

Removal of Zinc ions from water and wastewater using low cost adsorbents like Red mud and Fly ash.

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Abstract- Water is one of the most important renewable natural resources needed to sustain life on Earth. Increased concentrations of heavy metals such as zinc are affecting biological life. Most sanitation measures to remove contaminants from water are expensive and uneconomical. Adsorption is widely used for the removal of toxic metals due to its high removal rate, simplicity, and effectiveness. In this paper, we compared the efficiency of removing zinc metal from water using a spectrophotometer to remove Red mud and Fly ash. We investigated the effects of various parameters, such as pH, adsorbent dosage, initial concentration, and contact time. The maximum removal efficiencies of metallic zinc were 86% and 84%, respectively, using the Red mud and Fly ash as adsorbents. The Freundlich and Langmuir isotherms were plotted and the Langmuir isotherm was found to be the best model, with a correlation coefficient (R^2) value of 0.9810.

Index Terms:- Adsorption, Zinc, Red mud, Fly ash, UV Visible Spectrophotometer, pH.

I. INTRODUCTION

The availability and distribution of drinking water are decreasing globally because of increased population, industrialization and over exploitation of natural resources. Water contamination is generally caused by the accumulation of foreign pollutants in water bodies due to geogenic and anthropogenic activities. The pollutants of major concern are categorised as organic, inorganic and biological contaminants. Inorganic pollutants are non-biodegradable chemical elements that exist in the environment for a long time. They accumulate in living systems through water and the food chain and, if ingested beyond allowable limits, can lead to several acute and chronic diseases. It mainly includes heavy metals such as zinc, lead, copper, and cadmium [1-3]. The main sources of these pollutants are groundwater, surface water or river water, mainly related to the uncontrolled discharge of industrial chemicals directly into water resources without treatment. It may also be due to unbalanced geological leaching due to environmental and human disturbances [4-5].

Therefore, it is necessary to control the presence of heavy metals in water resources and develop sustainable countermeasures. Zinc is a heavy metal that is in great demand in industrial production. It is an unavoidable raw material for many industries such as electroplating, automobiles, fertilizers, and paints [6]. The malleability of zinc helps to easily transform them into different shapes and sizes. Although the presence of zinc in air, water, soil, plants, and humans is unavoidable, excess concentrations can be dangerous [7]. The Bureau of Indian Standards has set the allowable level of zinc in drinking water at 5 mg/l, considering all sources from which zinc enters the body. Too much zinc can cause nausea, stomach pain, and vomiting in humans [8]. The excessive intake of zinc into the body through food, water or other dietary supplements can also affect human health. The recommended dietary allowances of zinc for man are 11mg/day and for women is 8mg/day [9]. In plants, this can lead to stunted shoots, curled and curled leaves, and more. Therefore, there is a need to remove excess zinc metal from water.

II. METHODOLOGY

2.1 Preparation of Stock Solution

To prepare stock solution of zinc metal, 110 gm of Zinc Sulphate Heptahydrate [$ZnSO_4 \cdot 7H_2O$] was weighed and diluted with distilled water in a 250ml volumetric flask to give a concentrated solution of 1000mg/L. The above prepared solutions were further diluted for getting solutions with required concentrations.

2.2: Preparation and Characterization of Adsorbents:

The batch adsorption method was carried out in 250ml flask using Red mud as an adsorbent. 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: Chemical analysis of Red mud Adsorbent

<u>Constituents</u>	<u>Percentage by weight</u>
Fe ₂ O ₃	39.45
Al ₂ O ₃	22.65
TiO ₂	13.80
SiO ₂	8.55
CaO	5.20
Loss of ignition	10.25
Particle size	53µm
Mean Particle size diameter	48 x 10 ⁻⁴ cm
Surface Area	10.27 m ² g ⁻¹
Porosity	0.197
Density	2.632 gcm ⁻³

Fly ash was obtained from Obera Thermal Power Plant, Mirzapur, UP (INDIA). They were used as such without any pretreatment just after sieving through 53µm pore size sieve (Table:2).

