

Studies on Removal of Chromium (VI) from Wastewater Using Electrocoagulation

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Abstract: Electrocoagulation is an efficient method where the flocculating agent is generated by electro-oxidation of a sacrificial anode, generally made of iron or aluminium. In this study Al Electrodes are used to remove Cr(VI) from model wastewater by Optimizing different parameters pH, Current Density, Initial Concentration and Time. From our present study, it was found that the removal of chromium (VI) using aluminium electrodes by Electrocoagulation is a feasible process. At elevated pH, the removal of chromium is higher due to simultaneous co-precipitation and chemical precipitation. This effect is observed till the pH is increased to 7 and the percentage removal starts decreasing beyond that point. And Maximum removal efficiency of 96.89% was achieved at an optimum current density of 58.60 mA/cm². The samples from this experiment were analyzed using the atomic Absorption Spectroscopy (AAS).

Keywords: Chromium removal, Electrocoagulation, initial pH, Current Density, Atomic Adsorption Spectroscopy

1. Introduction

Various techniques have been employed for the treatment of heavy metals, including precipitation, adsorption, ion exchange and reverse osmosis. Precipitation is most applicable among these techniques and considered to be the most economical. It is based on chemical coagulation by adding lime to raise the pH and aluminium salt to remove colloidal matter as gelatinous hydroxides[2]. Although, it is shown to be quite effective in treating industrial effluents, chemical coagulation induces secondary pollution caused by added chemical substances. This drawback, together with the need for low cost effective treatment, encouraged many studies on the use of Electrocoagulation for the treatment of several industrial effluents.

1.1 Math and Reactions

Current density is an important parameter in Electrocoagulation because it is the only parameter that can be controlled directly. It directly determines both coagulant dosage and bubble generation rates and also influences both solution mixing and mass transfer operations at the electrodes[1][4]. A simple relation between current passed and the amount of metal dissolved is given by faraday's law

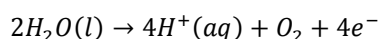
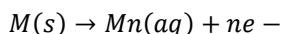
$$w = \frac{Itm}{zf}$$

Where 'w' is the quantity of electrode material dissolved, 'I' is the current in amperes, 't' is the time in seconds, 'z' is the number of electrons in reduction/oxidation reaction, m is the molecular weight of the electrodes metal and f is the faraday's constant.

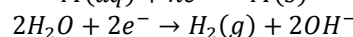
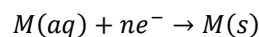
1.2 Formation of coagulants by electrolytic oxidation

In this process, a potential is applied to the metal (M) anodes, typically fabricated from either iron or aluminium, which causes two separate reactions depicted as follows:

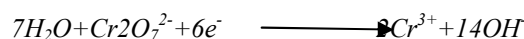
• At the anode:



• At the cathode:



Reduction of Cr(vi) to Cr(III)



Al is dissolved from the anode, as depicted by the above figure, generating corresponding metal ions, which almost immediately hydrolyze to polymeric aluminium hydroxides[5][6].

1.3 Material Development and components used

Potassium dichromate dissolved in de-ionized water was used as our source of chromium. 2.8284 g of the dichromate was dissolved in water and made up 1000 ml in a standard flask thus giving a chromium solution of 1000ppm concentration. From this bulk, quantitative measures were retrieved to obtain solutions of 250ppm concentrations. 0.1 N HCl was used to control the initial pH. This solution was prepared by mixing 10 ml of HCl with water and made up to 1000 ml. 0.1 N NaOH was prepared by dissolving 4 g of NaOH pellets in 1000ml water. NaCl was used as coagulant. Aprox 3 gm of NaCl was used for every run.

Table 1: Component Specification

Component	Specification
Electrodes	68.25 cm ² MOC Aluminium
Stirrer	1 MLH Magnetic stirrer
Flask	2000 ml borosil
DC supplier	0-30 V, 5 Amp

2. Experimental Procedure

The experiment was conducted in an Electrocoagulation cell of capacity 2000 ml fabricated out of borosilicate glass. Aluminium of 24 gauge (UK) thickness was used. Plates of dimension 105 mm lengths, 65mm breadth provided an effective electrode area of 68.25 cm². The electrode assembly was seated on the non-conducting wedges fixed to the bottom plate of the cell. In order to avoid short-circuiting, spacers were provided between anode and cathode plates. The gap

between anode and cathode was maintained at 2mm in order to minimize ohmic losses. Fresh electrodes were used for each run with the same electrode area. A 1MLH magnetic stirrer was used. The schematic diagram of the complete system and the electrode assembly is shown in Figure 1. Upon completion of the experiment, the test sample's concentration was diluted and analyzed in an Atomic Absorption Spectrophotometer [8].

