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Removal of Chromium, Lead and Cadmium heavy metal ions from water and wastewaters using Fly ash, China clay and Red mud as low cost potential adsorbents

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***Abstract*— In this study, fly ash, china clay and red mud were investigated for their potential as adsorbents to remove heavy metals such as lead, cadmium and chromium from wastewater of known concentrations. Therefore, this study shows that the low-cost adsorbent China clay was used to remove 89%, 86% and 90% of chromium, lead and cadmium, respectively. Red mud removes 91%, 94% and 89% of chromium, lead and cadmium, respectively. Fly ash was used to remove 84%, 89%, and 83% of chromium, lead, and cadmium, respectively, from the effluent of solutions with an initial metal ion concentration of 100 ppm. Batch adsorption studies have shown that the adsorbent has significant adsorption capacity for chromium, lead, and cadmium in aqueous solutions. The adsorption was found to increase with increasing contact time.**

Index Terms: **Heavy metals, Adsorbents, Effect of Contact time and Agricultural waste.**

INTRODUCTION

Discharge of untreated metal-laden wastewater into water bodies' results in the presence of toxic heavy metal pollutants such as chromium, copper and lead in the water stream, which is one of the most important environmental concerns. Pollution is one of the most important problems facing human beings today. In recent years, it has grown exponentially, with an astonishing degree of impact on living things. Toxic heavy metals are one of the pollutants that have direct effects on humans and animals [1]. The main processes through which these trace metals enter the ecosystem are mining operations, ore refining, sludge treatment, incineration fly ash, radioactive material processing, metal plating or electrical appliances, paints, alloys, batteries, pesticides and preservatives [2].The discharge of metal ions into industrial wastewater has attracted great attention because their presence and accumulation have toxic effects on biological species [3]. The maximum allowable (ISI) limit for lead in drinking water is 0.05 ppm. If lead levels exceed this limit, it can lead to harmful effects such as cardiovascular problems, kidney dysfunction, reproductive problems, and more. It is a toxic heavy metal that interferes with the proper functioning of many enzymes in our body, causing them to malfunction. The maximum allowable (ISI) limit for chromium in drinking water is 0.1 ppm. Chromium is a potentially toxic metal found in water and groundwater of natural and anthropogenic sources. The maximum allowable (EPA) limit for copper in drinking water is 1.3 mg/l,consuming large amounts of copper can cause nausea, vomiting, diarrhea, upset stomach, and headaches. Long-term exposure over months or even years can lead to liver damage and death.

MATERIALS AND METHODS

Preparation of Adsorbents:
1: Fly ash - Fly ash was obtained from Obera Thermal Power Plant, Mirzapur, UP (INDIA). They were used as such without any pre-treatment just after sieving through 53μm pore size sieve (Table1).

Table1: Chemical analysis of Fly ash as Adsorbent.

Constituents	Percentage by weight
SiO_2	56.04
Al_2O_3	25.90
CaO	2.22
Fe_2O_3	1.26
MgO	0.94
Loss of ignition	13.64
Particle size	53μm
Mean Particle size diameter	$48x10^{-4}$ cm
Surface Area	5.77 m^2g^{-1}
Porosity	0.360
Density gcm^{-3}	3.420

2: China clay- China clay is a mineral of kaolinite group. It does not swell with addition of water. The alumina content present in it does not form isomorphous series with any other metallic compounds. It was collected from Patharghatt village of Bhagalpur district, Bihar (India). It was used as such without any pretreatment just after sieving through 53µm pore size sieve. The chemical analysis and characterization of China clay is given in Table:2.

Table2: Chemical analysis of China clay as Adsorbent.

Constituents	Percentage by weight
SiO_2	46.22
Al_2O_3	38.40
CaO	0.86
Fe_2O_3	0.68
MgO	0.37
Loss of ignition	13.47
Particle size	53µm
Mean Particle size diameter	$51x10^{-4}$ cm
Surface Area	13.52 m^2g^{-1}
Porosity	0.330
Density	2.692 gcm^{-3}

Table3: Chemical analysis of Red Mud as Adsorbent

Constituents	Percentage by weight
Fe_2O_3	39.45
Al_2O_3	22.65
TiO_2	13.80
SiO_2	8.55
CaO	5.20
Loss of ignition	10.25
Particle size	53 µm
Mean Particle size diameter	$48x10^{-4}$ cm
Surface area	10.27 m^2 g^{-1}
Porosity	0.197
Density	2.632 gcm^{-3}

3: Red mud- Red mud sample were collected from aluminium producing industries. Physicochemical characteristics of Red mud such as bulk density, particle size, porosity, water holding capacity and surface area makes it suitable for use as an adsorbent(Table:3).