Table2: Chemical analysis of Fly ash as Adsorbent.

<u>Constituents</u>	<u>Percentage by weight</u>
SiO ₂	56.04
Al ₂ O ₃	25.90
CaO	2.22
Fe ₂ O ₃	1.26
MgO	0.94
Loss of ignition	13.64
Particle size	53µm
Mean Particle size diameter	48 x 10 ⁻⁴ cm
Surface Area	5.77 m ² g ⁻¹
Porosity	0.380
Density	3.420 gcm ⁻³

III. EXPERIMENTAL PROCEDURES

Diluted solutions with different metal ion concentrations were prepared from stock solutions. The adsorbent was weighed and added to each sample prepared. Each sample was stirred with a magnetic stirrer and held for the indicated time. The filtered solution was then introduced into a spectrophotometer and the absorbance value of each sample was recorded. The corresponding final concentration for each absorbance value was obtained from the calibration curve. The percentage removal efficiency of zinc can be determined by using the following formula:

$$\text{Percentage removal efficiency of zinc (R)} = \frac{(CI - CF)}{CI} \times 100 \quad (1)$$

CI and CF are initial and final concentration of metal ion concentrations (mg/L) respectively.

IV. RESULTS & DISCUSSIONS

4.1 Effect of Initial Concentration:

Experimental studies were carried out by varying the initial metal ion concentration from 10 – 50 mg/L and keeping the pH, adsorbent dosage and contact time constant. The adsorption efficiency was observed to increase with increasing concentration. The maximum adsorption efficiencies observed at 50 mg/l were 86% for red mud and 81% for fly ash (Figure: 1).

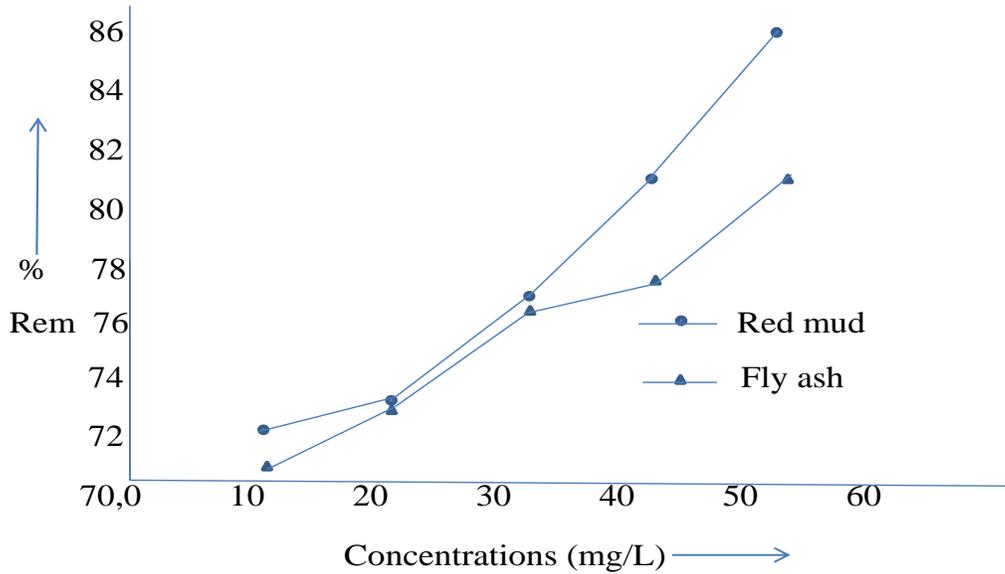


Figure:1 Percentage removal vs Concentrations of metal ions.

