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ORIGINAL RESEARCH PAPER

Engineering

PERFORMANCE OF FLYASH AND BAGASSE FOR THE REMOVAL OF ZINC IONS FROM AQUEOUS SOLUTIONS BY ADSORPTION

KEY WORDS: Zinc, Flyash And Bagasse, Adsorption, Langmuir, Freundlich

Akhila Swathanthra P	Assiatant Professor, Dept .of Chemical Engg, SVUCE, S. V. University, Tirupati
Basava Rao V V*	Professor, Dept.of Chemical Engineering, Osmania University, Hyderabad *Corresponding Author
Pranay Kumar Y	M.Tech Student , Dept . Of Chemical Engg, SVUCE, S. V. University, Tirupati
Sreedhar. P	Research Scholar, Dept .of Chemical Engg, SVUCE, S. V. University, Tirupati

ABSTRACT

Economically feasible adsorbents of bio-origin with more adsorptive capacity are in demand for the removal of heavy metals from waste water. As the heavy metals are perilous to the environment, they should be removed from the industrial effluents before their disposal. Zinc is one of the most hazardous heavy metals, widely used in metal alloys and zinc industries. Therefore we propose flyash and bagasse as potential low cost adsorbents for the removal of zinc. Present research mainly focuses on the removal of zinc ions from aqueous solutions. A series of experiments were conducted in batch wise to estimate the effect of system variables on the amount of percentage removal of zinc from the aqueous solution. The effect of variables such as contact time, pH, initial concentration of zinc in solution, amount of adsorbent dosage and temperature of the solution on the adsorption were studied. The adsorption data were well fitted by Freundlich isotherm model for flyash and Langmuir isotherm model for bagasse. Flyash and bagasse showed 89% and 98% removal of zinc at the optimum operating conditions.

INTRODUCTION:

The amount of heavy metal ions released to the environment has been increasing significantly, resulting from industrial activities and technological developments[Ref]. Heavy metal ions present in waste waters are released by various industries such as mining, electroplating, electronic equipment and battery manufacturing processes [8].Effluent treatment has become important because of its possible environmental impact as well as its possible adverse effects on human health. [1].Heavy metals like chromium, nickel, zinc and copper[ref] are at elevated concentrations, detrimental to human health as well as ecosystem stability and threshold limits have been set for these metals for waste water discharged into environment. In order to reduce pollution, contaminated waters need to be cleaned [2].

The effects of too much Zinc can still cause eminent health problems, such as stomach cramps, skin irritations, vomiting and respiratory disorders[ref]. Therefore these waste waters are to be treated using low cost methods [3]. Many conventional methods are available like ion exchange, electrolysis, membrane filtration, chemical precipitation etc. [ref]for removing of metal ions from industrial effluents. Therefore, these are not suitable for the small scale industries [3].Compared with conventional methods for the removal of toxic metals from waste water by using low cost adsorbents have several advantages such as low operating cost, minimization of chemical sludge, high efficiency of heavy metal removal from diluted solutions, regeneration of biosorbents, possibility of metal recovery and environmental friendly [4].

MATERIALS AND METHODS:

All the chemicals used in this study were of analytical grade and they were from SD Fine Chemicals Limited (Chennai, Tamilnadu, India). Concentrations of zinc were measured by double beam Atomic Adsorption Spectrophotometer (AA-6300), pH measurements were made with pH meter (ELICO, LI 613).

PREPARATION OF TREATED ADSORBENTS:

Both the adsorbents flyash and bagasse were grounded separately and sieved. The size of the particles of 0.5-1 mm were taken after sieving. These were washed thoroughly with distilled waterand dried at room temperature (32 ±1°C) for 48 h such that weight of the adsorbents remains same. This is done toavoid the release of color of adsorbent into the aqueous solution. Further the adsorbents were treated with concentrated sulphuric acid (0.1N) and was maintained at 150°C for 24 h. In order to remove acid traces these particles were washed again with distilled water.

ZINC SOLUTION PREPARATION:

Stock solutions of zinc were prepared by dissolving a weighed quantity of zinc sulfate ($ZnSO_4$ $7H_2O$)in distilled water. Before the adsorption study, the pH of the prepared zinc solution was adjusted using 0.1N $H_2SO_4$and 0.1 N NaOH solutions as per the required value.

