Removal of Chromium from Wastewater Using Black Cotton Soil Amended with Fly Ash and Bentonite Mixtures

Bhavya K, Nagesh M.D., Shankara, S. N. Maya Naik

Abstract— Majority of solid wastes generated in India is directly disposed on land/water bodies in an unscientific manner. This poor handling practices of liquid/solid wastes has resulted many incidents of water, soil and air pollution contamination. The heavy metals/toxicants which are present in these wastes can enter human body through contaminated environments which leads to major health issues. In the process of finding the defensive/remedial measures to safeguard the environment an attempt has been made tostudy adsorption of Cr(VI) metal ion from aqueous solution onto different mixtures of low cost adsorbents, viz., black cotton soil (BCS) – fly ash (FA) and BCS – Bentonite (BT) mixtures using batch kinetics. The relation between the percent removal of chromium and various factors such as adsorbent dosage, contact time pH, and initial concentration of metal ion have been studied. The residual concentration of the chromium ion was resolved using AAS (Atomic Absorption Spectrophotometer). It is observed that maximum adsorption was in acidic range and interaction time of 50 min at 150 rpm. BCS–FA mixture has showed better adsorption than BCS–BT under varied proportions and identical experimental conditions. The sorption data has been modelled and compared with classical Langmuir and Freundlich adsorption isotherms. Langmuir isotherm is found to be best fit for both BCS-FA and BCS-BT mixtures, due to the R2 value which is observed to be higher when compared to Freundlich model indicating monolayer adsorption.

Index Terms— Pollution, Fly ash, Bentonite, Chromium, Sorption, Adsorption, Isotherms

1 INTRODUCTION

Rapid industrialization, urbanization and tremendous increase in population has led to serious problem with respect to pollution in various environmental attributes like air, water, soil etc., Heavy metal pollution in water has been has receiving wide spread attention by researchers from many years [1]. There is a direct connection with the increase of use of heavy metals in industrial sector to the increase of concentration of heavy metals in the aquatic systems. It has been documented that within the range of criteria pollutants, these heavy metals are more dangerous, toxic and carcinogenic. [2]. The heavy metals pollution in the environmental compartments is a great concern due to their toxicity at a very low concentration. To be specific, the chromium pollution in water is consider to be very serious issue due to its versatile use in various industrial uses such as electroplating process, textile industries etc. Chromium exists as hexavalent as well as trivalent in water (aqueous systems) [1]. It has been found that hexavalent chromium is several hundred times more toxic than trivalent chromium. It is known that trivalent form of chromium is essential nutrient to various organisms whereas the hexavalent form of chromium is highly dangerous in environment. Known major health effects of hexavalent chromium in humans are kidney respiratory organs skin damages. It is also known for its high mobility in soil and water, solid oxidant to an extent it can easily adsorbed by the skin [3].

Many researchers have worked towards to develop methods to remove hexavalent chromium particularly from industrial wastewater. The notable works include, membrane technology ion exchange precipitations electrochemical processes and adsorption. [4, 5]. The above techniques have been compared with the adsorption method and proved to be costly and less efficient. The chemical methods of purification indirectly put the extra load on environment [6, 7]. The applicability of the technique otherthan adsorption are definitely difficult as they are not cost effective nor easily implimentable in developing contries[6, 7] Therefore, the adsorption is proved to be cheap and practicable due to its versatile nature of removing various metals from aqueous solutions using low cost adsorbents [8, 9]. In this study, attempt has been made to compare the adsorption capacities of low-cost adsorbents such as black cotton soil amended with fly/bentonite at varied proportions, to remove hexavalent chromium ion from wastewater at various operational conditions.

- *Bhavya K. Research scholar, Dept. of Civil Engineering, BMS College of Engineering, Bull Temple Road, Bangalore-560019 India, E-mail: bhavya.k.689@gmail.com*
- *Nagesh M.D., Research scholar, Dept. of Civil Engineering, BMS College of Engineering, Bull Temple Road, Bangalore-560019 India, E-mail: nagesh_md@yahoo.com*
- *Shankara, Department of Civil Engineering, Amrita School of Engineering, Bengaluru, Amrita Vishwa Vidyapeetham, India. E-mail: shankarsamrud@gmail.com*
- *S. N. Maya Naik, Dept. of Civil Engineering, BMS College of Engineering, Bull Temple Road, Bangalore-560019 India, E-mail:snmcivbmsce@gmail.com*

2 MATERIALS AND METHOD

2.1 Materials and reagents

In the present study black cotton soil (BCS) and bentonite were collected from low lying areas and local shop respectively in Bangalore, India. Black cotton soil obtained was oven dried for 24 hours at 105°C. Soil passed through 4.75µ sieve has been used in the entire study. A fly ash of class "F" collected from Raichur thermal power plant, Karnataka, India, has been used in this work. BCS passed through 4.75µ has been used for the experiment.
A 2.827g of potassium dichromate [$K_2Cr_2O_7$] was dissolved in 1000 ml distilled water to represent a solution of 1000 mg/l of Cr(VI). The subsequent dilutions were done based on the range of the calibrations of the instrument and to the testing procedure. The required pH was adjusted using 0.1N HCl and 0.1N NaOH.