4.2 Effect of pH

pH of the solution influences percentage removal. pH of prepared sample solution was varied by adding HNO₃ or, NaOH. From the Figure: 2 it was observed that there is a continuous increase in percentage removal up to pH 6.0 followed by a gradual decrease. Maximum adsorption efficiency was found while testing the solution having pH 6.0 and they are 81% for Red mud and 78% for Fly ash.

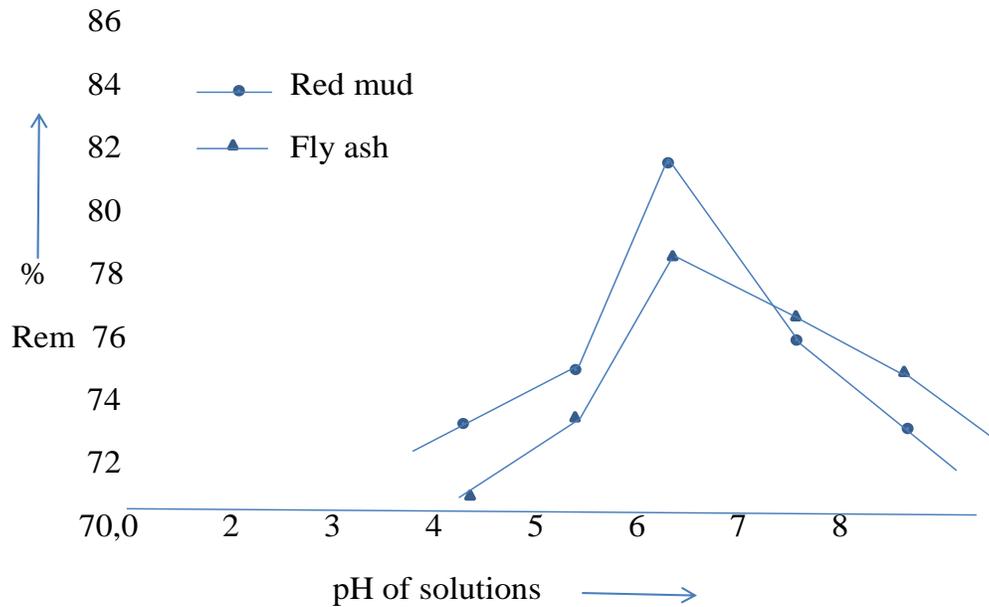


Figure: 2 Percentage removal vs pH of metal ions solutions.

4.3 Effect of Adsorbent Dosage

The adsorption efficiency varies with the amount of adsorbent used. The study was performed by varying the adsorbent dosage and keeping all other parameters constant. As can be seen from the figure:3, at an adsorbent dosage of 1.0 g, the maximum percentage of zinc removal using red mud and fly ash is 85% and 84% of that of Red mud and Fly ash, respectively.

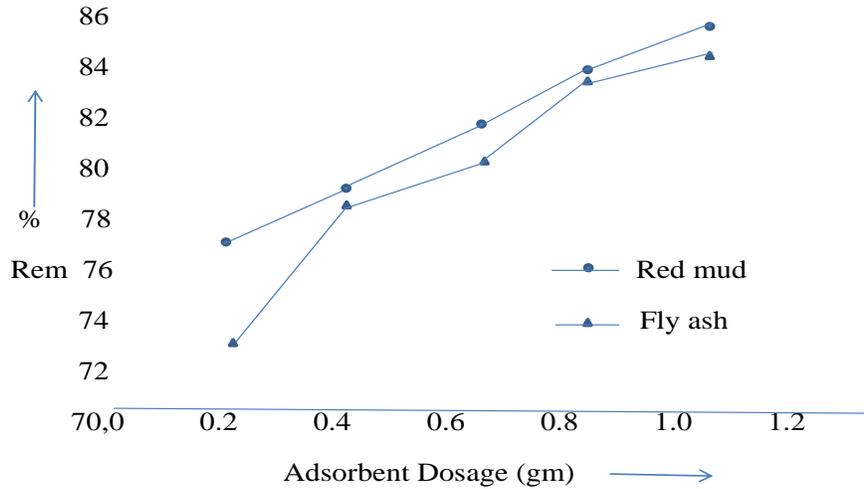


Figure: 3 Percentage removal vs Adsorbent Dosage.

