

Phosphorus removal through adsorption on locally prepared adsorbents

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Abstract

Adsorbents were prepared from animal bones to adsorb phosphate from its aqueous solution. Samples were carbonised at 850°C in the muffle furnace and activated separately with three different activating chemicals namely KOH, H₃PO₄ and ZnSO₄. The work compares the activating efficiencies of different chemicals, the effect of contact time and particle sizes on the equilibrium sorption. The results show that within the first five minutes of the process, the removal efficiencies of the 0.5mm particle size adsorbents that were activated with H₃PO₄, KOH and ZnSO₄ were 49.93%, 48.64% and 47.42% respectively while those 0.8mm particle size adsorbents of the same order of activating chemicals were 49.64%, 47.13% and 45.63% respectively.

1. Introduction

Surface waters contain certain level of phosphorous in various compounds, which is an important constituent of living Organisms. However, the excessive release of phosphorous into the receiving waters such as lakes, rivers and streams promotes the growth of algae (eutrophication) and other undesirable vegetation (Song et al.,2000). The phenomenon of eutrophication usually prevents the recreational use of water due to the resulting obnoxious odours on decaying and, in addition the waters may be toxic to aquatic, domestic and wild animals (Design Manual, 1987).The load of phosphorous discharged due to receiving waters comes from various groups of sources of which the main sources are agricultural use of fertilizers, domestic and industrial waste waters and atmospheric deposition.

Treating or purifying these waste waters involves a number of unit processes depending on the quality of the water source, affordability and existing guidelines or standards(Jenkins et al.,1971). The cost involved in achieving the desired level of treatment depends among other things, on the cost and availability of chemicals. Commonly used chemicals for the various treatment units are synthetic organic and inorganic substances such as aluminium and iron salts, limes, polyelectrolytes e.t.c(Ueda et al.,1996). In many places these are expensive and they have to be imported in hard currency. Many of the chemicals are also

associated with human health and environmental problems(Jenkins et al.,1971) and a number of them have been regulated for use in water treatment systems. Natural materials can minimize or avoid the concerns and significantly reduce treatment cost if available locally. This work, therefore presents a study on the use of natural materials for adsorbing phosphate from its solution in an adsorption column.

2. Materials and Methods

2.1. Activated carbon from animal bones

Animal bones were collected from open market opposite Anambra State University, Uli campus. The bones were scrapped and washed with water to remove dirt and other impurities after which they were cut and ground before exposing it to sunlight for four weeks so as to reduce the moisture content. The sample was further dried in an oven at a temperature of 110°C for two hours before it was introduced into the hot zone of the muffle furnace for charring. The furnace temperature was increased at a temperature of 10°C/min from room temperature to 800°C and was held at this temperature for 3hrs. The charred product was allowed to cool down to room temperature, ground to workable size and sieved(Okeola,1999;Gimba,2001;Lyman,1978) size fraction of 0.5mm and 0.8mm were used.The next step involved purification of the sample in 0.5M hydrochloric acid solution followed by rinsing with

distilled water to remove the excess acid. The sample was then dried in the oven at 110°C for one hour (Okeola, 1999). Activation of samples was carried out using orthophosphoric acid (H₃PO₄); Potassium hydroxide (KOH) and Zinc Sulphate (ZnSO₄) separately as activating agents. 25.0g of each of the size fractions was put in separate beakers containing 500cm³ of 1.0M solution of activating reagent. The content of the beaker was thoroughly stirred and left for three hours before rinsing in deionized water to remove excess acid. Finally, the rinsed samples were dried overnight in an oven at 110°C, cooled at room temperature and packed in an air tight sample bag until use.

2.2. Determination of the pH of the adsorbent

5.0g of each of the samples was measured into a beaker and 100ml of distilled water was added to each of the samples. The mixture was manually well shaken and was left in the laboratory at room temperature for four days, after which the liquid was decanted and the pH of the aliquot was measured using hand pH meter.

2.3. Adsorption experiments

Adsorption experiments were carried out in a 50cm³ capacity burette as alternative to adsorption column. The burette was blocked at the bottom with cotton wool and filter paper to disallow the passage of granules of the adsorbent with the effluent. 5.0g of the adsorbents was put into the column (burette) and was filled with distilled water. The valve was adjusted to fix the rate of flow and the water was allowed to drain out of the column. Phosphate solution was prepared from the phosphate rock, which was obtained from Federal Superphosphate Fertilizer Company, Kaduna and was added into the column. At every five minutes interval, the effluent was sampled and its concentration checked using U.V spectrophotometer model spectrumlab 752S set at wavelength of 650nm. Constant dosage of the adsorbents was used throughout the experiment and the effects of the contact time, particle sizes and different activating agents were studied. The removal efficiency (E) of the adsorbent on phosphate was defined as

$$E(\%) = [(C_0 - C_1) / C_0] \times 100 \quad (1)$$

Where C₀ and C₁ are the initial and final concentration of phosphate in the influent and effluent solution (mg/l) respectively.