2.2 Adsorption experiments

Sorption experiments were conducted using different adsorbents with a stock solution of 10 mg/L of Cr(VI). The adsorbents used are BCS, BT and their mixtures at varied proportions. All the experiments were conducted at room temperatures, and at various optimum condition factors that promotes adsorption. The test procedures were followed with 250 ml borosil conical flask with a 100 ml of stock solution mixed with 1-5 g of adsorbents. The mixtures will be mechanically stirred at the rate of 150 rpm using rotary flask shaker[10-12]. After shaking for a predetermined time interval the solution will be filtered through whatmann-42 filter paper the concentration of Cr(VI) residual ions were found using AAS. the percentage of removals will be calculated by knowing initial amount and the residual amounts of Cr(VI).

2.3 Adsorbents

The two mixtures comprising black cotton soil-fly ash and black cotton soil -bentonite in a predetermined proportion have been considered. The control factors such as adsorbent dosage, contact time, pH etc. were considered to examine the percent removal of chromium ion from the aqueous solutions. The Table 1 represents the mix designations and their different percentages that are under consideration.

TABLE 1 MIX DESIGNATIONS

Mix Designations	% BCS	%FA	%BT
M1	60	40	0
M2	70	0	30

3 RESULTS AND DISCUSSION

Based on batch studies conducted on BCS-FA and BCS-BT mixtures under various parameters are presented based on three sections, namely effect of contact time, effect of pH and initial chromium ion concentration. The figures 1 to 4 represents the percent removal of chromium ion removal under these sections. In the sections effect of contact time and effect of pH, percent removals were observed under different adsorbent dosages. In the third section, percent removals were observed under different mix designations. The figures 5 represents the percent removal of chromium ion removal under this section.