BATCH ADSORPTION STUDIES:

The batch experiments are carried out in 250 mL borosil conical flasks by stirring a pre-weighed amount of the adsorbent with 100 mL of the aqueous zinc solutions of known concentration and pH. The metal solutions were agitated in a rotary shaker at 120 rpm for a desired time interval. The samples were withdrawn from the shaker at the regular time intervals and adsorbent was separated by filtrationusing filter paper. The experiments were carried out by varying the zinc concentration in the solution (50-500 mg/L), adsorbent dosage (0.2-1 g/100 mL), pH (2-10) and temperature (30-60°C) for 3 h contact time.

RESULTS AND DISCUSSION:

EFFECT OF CONTACT TIME:

The contact time was evaluated as one of the important parameter for the adsorption of zinc on adsorbent, initially optimum time required for the maximum adsorption was investigated. Fig 1 shows the percentage removal of zinc for initial concentration of 100 mg/L at 32 °C temperatureand 2 g/L adsorbent dose. The percentage removal was calculated using the following formula

$$\%\,Removal\ of\ zinc = \frac{(c_i - c_t)}{c_i} \times 100$$

Where Ciis the initial concentration of zinc in mg/L and Ctis the concentration of zinc in mg/L at time trespectively.The % removal of zinc increased with increase in contact time of10-150 min from 30-74% for fly ash and 32-78% for bagasse.

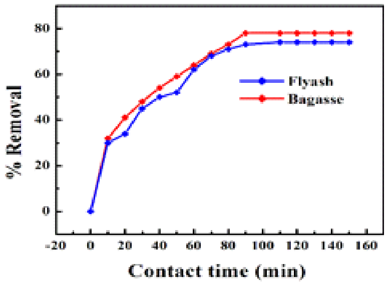

FIGURE 1. Effect of contact time

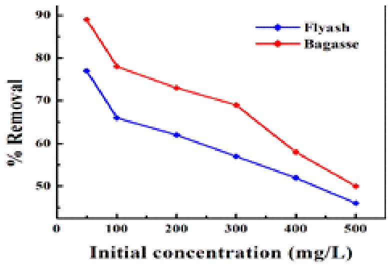

FIGURE 2. Effect of initial concentration

EFFECT OF INITIAL CONCENTRATION:

The initial zinc concentration in the aqueous solution effects the removal efficiency. Hence same aqueous solutions with different initial zinc concentrations ranging from50 -500 mg/L were agitated with adsorbent dosage of 2 g/L at 32 ^{0}C temperature and 150 min contact time. After completion of 150 min the percentage removal of zinc decreases from 77 to 46% for fly ash and 89% to 50% for bagasse with increase in initial zinc concentration. Fig 2 shows the effect of initial concentration on % removal for flyash and bagasse at fixed parameters. The amount of zinc adsorbed per unit mass of adsorbent (adsorption capacity, q_e) was calculated using the following equation

$$q_e = \frac{(C_i - C_e)}{m} \times V$$

Where C_i is the initial concentration (mg/L) of zinc, C_e is the concentration of zinc (mg/L) in solution at equilibrium, V is the volume of solution (L) and m is the mass of the adsorbent (g). Adsorption capacity q_e increases from 1.925 to 11.5 mg/g for flyash and 2.225 to 12.5 mg/g for bagasse with increase in initial zinc concentration. Fig 3 and 4 shows the effect of initial concentration on % removal as well as q_e for bagasse and flyash.

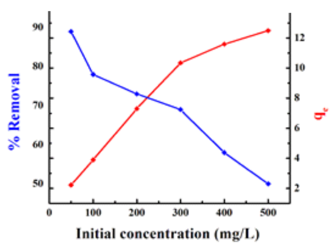

FIGURE 3. Effect of initial concentration (bagasse)

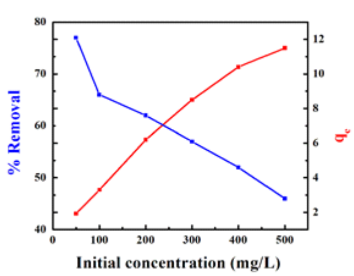

FIGURE 4. Effect of initial concentration (flyash)

