

# Use of activated red mud for removal of phosphate and selenite from aqueous solutions

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## ABSTRACT

*Red mud, a voluminous waste produced from alumina industry, mainly consist of oxides of aluminium, iron, titanium and silicon as major and oxides of calcium and sodium as minor constituents. Due to its fineness and active surface sites it can be used to absorb heavy metal ions present in industrial effluents. It is activated by different methods and used for removal of phosphate and selenite ions from aqueous solutions. Adsorption experiments were conducted to obtain the optimum conditions of pH, temperature, concentration of absorbate and amount of adsorbent. Applicability of Langmuir as well as Freundlich isotherms to the process was studied. Activated red mud samples produced from simple treatment with 20% HCl with and subsequent ammonia precipitation showed highest adsorption capacity for both the ions. An increase in absorption capacity with increase in absorbate concentration and vice-versa were also observed. However, with increase in temperature, an increase in the percentage of adsorption for phosphate and decrease for selenite ions were observed. The adsorption capacity of the activated sample was correlated with the surface properties. The activated sample can be effectively used for the removal of phosphate and selenite ions from aqueous solutions.*

**Keywords :** Red mud activation, Phosphate/Selenite ion removal, Active surface sites.

## INTRODUCTION

The problem of solid waste disposal has now attained complex dimensions. It has become essential either to find suitable ways for safe disposal or to suggest novel uses considering them as by-products. Otherwise, this will remain as an accumulated waste contributing significantly to environmental pollution<sup>[1]</sup>. Red mud is a waste material from alumina industry which contains mainly the

oxides of iron, aluminium, silicon, titanium, sodium and calcium. Although several processes are patented on the use of red mud, none of them are actually practised either due to technical problems or adverse economy. Adsorption of heavy metal ions on oxide material surfaces has received considerable attention. Studies on the use of red mud as an adsorbent for toxic heavy metal ions are limited and inconclusive. An attempt is made here to prepare activated red mud out of red mud from the Bayer's process and use it as an adsorbent for phosphate and selenite ions in aqueous media. Adsorption of phosphate and selenite ions were investigated as a function of time, pH, temperature, amount of adsorbate and adsorbent concentration.

## **MATERIALS AND METHOD**

### **Preparation of Activated Red Mud**

Activated red mud (ARM) was prepared by selectively dissolving iron oxides present in red mud in hydrochloric acid and subsequently precipitating with ammonia and drying at 110°C. The process is similar to that reported earlier<sup>[2]</sup>. All the chemicals used for adsorption experiments were of analytical grade.

### **Adsorption Experiments**

The experiments were carried out in 100 ml stoppered conical flasks in acetic acid - sodium acetate buffer medium<sup>[3]</sup>. The ionic strength of the medium was maintained by 1M KCl. After gentle shaking of the flasks for the stipulated contact time in a mechanical shaker, the contents were filtered through G4 crucible. The filtrates were collected and the concentration of phosphate<sup>[4]</sup> and selenite<sup>[5]</sup> were determined spectrophotometrically at 440 nm and 290 nm respectively.

Each run was made in duplicate. All the pH measurements were made by an Elico-digital pH meter (model LI-120) using a combined glass electrode (model CL-51). All the spectrophotometric measurements were made with a Chemito-2500 recording UV-visible spectrophotometer using 1 cm matched quartz cells. The percentage of adsorption were determined from the ratio of the concentrations of ions present in the solution and particulate phases.

## **RESULTS AND DISCUSSION**

### **Effect of Contact Time**

The kinetics of adsorption of phosphate and selenite ions at pH 5.2 showed that equilibrium was attained at about six hours and one hour respectively