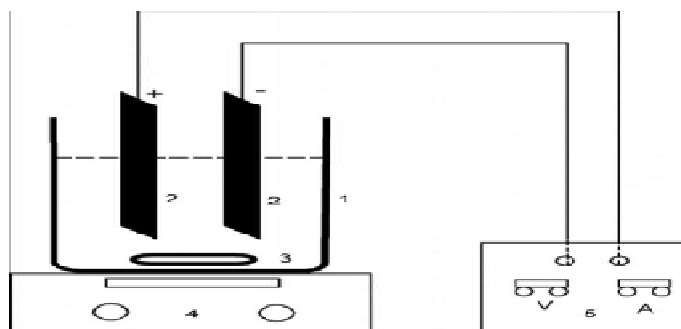


Figure 1(1): Borosil cell, (2)aluminium electrode, (3)magnetic pellet, (4)magnetic stirrer, (5) DC supplier

3. Result Analysis

3.1 Effect of initial pH

Experiments were conducted with initial pH of 3.95, 6, 7, 8 and 9 and Initial Concentration 250 ppm. The results were plotted in a graph and shown below Figure2. All experiments were conducted for a period of 100 mins and the final conversion varied between 50 to 75%. Current density was maintained at 29mA/cm² throughout the study.

The removal of chromium increase with increase in pH. This effect is observed till the pH is increased to 7 and the percentage removal starts decreasing beyond that point. The highest removal obtained was 71.19% at pH 7 and current density of 29.41 mA/cm². Solution pH determines the speciation of metal ions. The pH influences the state of other species in solution and the solubility of products formed. It has an effect on the conductivity of the solution, dissolution of the electrodes, speciation of hydroxides and zeta potential of colloidal particles. The solubility of gibbsite is maximum at pH 7. This leads to a higher removal [11].

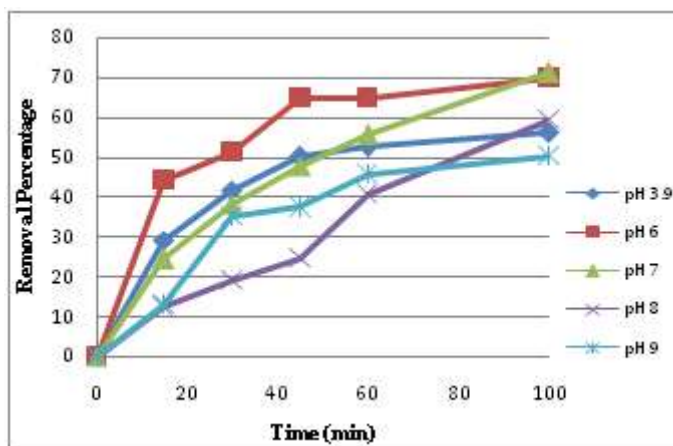


Figure 2: Effect of pH (Initial Concentration = 250 ppm; Current Density = 29 mA/cm²)

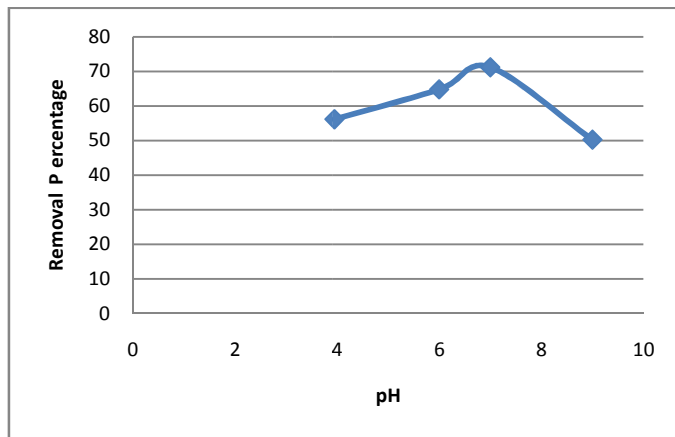


Figure 3: Removal Percentage vs Time to find Optimum pH (Current Density=29.41 mA/cm², Time=100mins; Initial Conc= 250 ppm)

3.2 Effect of Current Density

pH was fixed at the optimum value that we found out by the above method. The current density was varied from 7mA/cm² to 58 mA/cm².