EFFECT OF PH:

Adsorption of heavy metal ions depend on the pH of solution. The effect of pH on adsorption of zinc was investigated over the pH range of 2-10 with 2 g/L adsorbent dose, 150 min contact time, 32 ^{0}C temperature and 100 mg/L initial zinc concentration. The percentage removal of zinc increased up to pH 6 and then declined rapidly with further increase in pH for bagasse but in case offlyash percentage removal increased with increasing pH as shown in Fig 5. This phenomenon could be explained by increasing total net negative charges of surface adsorbent with intensified electrostatic forces in the adsorption process. Moreover with increasing pH, total number of negative groups available for the binding of metal ions increased and therefore competition between proton and metal ions became less pronounced. Similar findings were reported by Taty-Costodes *et al.*[6]. Therefore, all further studies were carried out at pH 6 for bagasse and flyash.

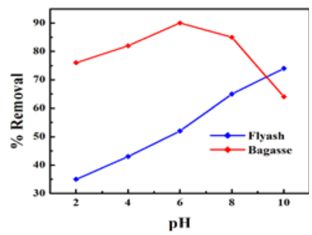

FIGURE 5. Effect of pH

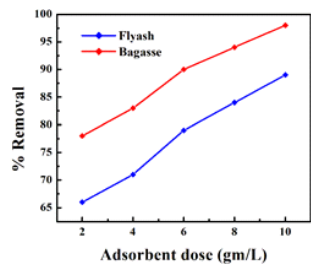

FIGURE 6. Effect adsorbent dose

EFFECT OF ADSORBENT DOSE:

Removal of zinc from aqueous solution increases with increase of adsorbent dosage. The percentage removal of zinc increased from 66% to 89% for fly ash and 78- 98% for bagassewith increasing adsorbent dose from 2-10 g/L at 32 ^{0}C, pH 6, 100 mg/L initial zinc concentration and 150 min contact time. It was due to the increasing surface area and available sites for adsorption of zinc ions. The adsorption capacity decreased from 3.3 to 0.81 mg/g for flyash and 3.9 to 0.94 for bagasse by increasing the adsorbent dose from 2 to 10 gm/L as shown in Fig 7 and 8.

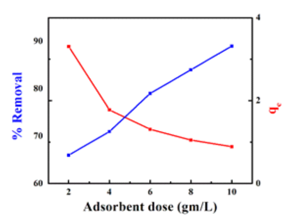

FIGURE 7. Effect of adsorbent dose (flyash)

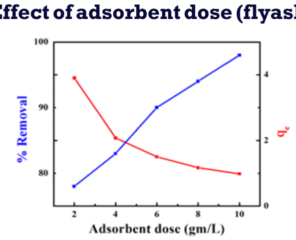

FIGURE 8: Effect of adsorbent dose (bagasse)

EFFECT OF TEMPERATURE:

Batch adsorption studies were conducted at 30, 40 and 50°Cto determine the effect of temperature on the adsorption of zinc on flyash and bagasse. The effects of temperature variation on the adsorption of zinc from aqueous solution were shown in Fig 9. Thepercentage removal for zinc increases along with an increase of temperature from 52 to 65 % for fly ash and 78 to 86 % for bagasse at pH 6, 100 mg/L initial concentration, 150 min contact time and 2 g/L adsorbent dose. The increase in adsorption intake with increase in temperaturewas indicating the adsorption process is endothermic in nature [3].

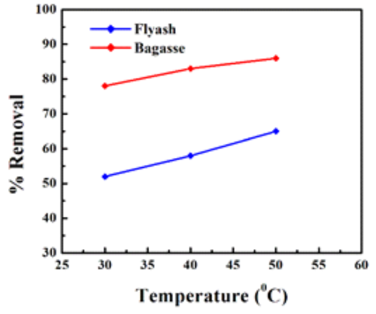

FIGURE 9: Effect of Temperature

ADSORPTION ISOTHERM MODELS:

In literature there are several isotherms available to interpret the factors effecting adsorption. In this study, Langmuir and Freundlichadsorption isotherms were tested to fit the experimental data.