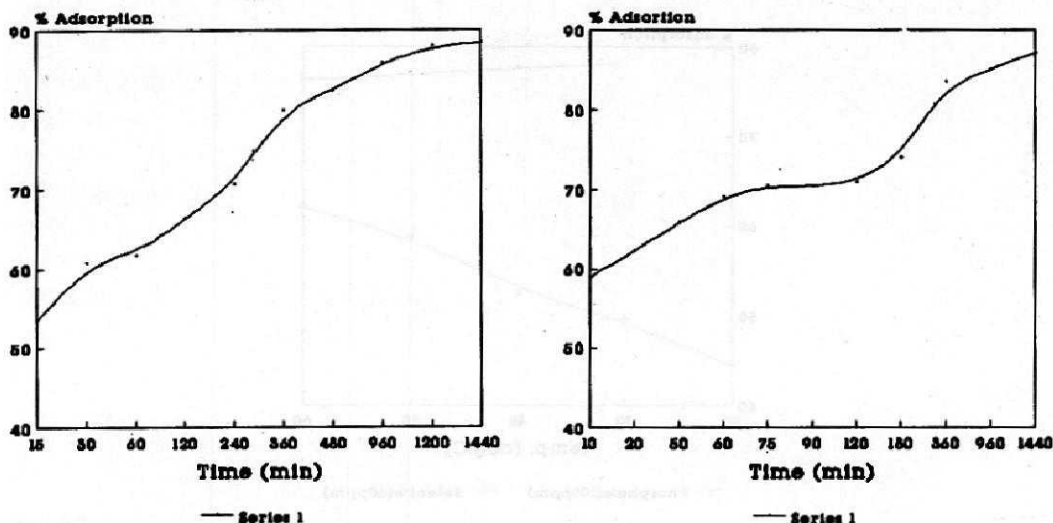


Fig. 1 : (a) Variation of adsorption with time (for phosphate),  
(b) Variation of adsorption with time (for selenite).

[Figs. 1(a) and 1(b)]. No further change in equilibrium concentration was observed for both the ions upto 24 hours.

### Effect of pH

The effect of pH on removal of phosphate and selenite ions were studied by keeping the ARM dosage, concentration of adsorbate and contact time constant

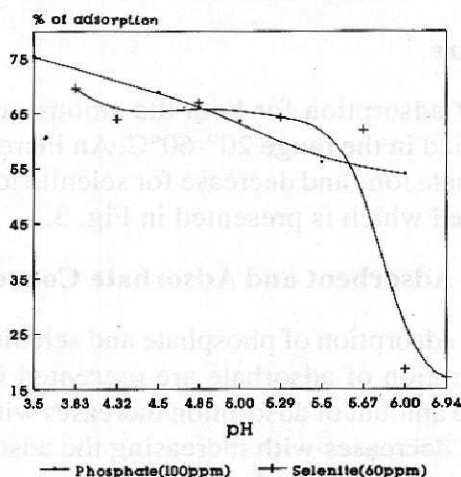


Fig. 2 : Variation of adsorption with pH.

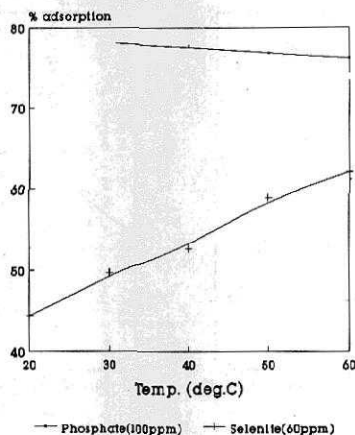


Fig. 3 : Variation of adsorption with temperature.

(Fig. 2). For phosphate ion a steady decrease in the percentage of adsorption with increasing pH was observed. For selenite ion, with increasing pH a sudden decrease in adsorption at pH 5.8 and almost negligible adsorption at pH 6.8 were observed. According to the anion adsorption reactions, an increase in pH should decrease in the amount of anion adsorption. This trend is indeed observed for both the ions in activated red mud. The observation is consistent with previous results of anion adsorption over metal oxides reported earlier [5-9].

### Effect of Temperature

The percentage of adsorption for both the anions on ARM as a function of temperature was studied in the range 20°-60°C. An increase in the percentage of adsorption for phosphate ions and decrease for selenite ions with increasing temperature were observed which is presented in Fig. 3.

### Effect of Amount of Adsorbent and Adsorbate Concentration

The percentage of adsorption of phosphate and selenite with varying amounts of ARM and concentration of adsorbate are presented in Figs. 4 and 5 respectively. As expected the amount of adsorption increases with increasing the amount of adsorbent whereas decreases with increasing the adsorbate concentration for both the ions indicating that the adsorption depends upon the availability of binding sites for the ions.

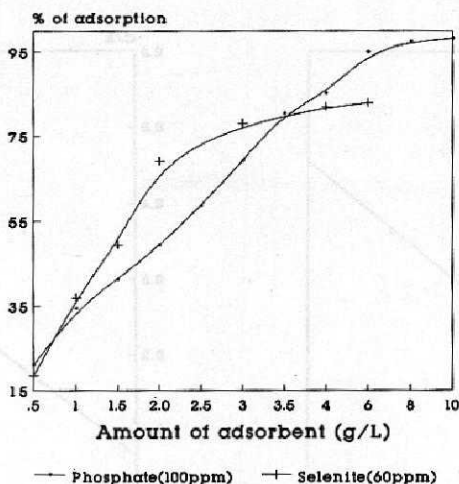


Fig. 4 : Variation of adsorption with amount of adsorbent.