4.4 Effect of Contact Time

The sample solutions were prepared and tested at specific time intervals. From the results obtained it was observed that there is an initial increase in adsorption efficiency with time and there after remains constant. Thus it can be concluded that the best contact time is 120 minutes, with adsorption efficiencies 86% and 81% for Red mud and Fly ash respectively.

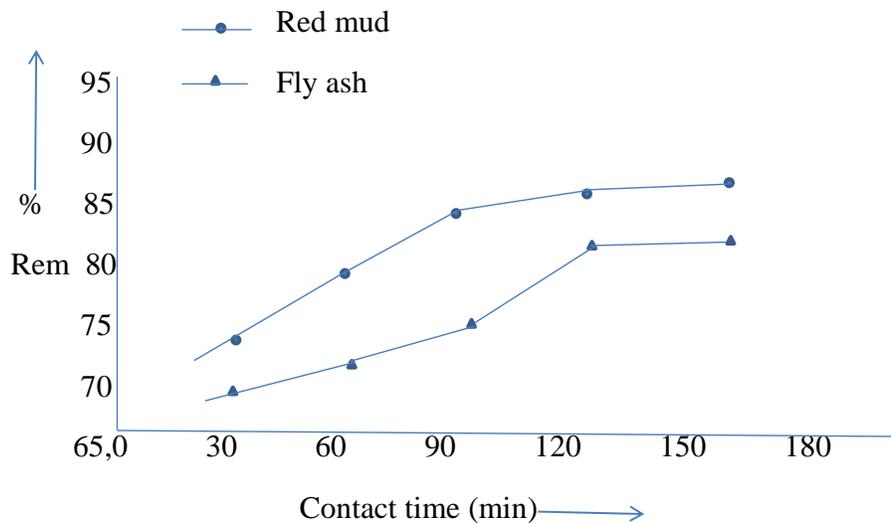


Figure: 4 Percentage removal vs Contact time (min).

6. ADSORPTION ISOTHERMS

Langmuir and Freundlich adsorption isotherms were plotted to validate the results. The best adsorption efficiency for zinc metal removal was shown by Red mud. So, Adsorption isotherms with Red mud as adsorbent was prepared and compared. The R^2 value obtained for Langmuir isotherm (0.9810) is higher than that of Freundlich isotherm (0.9444) and thus the values fitted well with the Langmuir model.