LANGMUIR ADSORPTION ISOTHERM

Here the observed sorption of zinc ions was described by using Langmuir adsorption isotherm with the following equation.

$$\frac{C_e}{q_e} = \frac{1}{K_L q_m} + \frac{C_e}{q_m}$$

Rewriting the above equation as

$$\frac{1}{q_e} = \frac{1}{K_L q_m C_e} + \frac{1}{C_e}$$

Where q_m, K_L are langmuir constants, q_e is the amount of zinc adsorbed at equilibrium (mg/g) and $C_e$is the equilibrium concentration of zinc ions in solutions (mg/L).Fig 10 and are plots between (C_e/q_e) vs.(C_e) of bagasse and flyash, shows thatq_m is a measure of the monolayer adsorption capacity.

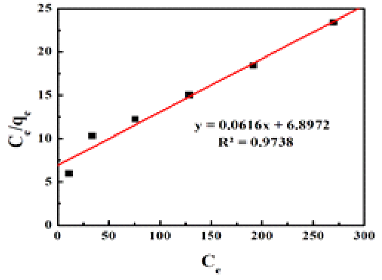

FIGURE 10: L-isotherm (flyash)

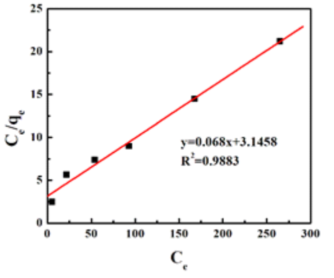

FIGURE 11: L-isotherm (bagasse)

FREUNDLICH ADSORPTION ISOTHERM

Freundlich adsorption isotherm model is used to explain the adsorption in aqueous systems and to explain the adsorption of zinc ions on the adsorbent. Freundlich isotherm is analyzed by the adsorption of zinc by using the same equilibrium data. Freundlich constants K_f and n are obtained by plotting the graph between log q_e vs. log C_e, as shown in Fig 12 and 13. Freundlich equation is

$$q_e = K_f C_e^{\frac{1}{n}}$$

Rewriting as

$$\ln q_e = \ln K_f + \frac{1}{n} \ln C_e$$

A high value of regression correlation coefficient (R^2=0.9902) is obtained for fly ash, was best fitted to Freundlich isotherm model. The dimensionless parameter R_L, which is a measure of adsorption favorability is found (0< R_L<1) which confirms the favorable adsorption process for removal of Zinc by flyash. R_L, also known as the separation factor [7], given by

$$R_L = \frac{1}{1 + K_L C_0}$$

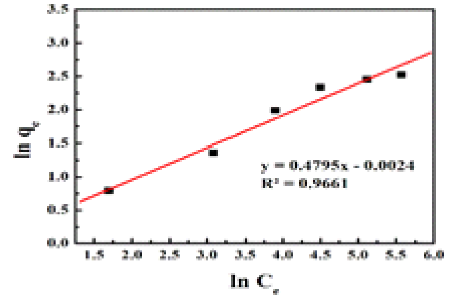

FIGURE 12. F-isotherm (bagasse)

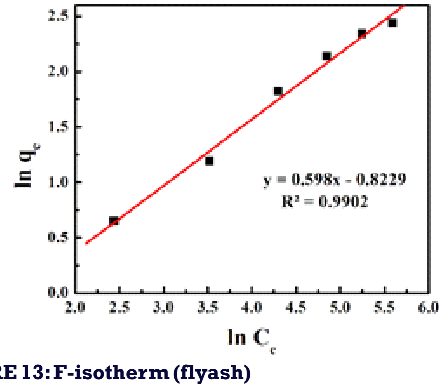

FIGURE 13: F-isotherm (flyash)

CONCLUSIONS:

This study indicates that flyash and bagasse has rapid adsorption rate as well as good adsorption capacity for zinc. The zinc adsorption was found to be dependent on initial concentration, pH, contact time, adsorbent dose and temperature. The adsorption of zinc was found to be fitted the Langmuir isotherm model for bagasse and Freundlich for flyash, which suggests monolayer coverage of adsorbent surface. This work showed that flyash and bagasse could be used as a good adsorbent material for Zinc removal from dilute aqueous solution. Flyash and bagasse are readily obtained, and they were considered as waste products. These materials were cheaper and environmental friendly alternatives. In this way, their use should be seriously considered for this task.

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