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Removal of Hexavalent Chromium in Waste Water of Electroplating Industry using Aluminium silicon dioxide

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Abstract—**The present study aims to remove chromium (VI) from electroplating industry's wastewater using aluminium silicon dioxide (ASD) as an adsorbent. The preliminary investigation involved physicochemical analysis of the wastewater and structural characterization of the adsorbent using FTIR, SEM, EDS, XRD and BET analysis. Batch adsorption experiments were performed to study various parameters like adsorbent dosage, pH, contact time, temperature, and RPM while effect of varying bed height, diameter and flow rate were investigated in column studies to evaluate the adsorption capacity of ASD. The adsorption data obtained was validated to both Langmuir and Freundlich models. The best removal efficiency of 96.11% of Cr (VI) was observed at pH 4. Removal of Cr (VI) increased from 73.33% to 96.69% with increasing adsorbent dosage from 0.5 g/L to 10 g/L. The removal rate of Cr (VI) ions increased with increase in contact time and remained constant after an equilibrium time of 150 min. The results show that ASD is an alternative low cost adsorbent for removal of Cr (VI) ions in wastewater of electroplating industry.**

Keywords— Adsorption, Chromium (VI), Electroplating Waste Water, aluminium silicon dioxide.

I. INTRODUCTION

A large number of heavy metals are generated every year by industries that have contaminated water bodies. With the advent of green chemistry heavy metal pollution has received considerable attention. Heavy metals in wastewaters have a detrimental effect on human health and are also hazardous to the environment; therefore their removal before waste water discharge is apparent [1]. Chromium is one of most common toxic metals often found in effluents discharged from industries involved in paints, pigments, dyes, textiles, leather tanning, electroplating, metal finishing, nuclear power plants and chromate preparation [2]. Chromium exists in several oxidation numbers but only chromium (III) and chromium (VI) are stable enough to occur in the environment. The hexavalent form is found to be more toxic than the trivalent one [3]. The toxicity studies reveal that inhalation and retention of Cr (VI) containing material can cause damage to internal organs [4]. Further, skin contact of chromium (VI**)** compounds can also lead to skin diseases [5].

The toxicological impact of chromium (VI) initiates from its oxidizing ability as well as formation of free radicals during the reduction of Cr (VI) to Cr (III) occurring inside the cell [6]. Many physicochemical methods for heavy metal removal from aqueous solution have been developed. These methods include precipitation, adsorption, electrochemical deposition, reverse osmosis, ion exchange, coagulation and solid-phase extraction [7]. Adsorption using commercially available activated carbon has always been in the forefront for the removal of heavy metals from the effluent waste waters. However cost effective viable options have been attempted by various researchers [8-10]. Aluminium Silicon dioxide (ASD), a mesoporous adsorbent has a large surface area-to-volume ratio and uniformly shaped pores, with active sites enabling it to be used for ions detection and removal from aqueous media. The advantages of ASD included high permeability, rapid mass transfer, and simple preparation with variable chemistries. [11]. The study focuses on the efficiency of using ASD as an alternative adsorbent in removing chromium ions from a local electroplating wastewater considering parameters like effect of adsorbent dose, pH, contact time, initial metal ions concentration, temperature etc.

II. MATERIALS AND METHODS

A. Physicochemical analysis of electroplating wastewater

The effluent sample was collected from S.V. Metal Finishers Pvt. Ltd, Dhayari, Pune, Maharashtra, India. The sample was collected and subjected to chemical analysis which shows that the sample is yellow in color with a pH of 1.66, COD content 3260 ppm and chromium 194.33 ppm.

B. Characterization of Adsorbent

The adsorbent ASD was characterized by SEM analysis, XRD, EDS, FTIR and N_2-BET to understand its surface morphology, crystallography, chemical composition, functionality and surface area.

C. Preparation of Stock solution

A stock solution (1000 mg/L) of Cr (VI) was prepared by dissolving $K_2Cr_2O_7$ in distilled water. For adsorption experiments, Cr (VI) solutions (100 mg/L) were prepared from the stock solution by dilution.

