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Use of Fly Ash as Adsorbent for Removal of Chromium from Aqueous Solution

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Abstract: ***ater pollution is cause due to toxic heavy metals that has become a major cause of concern for environmental engineers. Cr (VI) is a highly toxic metal ion and considered a priority pollutant released from various industries. Adsorption is one of the effective techniques for chromium (VI) removal from wastewater. In the present study, fly ash is used as an adsorbent for removal of Cr (VI) from aqueous solutions. Fly ash samples were collected from the Kota Super Thermal Power Station, Kota (Rajasthan). Physico – chemical analysis was performed of collected fly ash samples. Batch adsorption studies were carried out systematically. Different parameters such as initial metal ion concentration, adsorbent doses, pH and contact time were studied.***

Keywords: Adsorption, chromium, fly ash, pH, batch method

1. Introduction

Contamination of water by toxic heavy metals through the discharge of industrial wastewater is a worldwide environmental problem. Rapid industrialization has severely contributed to the release of toxic heavy metals to water streams. Metals such as lead, cadmium, copper, arsenic, nickel, chromium, zinc and mercury have been recognized as hazardous heavy metals[1].The release of large quantities of hazardous materials into the natural environment has resulted in a number of environmental problems and due to their non-biodegradability and persistence, can accumulate in the environment elements such as food chain, and thus may pose a significant danger to human health [2].Chromium and its compounds are widely used in many industries such as metal finishing, dyes, pigments, inks, glass, ceramics, chromium tanning, textile, dyeing and wood preserving industries and certain glues. [3] Chromium are present in two oxidation states as Cr (III) and Cr (VI). The hexavalent form is 500 times more toxic than the trivalent.[4]Since Cr (VI) is known to be very mobile and hazardous to human health through inhalation, skin contact, and ingestion, being highly toxic, carcinogenic and mutagenic to living organisms, even when present in very low concentrations in water.[5, 6] Extensive use of chromium results in large quantities of chromium containing effluents which need sufficient treatments. [7] Many textile and dye industries are situated in Kaithun (near Kota city). Which is famous for Kota Doria. The effluent from these industries contains hexavalent chromium.

Fly Ash, the after-burnt tiny coal dust is a by-product of the thermal power plants. Property of fly ash is dependent on the nature of the coal. The primary effect of flyash production is the generation of a number of problems, mainly because of its minute size, non-reactive nature, presence of toxic elements and huge production. [8] FA pollutes the atmosphere and threatens human health if it is discharged directly from power plant chimneys into the atmosphere without treatment. [9, 10] FA has a number of useful applications that serves to utilise some of the large amount being produced all over the world. Main applications of FA are in the field of manufacturing of cement and other construction materials (Sear et al., 2001), agriculture, metal recovery, water and atmospheric pollution control (Blanco et al., 2006) etc. FA can also be used as a low-cost adsorbent because of its excellent specific surface area, porosity, particle size [11], and other natural characteristics. [12]

As Kota Super Thermal Power Station is located in Kota (Rajasthan). So we used fly ash as an adsorbent for removal of Chromium.

2. Material & Method

The Batch test were carried out in 250 ml flask using fly ash as a sorbent. The flyash samples were collected from the Kota Super Thermal Power Station, Kota. Chromium samples were prepared by dissolving a known quantity of potassium dichromate ($K_2Cr_2O_7$) in double-distilled water and used as a stock solution and diluted to the required initial concentration. A 1g flyash was mixed with 100 ml of the aqueous solutions of various initial concentration (0.5mg/L, 1mg/L, 2mg/L, 3mg/L) of chromium (VI) in each flask. The stirring speed was kept constant at 120 rpm. The pH of the solution was measured with a HACH – pH meter. The effects of various parameters on the rate of adsorption process were observed by varying contact time, adsorbent concentration, initial Cr Concentration and pHof the solution. The solution volume (V) was kept constant. The measurements were made at the wavelength λ = 540nm, which corresponds to maximum absorbance [13]. Using a mass balance, the concentrations of chromium (VI) at different time adsorbed in fly ash was calculated,

$$q_t = \frac{(C_o - C_t)\,V}{M}$$

Where q_t is the amount of chromium (VI) adsorbed onto the fly ash at time t, C_o is the initial concentration of chromium (VI), C_t is aqueous phase concentration of chromium (VI) at time t, V is the volume of the aqueous phase, M is the weight of flyash.

