution into electrochemical reactor. The cell comprised of two parallel plates, aluminum electrode as anode and stainless steel electrode as cathode with 67 cm^2 used area. The electrical circuit was switched on as soon as the electrodes were covered by the electrolyte and desired current was achieved by the altering the resistance of the electrical circuit. The schematic diagram of the system is shown in figure 1.

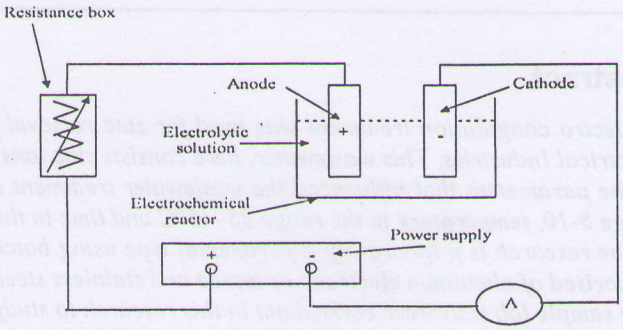

Fig. 1 Shematic diagram of the experimental apparatus

By the passage of the electrical current through the cell, the anodic dissolution occurred Hydrogen gas was produced at the cathode along with localized pocket of the hydroxide ions and the cell will produce aluminum cation (Al^{+3}) on the anode surface followed by their transfer to the bulk of the electrolytic solution, these cation will combine with OH^- ions from the water to form highly charged coagulants which adsorb pollutants to form insoluble floc particles, these particles will be rised to the surface of solution by bubbles gas which formed in electrolytic solution.

During each run, samples of the solution were taken at different time, then this solution will be filtrated to remove floc particles from it, so the filtrated solution taken to be analyzed by titration method to measuring the remaining concentration of zinc in it. The block diagram which represents this procedure is shown in figure 2.

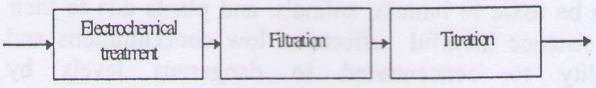

Fig. 2 Electrochemical block diagram

At the end of each run, the power supply was switched off and the system was washed several times with water and once with H_2SO_4 to remove any solids tend to cling at the inside walls of the cell.

Titration method was used to measure zinc concentration in the sample after the treatment process was finished. The main chemicals that used in the titration method are buffer solution with pH=10, Erio Chrome black T indicator, 0.1 M Ethylene di-amine tetra acetic acid solution [7].

Results and Discussion

The effectiveness of electrolytic cell in water treatment comes out through the results of experimental study under five time values namely 10, 30, 60, 120, 180 minutes, different pH values 5, 7, 10, current density values 1, 1.2, 1.4 mA/cm^2 and temperatures 25, 35, 45 ° C. It is decided to use the final zinc ions concentration as parameter of range of treatment when comparison is made after and before treatment.

The variation of zinc concentration with time at different pH, and constant current density and temperature are shown in Table (1), from this table we can observed that, at high value of pH (e.g. pH = 10) the amount of zinc removal will increase then the concentration of zinc in the treated solution will decrease, but at pH equal to 5 the amount of zinc removed larger than that removed at pH equal to 7 because of the solubility of aluminum hydroxide at that pH is larger than the others, this results was nearly similar to that shown on Powell water system [9].

Table 1, the variation of the zinc concentration with time at different pH, 45° C and i=1.4 m A/cm^2

time	pH=5	pH=7	pH=10
	conc.	conc.	conc.
0	90	90	90
10	72.727	30.3	22.5
30	57.272	25.6	16.36
60	40.909	19.8	11.2
120	22.5	18	9
180	6.6362	9	4.091

Also from Table 1 we can found that by using this process the zinc concentration will reduced from initial value 90 mg/l to 4.091 mg/l so that the efficiency of zinc removal can be reach 95.45% at the best operating conditions of pH =10, temperature =45° C, current density =1.4mA/cm^2 and 180 minutes.

Figures 3–5 show the effect of changing time of reaction on the concentration of zinc in the treated solution, when changing current density and temperature of the solution, at constant pH value at 10, due to aluminum dosage through the process. According to these figures, the remaining zinc concentration is decrease by increasing the time of process. It was observed that, almost, the same behavior can be achieved when changing current density, temperature and pH. This effect is occurs due to adsorbing aluminum hydroxide which formed in electrolytic solution to the contaminants in wastewater and also due to effect of current density on time.

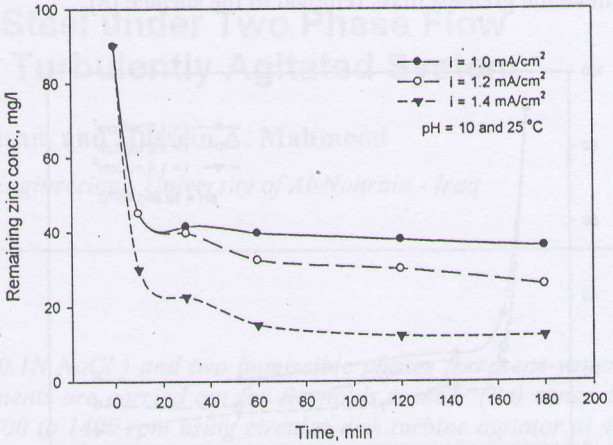

Fig. 3 The relation between time of treatment and remaining zinc concentration for different current density values at constant pH 10, constant temperature 25 °C