D. Spectrophotometric analysis of Chromium (VI)

A 0.25% solution of diphenylcarbazide in 50% acetone was prepared initially. 1 ml of this complexing reagent was added to the standard solutions containing 20-80 mg/L of Cr (VI) and estimated on a UV-visible spectrophotometer (make-UV 1800-Shimadzu) at 540 mμ[12].

E. Adsorption Isotherm studies

For the adsorption isotherm studies, 100 ml of the wastewater containing adsorbent dose of 0.5-15 g/L was shaken in reagent bottles for 8 hours. The results obtained were validated to both Freundlich and Langmuir isotherm models.

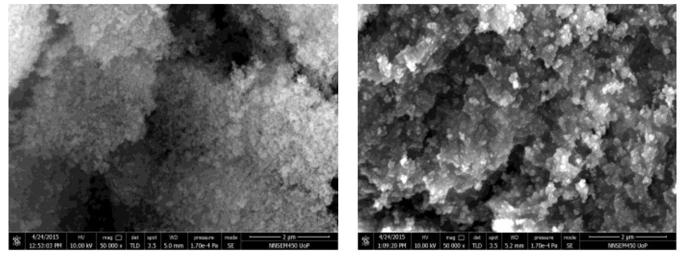
F. Methodology

Batch and Column experiments were carried out to study the effect of different parameters like effect of adsorbent dose, pH, contact time, rpm, initial metal ions concentration, column diameter, flow rate, varying bed height, etc.

III. RESULTS AND DISCUSSION

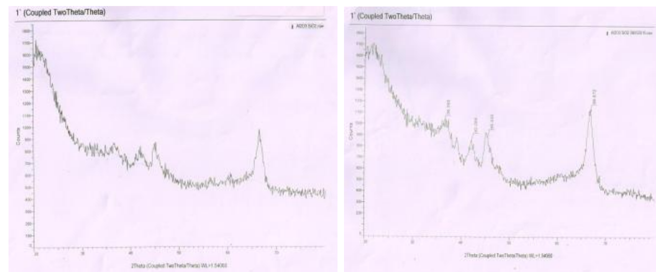
G. Characterization of the adsorbent

SEM images show the surface morphology of adsorbent ASD before and after adsorption. Before adsorption the surface texture appears to be dense and cloudy while after adsorption the appearance is in the form of agglomerates as shown in Fig 1 (a) and (b). The XRD in Fig 2 (a) and (b) shows significant spacing at a 2ɵ value of 36,°42°, 45° and 66° corresponding to Al, Si and Cr respectively. In the FTIR as shown in Fig 3, the peak at 2316 cm^{-1} is characteristic of the Si-C bond while peak at 1103 cm^{-1} may be due to stretching vibration of Si-O-Si bond. The N_2-BET analysis showed surface area of 219.023 m^2/g of ASD as shown in N_2-BET summary.



(a) before adsorption (b) after adsorption

Fig. 1 SEM image of ASD



(a) before adsorption (b) after adsorption

Fig. 2 XRD of ASD

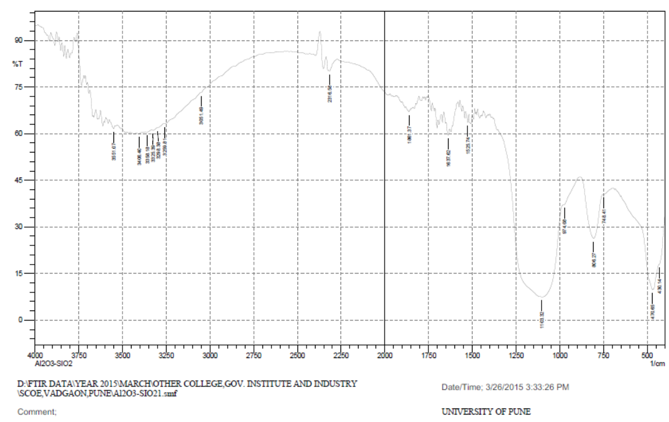


Fig. 3 FTIR of ASD

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BET summary
Slope = 15.803
Intercept = 9.765e-02
Correlation coefficient, r = 0.999778
C constant = 162.823
Total pore volume = 1.329e+00 cc/g for pores smaller than 1081.9 Å (Radius) at P/Po = 0.99106
Average Pore Size summary
Average pore Radius = 1.21364e+02 Å

H. Adsorption Isotherm studies

The isotherm data was subjected to both Freundlich and Langmuir models and showed a better fit for the latter with an R^2 value of 0.9812 as shown in Fig 4 and 5.