Fly ash consists of silica, alumina, iron oxide, lime, magnesia and alkali in varying amounts with some unburned activated carbon (Dogan et al., 2006; Fan et al., 2001). The chemical compositions of fly ash are high percentage of silica (56.07%), alumina (26.69%), Fe_2O_3 (8.03%), CaO (1.2%), SO_3 (0.18%) and other important physicochemical characteristics of the fly ash, like bulk density, particle size, porosity, water holding capacity, and surface area — makes it suitable for use as an adsorbent. [1, 14]

3. Result and Discussion

A. Effect of initial Cr (VI) concentration and Contact time

Four different concentrations of 0.5, 1, 2, and 3 mg/l for Cr (VI) were selected to investigate the effect of initial concentration of Cr (VI) onto flyash. The temperature was maintained at 30˚C and the amount of flyash 1 gm. The effect of different initial concentration of Chromium (VI) onto fly ash is presented in figure 1. It was found that the adsorption increases with increase in initial concentration of Chromium (VI).Percentage of Cr (VI) uptake was found to increase with initial chromium concentrations. This may be as a result of the fact that for a fixed adsorbent dose, the total available adsorption sites remain invariable for all the concentrations. Hence the percentage removal of Chromium has shown significant decrease with the increase in the initial chromium concentrations.[15]

Earlier studies [16] and [17] and [7] showed similar results with treated sawdust and type of zeolite synthesized from coal fly ash and Eco-friendly activated carbon respectively.

The effect of contact time on the adsorption of Cr (VI) was investigated. To study the effect of contact time, contact time were taken 24 hours, 48 hours, 72 hours and 96 hours. It was observed that with increase in contact time, percent adsorption increases. It has been observed that the metal adsorption rate is high at the beginning and then decreases slowly till saturation levels were completely reached at equilibration point (20 min.).[18] Prior studies [19], [20] says the same results for effect of contact time.

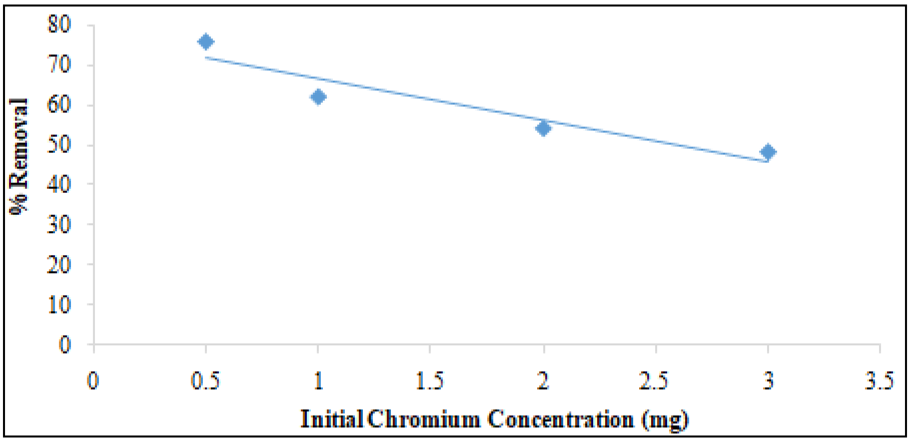

Figure 1: Effect of initial Cr (VI) concentration on adsorption of Cr (VI)

B. Effect of Fly ash amount

To study the effect of variation of amount of flyash, fly ash were taken 1gm, 1.5gm, 2gm and 3gm. The temperature was maintained at 30˚C and the Chromium concentration 2mg. The results reveals that the percent adsorption increases as the amount of fly ash increases (figure 2). This may be attributed to the availability of more sorption sites due to higher amount of the adsorbent.[21]As the adsorbent dosage increased, more active sites and surface area of the adsorbent became available for the adsorption. When the adsorption reached an equilibrium, increase in adsorbent dosage had no effect on the adsorbate uptake because it added unavailable sites.[22]The adsorbent dosage is an important parameter in adsorption studies because it determines the capacity of adsorbent for a given initial concentration of metal ion solution. [23]Some studies say that taking modified groundnut hull [24] as an adsorbent removal of chromium (VI) increases with increase of adsorbent dosage and Neem leave [25] as an adsorbent that the rate of the removal of chromium ions increases with an increases in the amount of adsorbent dose. Same as results were obtained by taking zeolite prepared from rawfly ash (ZFA) as the percent sorption increases with increasing amount of ZFA. [20]