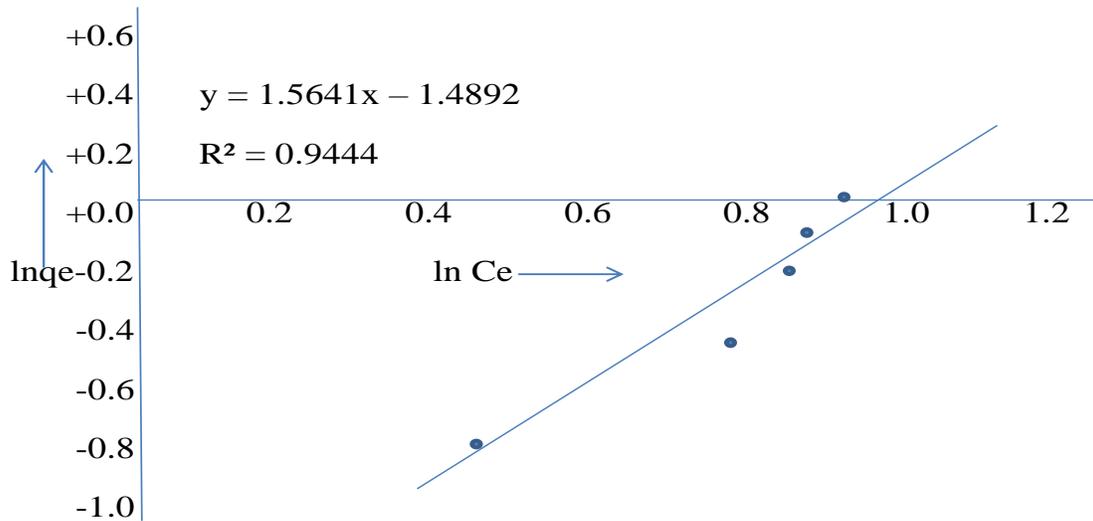


Figure: 5 Freundlich adsorption isotherm curve [$\ln q_e$ vs $\ln C_e$]

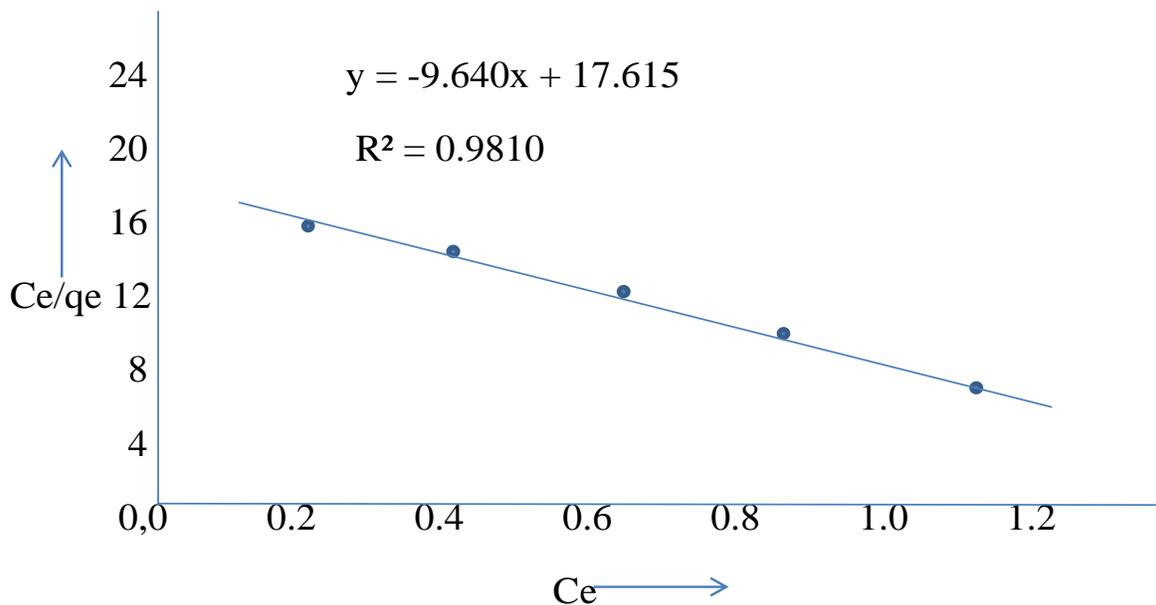


Figure: 6 Langmuir adsorption isotherm curve [C_e/q_e vs C_e]

V. CONCLUSION

Red mud and fly ash are inexpensive and effective adsorbents for removing zinc ions from water. The experiments carried out showed that red mud and fly ash were used as adsorbents to remove zinc metal with maximum removal efficiencies of 86% (150 min) and 84% (1.0 g adsorbent). It can be seen from the above results that the adsorption efficiency of red mud is higher than that of fly ash. Freundlich and Langmuir isotherms were plotted and the data were well fitted using the Langmuir model with a correlation coefficient (R^2) of 0.9810. From this it can be concluded that red mud and fly ash can be used to remove heavy metals and by using these adsorbents we can also overcome the limitations of more expensive traditional adsorbents.

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