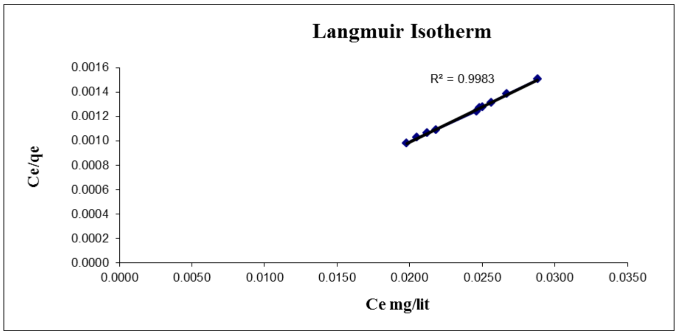

Fig 4: Langmuir adsorption isotherm

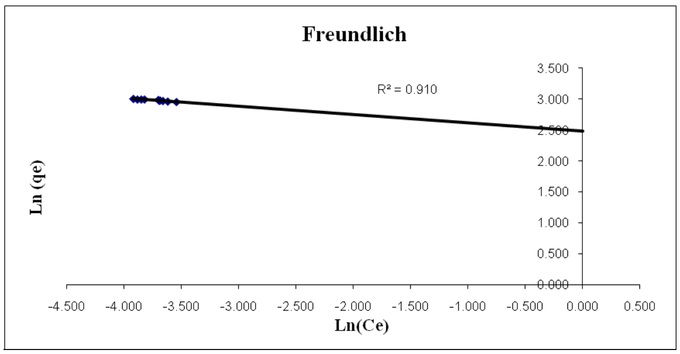

Fig 5: Freundlich adsorption isotherm

I. Effect of adsorbent dose

The result showed that the removal efficiency increased gradually as the adsorbent dose was increased. Chromium showed a removal efficiency of 73.33% at a dose of 0.5 g. and 96.69% for a dosage of 10 g. (Fig 6).

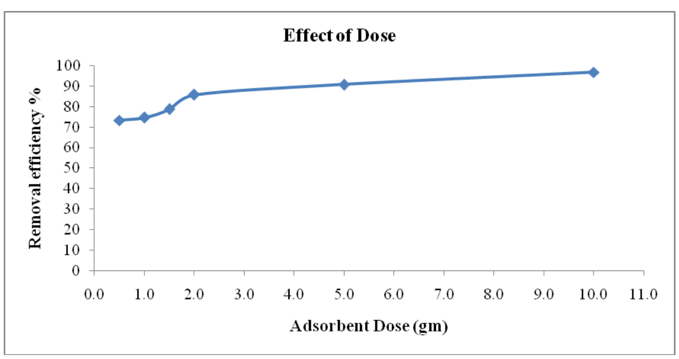

Fig. 6 :Effect of varying adsorbent dose

J. Effect of pH variation

The pH of the solution affects the functional groups on the metal chemistry. Fig shows the removal of Cr (VI) at varying pH range applying an initial constant Cr (VI) concentration of 100 mg/l, adsorbent concentration of 1g/L and contact time of 240 min. The maximum adsorption of Cr (VI) ions was observed at pH 4.0 (96.11%) and significantly decreased by increasing the pH. (Fig 7)

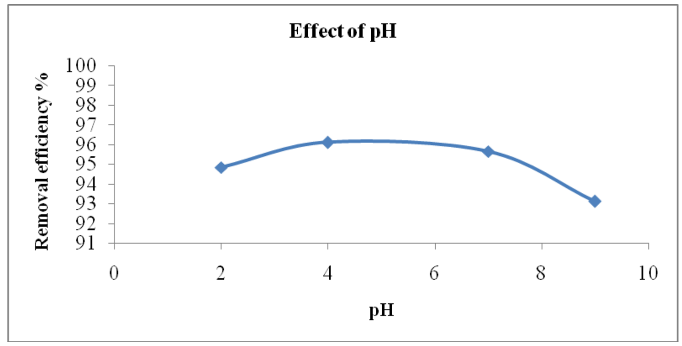

Fig. 7: Effect of pH

K. Effect of contact time

The effect of contact time on the removal efficiency of a Cr (VI) was studied by varying contact time from 15 min to 480 min. The results show that adsorption capacity increases with increase time and attain equilibrium in 150 min as 91.06%.