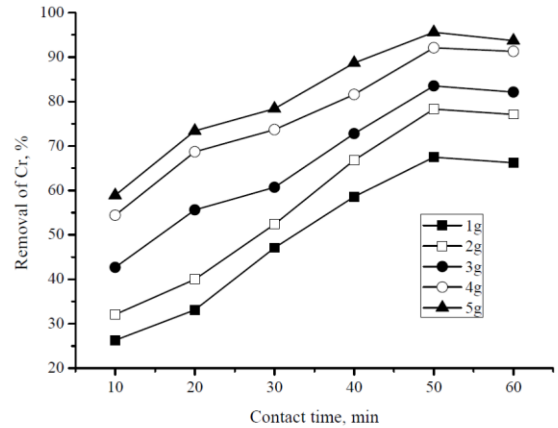

FIG 1 VARIATION OF %REMOVAL OF CHROMIUM AT VARIED CONTACT TIME FOR M1

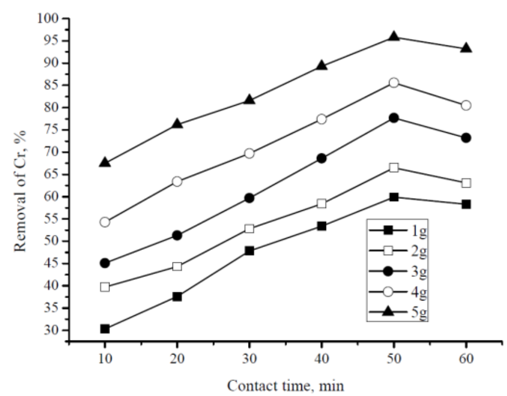

Fig 2 Variation of %removal of chromium at varied contact time for M2

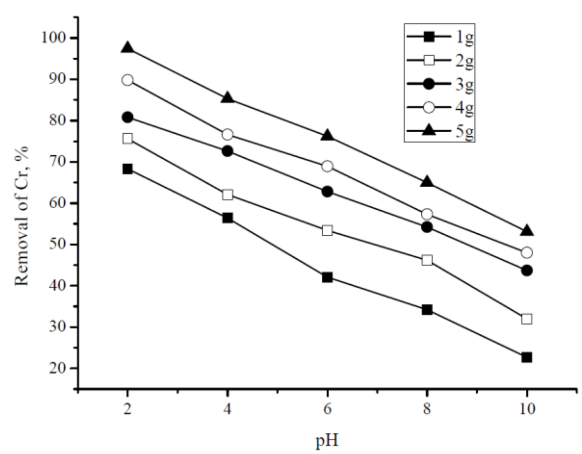

Fig 3 Variation of %removal of chromium at varied pH for M1

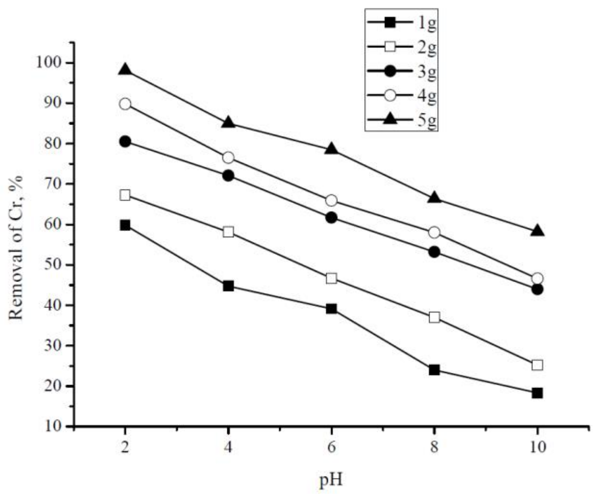

FIG 4 VARIATION OF %REMOVAL OF CHROMIUM AT VARIED PH FOR M2

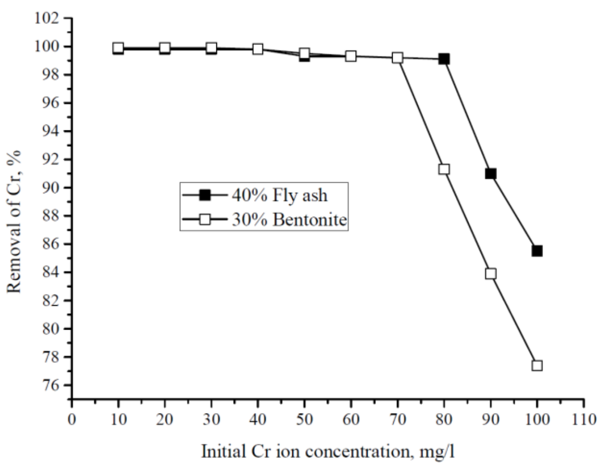

FIG 5 VARIATION OF %REMOVAL OF CHROMIUM AT VARIED INITIAL CONCENTRATION OF CHROMIUM AT OPTIMUM CONTACT TIME, PH AND ADSORBENT DOSAGE FOR BOTH M1 AND M2

3.1 Adsorption Models and analytical data

Sorption data analysis and their models are very important aspects in the field of adsorption of ions on adsorbents as these model serves as base for design procedures. Standard models (such as Langmuir and Freundlich models) are widely known to relate amount of adsorption, equilibrium concentration of ions in the solutions and types of adsorptions. (C_e). Most extensively Langmuir and Freundlich isotherms are used because of its simplicity and easy interpretability [13, 14]. The adsorption isotherms are modelled for 40%fly ash and 30%bentonite mixture, since the %removal of chromium was about 98% for these combinations of adsorbent. Table 2 and 3 represents the intercept and R^2 value for different models.

TABLE 2 ANALYTICAL DATA FOR LANGMUIR ISOTHERM MODEL

Adsorbent	Gradient	Intercept	R^2
M1	0.9147	0.7379	0.9847
M2	0.8332	1.0849	0.9782

TABLE 3 ANALYTICAL DATA FOR FREUNDLICH ADSORPTION ISOTHERM

Adsorbent	Slope	Intercept	R^2
M1	-0.1316	-0.1086	0.9159
M2	-0.1144	-0.1819	0.9047

4 CONCLUSIONS

1. Batch kinetic study reveal that, the % removal of chromium for M1 and M2 mixtures was found to be 97.4% and 98.1% respectively at the respective optimum operating conditions.
2. At optimum conditions of 40%fly ash and 30%bentonite mixtures the %removal of chromium was found to be 99% for 10-70ppm of initial concentration of chromium.
3. Langmuir’s constants show suitability of BCS-fly ash and BCS-bentonite mixture as adsorbent for Cr(VI) indicating monolayer adsorption.
4. From results it can be concluded that 40%fly ash and 30%bentonite when amended with BCS are considered as efficient adsorbents in removal of chromium from wastewater.
5. Process adopted is simple and economically viable. Henceforth, it can be concluded that, the black cotton soil when amended with fly ash and bentonite in varied proportions can be used as adsorbent favourably.

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