Batch adsorption studies:

The metal solutions used in this study were prepared as the stock solutions containing 1000mg/L of each metal.100ml of adsorbate solution of known concentration was taken in the 250 ml conical flask and 1.0 g of each adsorbent was added separately and then reactant was stirred by magnetic stirrer without any pH modification at roomtemperature. For a wide range contact time 30-180 minutes. After that the solution was filtered by whatmann 42 filterpaper and concentration of the filtered solution was determined by atomic absorption spectrophotometer (PerkinElmer, model 2380) [4]. The percentage removal was determined by the following expression. The amount of adsorption efficiency was calculated by,

Percentage Adsorption $=[\frac{Co-Ce}{Co}]$ x 100

Where, Co = initial concentration of metal ion in the solution (mg/l) Ce = final concentration of metal ion in the solution (mg/l).

Effect of Contact Time on Adsorption of Heavy Metals**:**

The percent decrease in adsorption was found to increase continuously with time until saturation equilibrium was reached at 180 min. The percentages of cadmium removal for china clay, red mud and fly ash were 59%-90%, 64%-89% and 60%-83%, respectively (Figure: 1). This may be due to the use of larger surface area active sites [2]. Then the chromium percentage removal rates of china clay, red mud and fly ash are 54%-89%, 71%-91% and 64%-84%, respectively (Figure: 2). The reduced adsorption efficiency is due to insufficient availability of active sites on the adsorbent [5]. The lead percentage removal for china clay, red mud and fly ash are then 63%-86%, 56%-94% and 69%-89% respectively (Figure: 3). The high reduction rates of chromium, lead and cadmium in China clay 89%, 86% and 90% increased rapidly. The high reduction rates of chromium, lead and cadmium in red mud 91%, 94% and 89% increased rapidly. This increase may be due to increased adsorption due to activation of adsorption sites, possibly through a surface exchange mechanism [7]. The high reduction percentages of chromium, lead, and cadmium in fly ash were 84%, 89%, and 83% respectively. This may be due to the smaller size of the adsorbent in the metal solution, provided that greater availability of metal ions to penetrate into the internal pore structure of the adsorbent is provided. The lower metal uptake of the larger sorbent particles is due to the high diffusive resistance to mass transport [8].

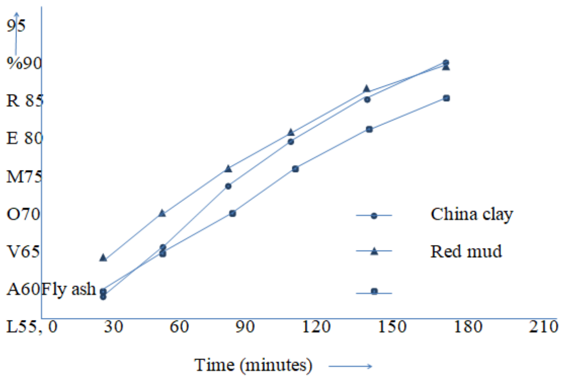

Figure: 1 Percentage Removal of Cadmium from different adsorbents

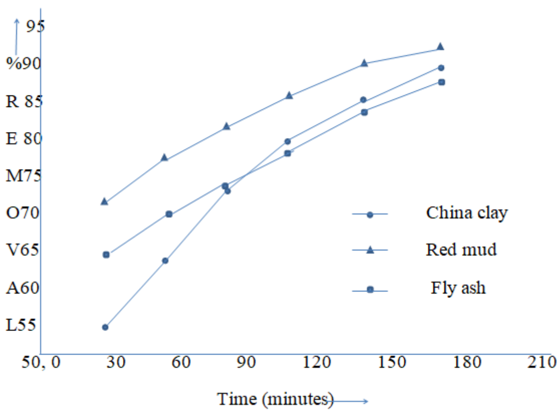

Figure: 2 Percentage Removal of Cadmium from different adsorbents

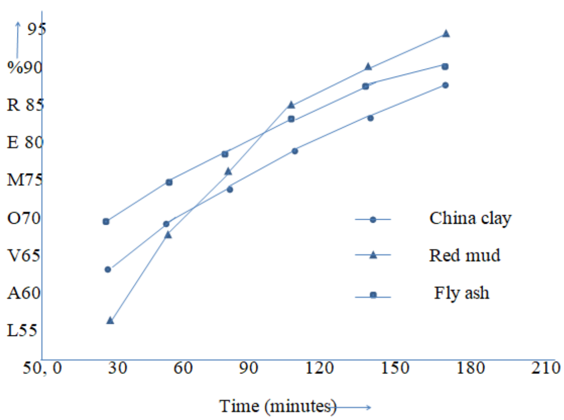

Figure: 3 Percentage Removal of Lead from different adsorbents

CONCLUSION

In the present study heavy metals such as Chromium, Lead and Cadmium was selected for removal from aqueous solutions using Batch adsorption technique. A particle size of 53 µm was observed to be highly efficient for the Lead, Cadmium and Chromium. A decrease in the size of the particle increased the adsorption, as a decrease in size of the particle increased the availability of the number of active sites. Hence these adsorbents appear to be technically feasible, user-friendly, eco-friendly, economical process and with high efficacy. This work showed that the various adsorbents could be used as a good adsorbent material for Lead, Cadmium and Chromium for water and wastewater treatment. The present adsorbents can be used as an industrial scale to remove the Chromium, Lead and Cadmium respectively. Hence, it is necessary to remove these metals from industrial effluents before discharging waste water into the environment.

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