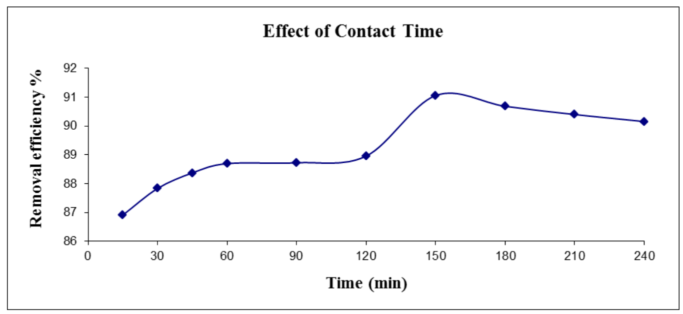

Fig. 8: Effect of varying contact time

L. Column studies

Column study was carried out by varying bed height of 4cm, 8 cm and 12 cm with flow rates of 3,5 and 10 ml/min and column diameter of 10,20 and 25 mm. The removal efficiency was found to be maximum with a column diameter of 25 mm, flow rate of 3 ml/min and a bed height of 12 cm as shown in Fig 9, 10 and 11.

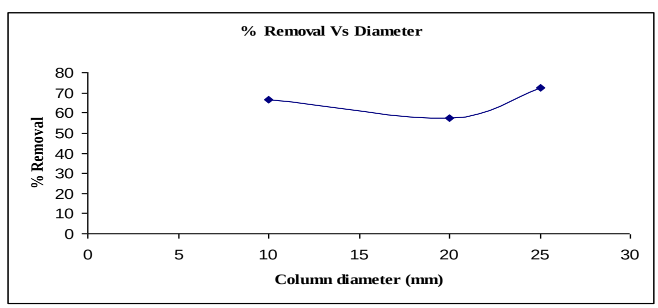

Fig. 9: Effect of column diameter

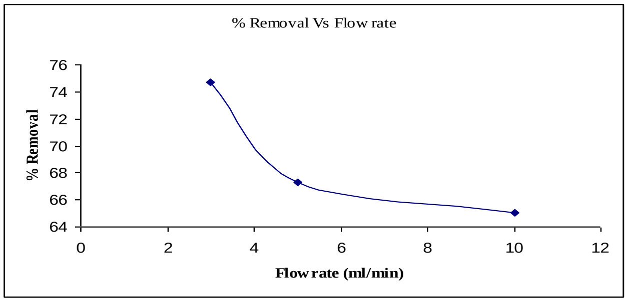

Fig. 10: Effect of flow rate

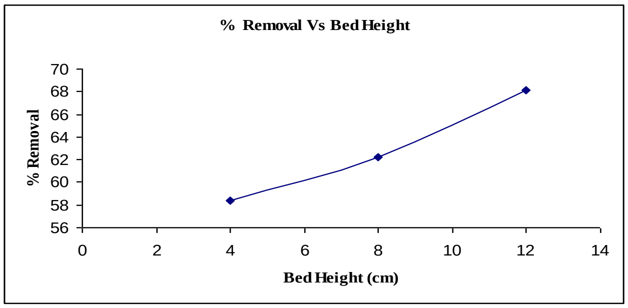

Fig. 11: Effect of bed height

IV. Conclusion

The removal of Cr (VI) from solution is strongly dependent on pH of the solution, adsorbent dosage, initial Cr (VI) concentration, and contact time. The maximum adsorption of Cr (VI) at 96.11% was obtained at pH 4.0, adsorbent dosage of 10g and contact time 150 min.

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