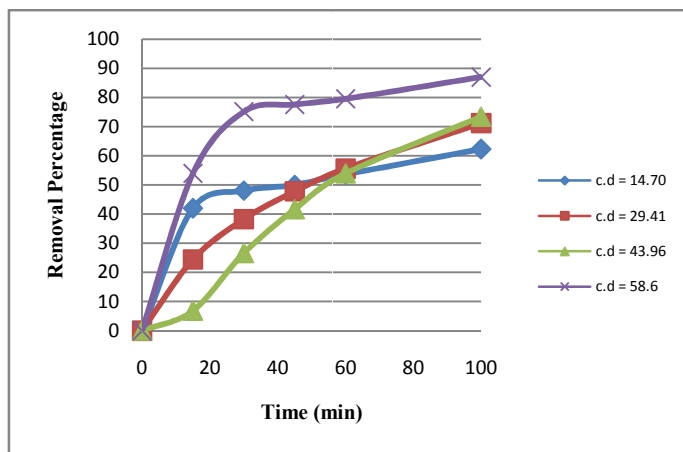


Figure 4: Effect of Current Density (pH=7; Time=100mins; Initial Concentration = 250 ppm; c.d = Current Density in mA/cm²)

The results have shown that as current density increases, reduction of chromium (VI) increases. The figure4 depicts the effect of current density on the percentage removal of chromium (VI) at various current densities after an operating time of 100 min. It was found that, with an increase in the current density, there has been a substantial increase in the chromium removal [3]. This is because increase in the amount of Al ions being generated in situ thereby resulting in rapid reduction of chromium (VI). [3]

3.3 Effect of Initial Concentration

Initial concentration was changed from 61 ppm to 237 ppm. The amount of chromium removed increased as the initial concentration increased for the same amount of coagulant formed due to electrocoagulation. It is evident from the figure 5, the percentage removal of Cr decreasing as initial concentration is increased.

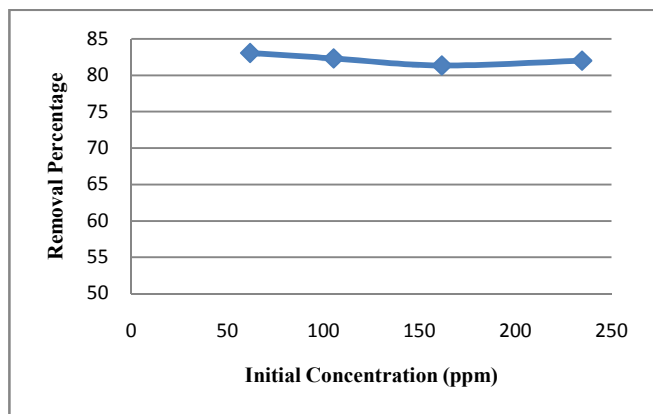


Figure 5: Effect of Initial Concentration (Current Density=58.60mA/cm², Time=100mins, pH=7)

3.4 Effect of time at Optimum Condition

Chromium removal increases along with time. However the rate of increase in chromium removal goes on decreasing as the time increases. 91% of chromium was removed in the first 100 mins. The removal percentage increased from 91% to 96% in the next 100 mins.[3][7][20]

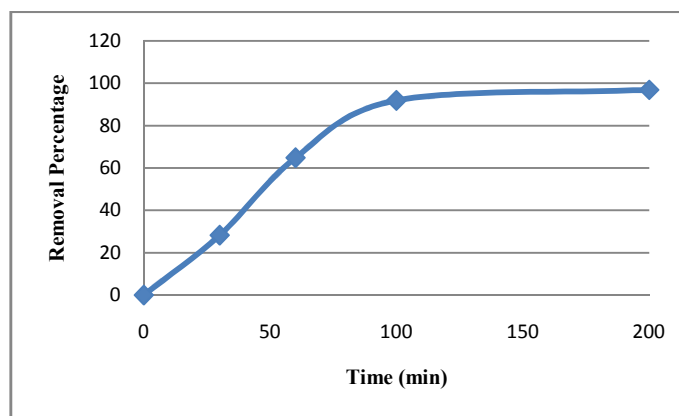


Figure 5: (Current Density=58.60mA/cm², Time=100mins, pH=7)

4. Conclusion

Chromium removal from synthetic wastewater was carried out using Electrocoagulation. Parameters like current density, pH, initial concentration and time were studied to get the optimum value. The results showed that the optimized removal efficiency of 96.89% was achieved at an optimum current density of 58.60 mA/cm² and a pH of 7.0 using aluminum electrodes. The aluminum hydroxide generated in the cell removes the chromium present in the water. At elevated pH, the removal of chromium is higher due to simultaneous co-precipitation and chemical precipitation. This effect is observed till the pH is increased to 7 and the percentage removal starts decreasing beyond that point. The treatment rate was found to increase upon increasing the current density from a range of 14.7-58.60mA/cm². Also, increasing the operating time from 20 to 100min further enhanced the removal of chromium (VI) and combined with optimum pH and current density, the percentage removal is highest.

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