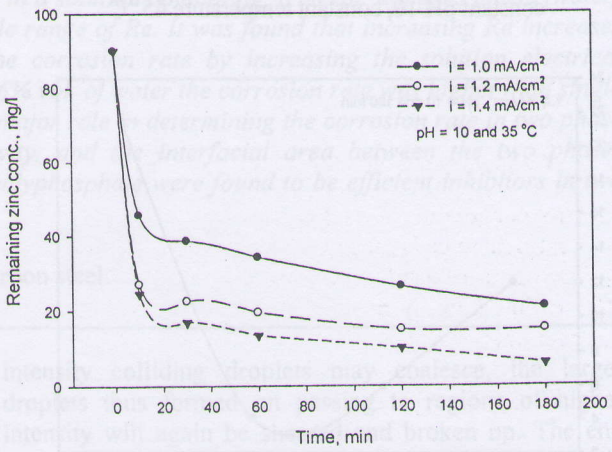

Fig. 4 The relation between time of treatment and remaining zinc concentration for different current density values at constant pH 10, constant temperature 35 °C

According to figures 3-5, the remaining zinc concentration is decreasing by increasing current density of process; therefore, the removal efficiency will be increase.

Because at lowest current density only small percent of the total mass input to the system had been transported to the surface by flotation after long time, settling of the aggregated pollutant was clearly the dominated removal mechanism at this low current density where fewer bubbles were produced

at the cathode resulting in a decrease in solution mixing and material uplift.

Conversely, at the highest current density larger percent of the total mass had transported to the surface after short time. Flotation was clearly favored here by the higher bubble density and coagulant dosage rate occurring at this current density. Operating at the highest current density (Which had the highest coagulant and hydrogen bubble generation rates) might be expected to achieve the greatest mass removal to the surface [8].

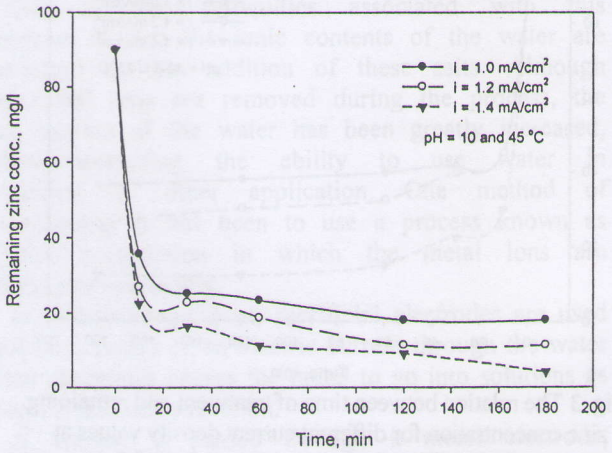

Fig. 5 The relation between time of treatment and remaining zinc concentration for different current density values at constant pH 10, constant temperature 45 °C

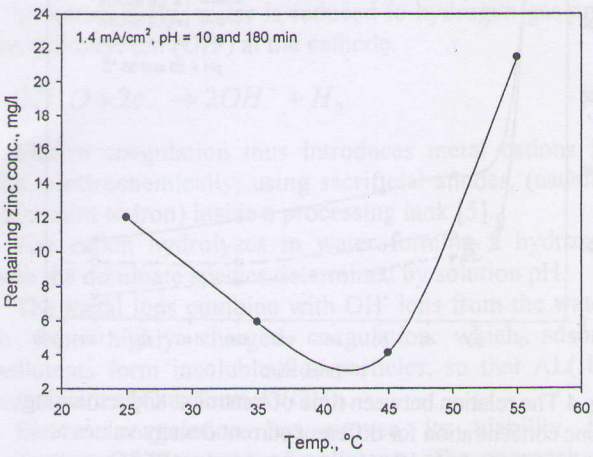

Fig. 6 The relation between temperature of solution and remaining zinc concentration at constant current density 1.4mA/cm^2, at constant pH 10, constant time 180 minutes.

It can be observed from figure 6, that the increasing of temperature up to 45 ° C will decrease the remaining zinc concentration in the treated solution, then the removal efficiency will be increase, this was obtained because when increasing the temperature the solution mixing will be increased then the probability of aluminum hydroxide to adsorp zinc ions will be increase, therefore the removal efficiency will be increased. But increasing the temperature more than 45° C is not effective because 21.428 mg/l zinc concentration in treated solution was remaining at temperature 55° C while it was 4.091 mg/l at 45° C at constant other operating conditions (pH = 10, current density = 1.4 mA/cm^2, time 180 minutes).

Conclusions

1. The electro coagulation followed by clarification and filtration is a very effective and successful technique for zinc removal (95.45 %).
2. Low current density as a direct current power will be required, leading to a small capital and operational cost.
3. It was shown that the best efficiency of electric current is at 1.4 mA/cm^2.
4. By testing different values pH of wastewater, the best pH is 10, which gives a higher effectiveness of electrocoagulation.
5. The study shows the best temperature used for zinc removal from wastewater was 45 °C.

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