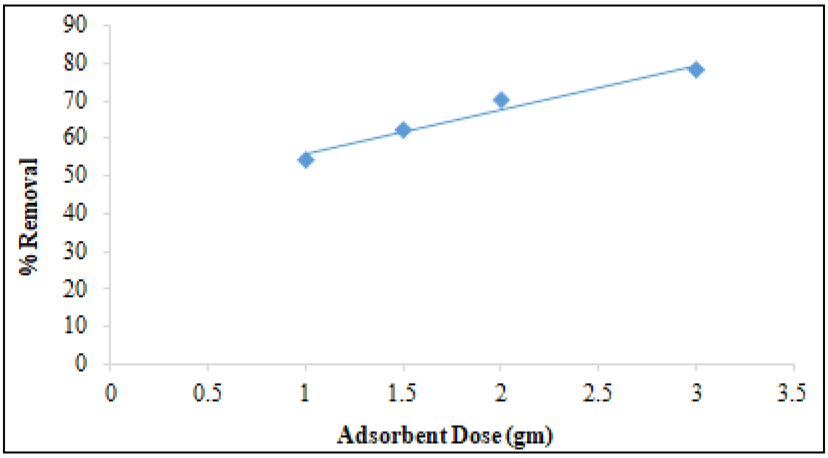

Figure 2: Effect of fly ash amount on adsorption of Cr (VI)

C. Effect of pH

The pH of aqueous solution plays an important role in the adsorption capacity. The effect of pH on adsorption of Cr onto fly ash was studied at pH 2, 4, 6, 8 and 10. The maximum adsorption capacity of fly ash was found to be at pH 2. Figure 3 shows the adsorption of chromium with pH, and it can be seen that chromium adsorption decreased with increasing pH value in the range of 2-10. And very slightly changes change between pH 4-10. The decrease in adsorption at higher pH may be due to the negative charges on the surface of the adsorbent repelling the negatively charged chromate ions. [7]The adsorption of metals is related to the surface functional groups and chemistry of the adsorbate metal ion-solvent interaction that vary with the pH. The hexavalent chromium ions can exist as hydrogen chromate ($HCrO_4^-$) or chromate (CrO_4^{2-}) or dichromate ($Cr_2O_7^{2-}$) depending upon the pH of the solution. At acidic pH 2, the dominant form of Cr (VI) is $HCrO_4$ − and higher pH other forms CrO_4^2− or $Cr_2O_7^2$− predominate. [26]Similar findings have also been reported in earlier studies such as an eco-friendly activated carbonanda low cost fertilizer industry waste material.[7, 18]

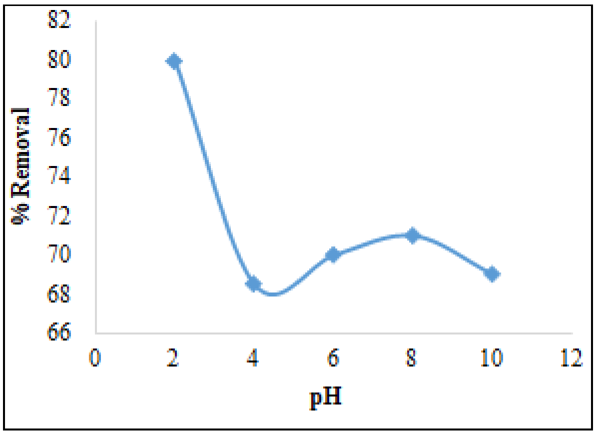

Figure 3: Effect of pH on adsorption of Cr (VI)

4. Conclusion

The aim of this work was to study removal of Chromium (VI) from aqueous solution on Fly ash. Adsorption of the Cr (VI) was studied by batch method and it was observed that using fly ash 76 % of the Cr (VI) was removed. Fly ash, a low cost material was found to be an effective one. The percentage removal of chromium depends on adsorbent dose, initial metal ion concentration, contact time and pH of the solution. The result indicates that the adsorption increases with increasing amount of fly ash and initial chromium concentration. A contact time of 14 min. was found to be optimum. Adsorption is maximum on pH 2 and decreases with increasing pH.

5. Future Scope

Study of Chromium adsorption on Fly ash will be helpful in utilization of Fly ash and also to get rid of problem of excess chromium in ground water in Kota and Hadoti region. This study will be future helpful to pollution control board to develop Chromium removal model.

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