3. Results and discussion

3.1. Effect of contact time

From the obtained results presented in figs. 1 and 2 it was observed that within the first five minutes of the process, close to 50% of the initial phosphate concentration (C₀=1396mg/l) was adsorbed but as time passed, the efficiency began to decrease. This may be due to the fact that, initially the active sites of the adsorbents were fresh, so much of the solutes could be adsorbed very fast but as the sites are gradually becoming saturated with the adsorbates, the solute started escaping the surface of the adsorbent into the effluent solution thereby bringing about an increase in phosphate concentration in the effluent. In addition, high influent concentration might be another contributory factors as adsorption process is more suitable for purification of the solution with low concentration of pollutants (Metcalf and Eddy, 2003). Also, the nature of the phosphate rock which may contain trace elements and other impurities could lead to competitive adsorption (Manning and Goldberg, 1977). It was also interesting to observe that there were no significant variations between the results obtained for the effluent concentration at the set time intervals. The column capacity (50cm³ burette) and the fluid flow rate that could not be accurately controlled might be responsible for such effects.

3.2. Effect of particle size on sorption

Size fractions of 0.5mm and 0.8mm were used in this study. 0.5mm particle size adsorbents figs. 1 and 3 owing to the large surface area of their pores, were found to be higher in efficiency than the 0.8mm particle size adsorbents (figs. 2 and 3). The observation is similar in the case of all the four adsorbents used in this work.

3.3. The activating efficiency of different chemicals on the adsorbent

The adsorbents activated with orthophosphoric acid (H₃PO₄) show greater removal efficiency than those activated with ZnSO₄ and KOH respectively including C.A.C. The reason may be partly due to the fact that orthophosphoric acid is both a strong acid and an oxidizing agent. Thus, it may be able to open up and enlarge pores in the carbonized samples better than either ZnSO₄ or KOH. However, the adsorbent that was activated with KOH showed the least removal capability probably due to its high alkalinity nature.

4. Conclusion

The results obtained from this work show that adsorbents developed from common animal waste can be effectively used for adsorption of phosphate from its aqueous solution.

It was also observed that low cost adsorbents especially those activated with orthophosphoric acid have the potential to be economically viable in the treatment of waste waters with low concentration of pollutants where the discharge of such could create a problem in the receiving waters.

5. Nomenclature

C_0 : Initial influent concentration of phosphate solution (mg/l)

C_1 : Final effluent concentration of phosphate solution (mg/l)

C : Concentration of the adsorbate (mg/l)

CAC : Commercial activated carbon.

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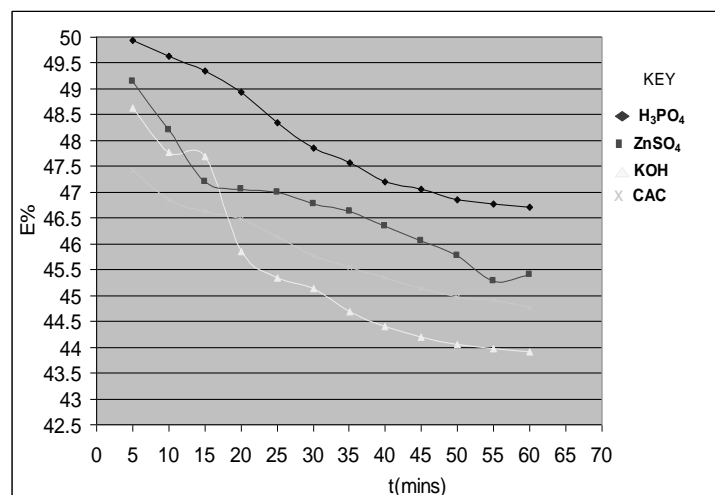


Fig.1. Comparison of contact time and percentage removal of phosphate with 0.5mm particle size adsorbent.

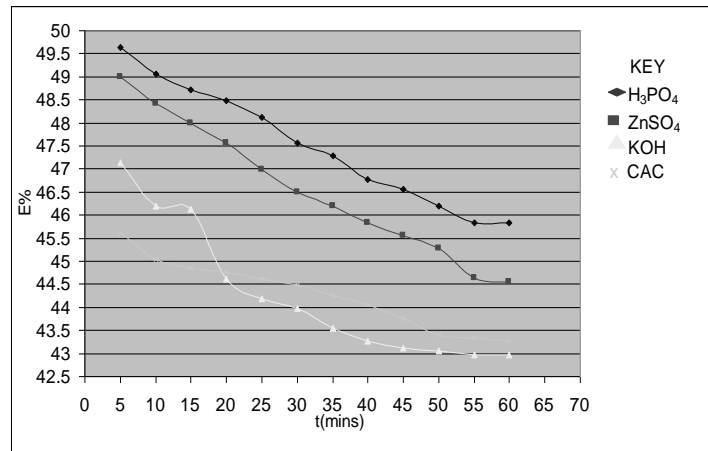


Fig. 2. Comparison of contact time and percentage removal of phosphate with 0.8mm particle size adsorbent.

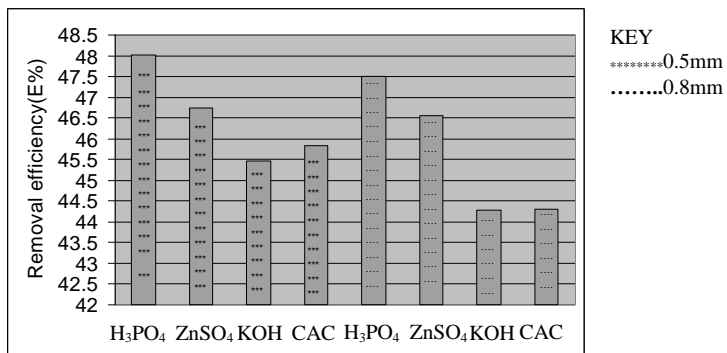


Fig. 3. Average removal efficiency of different adsorbents.