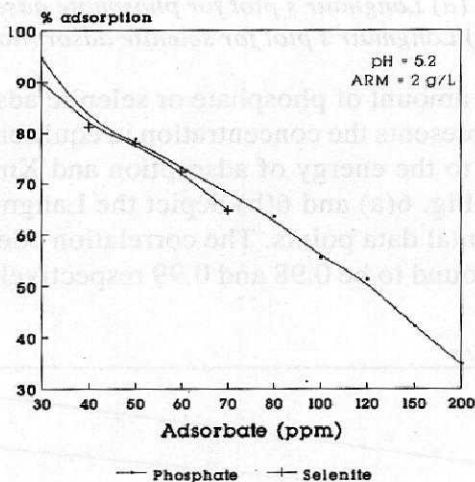


Fig. 5 : Variation of adsorption with adsorbate concentration.

## Adsorption Isotherms

Adsorption isotherm for both the ions on ARM are drawn for fixed adsorbent dose (2 gm/l) and varying initial adsorbate concentration for one hour contact time at pH 5.2. In order to determine the adsorption capacity of the sample, the equilibrium data for adsorption were analysed in the light of adsorption isotherm models. The experimental data points were fitted to Langmuir equation:

$$C/X = 1/bX_m + C/X_m \quad \dots \quad (1)$$

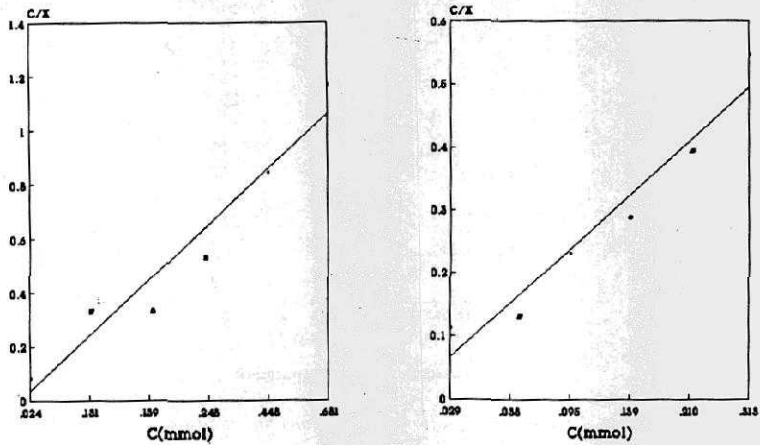


Fig. 6 : (a) Langmuir's plot for phosphate adsorption.  
(b) Langmuir's plot for selenite adsorption.

where  $X$  indicates the amount of phosphate or selenite adsorbed per unit weight of the adsorbent,  $C$  represents the concentration in equilibrium solution,  $b$  stands for a constant related to the energy of adsorption and  $X_m$  is the adsorption capacity of the sample. Fig. 6(a) and 6(b) depict the Langmuir plot between  $C/X$  vs  $C$  for the experimental data points. The correlation coefficient for phosphate and selenite ions are found to be 0.98 and 0.99 respectively. Values of  $X_m$  and  $b$

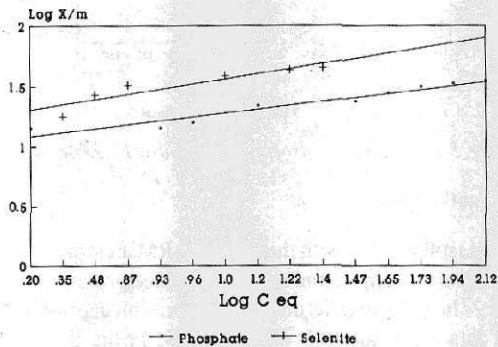


Fig. 7 : Freundlich plot for phosphate and selenite ions.



parameters of the Langmuir equation for phosphate ion are slightly higher than those for the selenite ion.  $K_a^{10}$ , the apparent equilibrium constant corresponding to the adsorption process can be calculated as the product of Langmuir equation parameters  $b$  and  $X_m$ . It was found to be 6.23 mmol/g for phosphate and 4.07 mmol/g for selenite.

The adsorption values plotted in Fig. 7 are calculated using Freundlich equation:

$$\text{Log } X/m = K + 1/n \text{ Log } C_e \quad \dots \quad (2)$$

where  $X/m$  is the amount of anion adsorbed per unit weight of adsorbent (mg/gm),  $C_e$  is the concentration of adsorbate at equilibrium (mg/l) and  $n$  and  $K$  are constants. The straight line nature of the graphs indicate that the adsorptions confirm to Freundlich model.

## CONCLUSIONS

On the basis of the reported results here and discussions the following conclusions can be drawn.

1. Red mud, a waste from the alumina industry, needs a simple treatment for activation.
2. Activated red mud, chiefly being a mixture of oxides and oxyhydroxides of alumina, iron, titania and silica, plays a significant role in the removal of phosphate and selenite from aqueous solutions.
3. The adsorption was favoured by low adsorbate concentration, acidic pH and room temperature.
4. This process can be extended to the treatment of aqueous industrial effluents for removal of phosphate and selenite ions.

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