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Adsorption of Phosphate from Waste Water Using Aluminium Impregnated Coir Pith

Kailas S¹, Deepika S²

Assistant Professor, Department of Civil Engineering, Vidya Academy of Science and Technology Technical campus
Kilimanoor, Kerala, India¹

Assistant Professor, Department of Civil Engineering, Vidya Academy of Science and Technology Technical campus
Kilimanoor, Kerala, India²

ABSTRACT: The efficiency of Aluminium impregnated coir pith was investigated by column study for the removal of phosphate from its aqueous solution and waste water. The effect of various parameters such as pH, initial phosphate concentration and contact time were analysed with the help of an up flow reactor. The break through time was found increasing with increase in bed height. With the same bed depth, the adsorption capacity was found increasing with the usage of treated coir pith. Using treated coir pith, the maximum phosphate removal efficiency was obtained as 86% at pH of 6, initial phosphate concentration of 0.015 – 0.025 g/L and contact time of 40 minutes. Using raw coir pith, the maximum phosphate removal efficiency was found to be 53% at pH of 7, an initial concentration of 0.015g/L – 0.030g/L and contact time of 50 minutes. Kinetic studies revealed that the adsorption process better fitted with Freundlich adsorption isotherm.

KEYWORDS: Phosphate removal, Industrial waste water, Raw coir pith, Aluminium impregnated coir pith, Adsorption isotherm

I. INTRODUCTION

Phosphate is a major nutrient required for plants and microorganisms. But excess amount of phosphate (>1mg/L) in effluent discharge is often responsible for eutrophication of water bodies. (Metcalf & Eddy, INC. 2003, Rao Y. 1995) Algal blooms causing high economic damage in coastal oceans can be caused by phosphate runoff. It can disturb the balance of organisms present in water and can affect the water quality, mainly through the depletion of oxygen level thus affecting fishes and aquatic life. (H.D. Ruan, R.J. Gilkes. 2000). In many countries, stringent regulations limit phosphorous level to 0.05 mg/L to prevent algal bloom. (WHO 1993). Phosphate input into water bodies may be from point sources and non point sources. (K. Anoop Krishnan, Ajit Haridas. 2008) Various techniques have been developed for the removal of phosphate from water and wastewater. This includes chemical precipitation, adsorption using suitable materials, (A. Ugurlu, B. Salman 1998; R. Chitrakar et. Al 2006; D. Patureau et. al 2001) biological treatment and crystallization. (G.W.Vanloon 2001; E. Eggers 1991) Adsorption is a good technique for the removal of trace amounts of solute from aqueous solution. Low cost and locally available materials can be used as adsorbents to remove phosphate. The adsorption capacity of materials can be increased by activation process or by surface modification. The activation process enhances the pore volume and hence enlarges the diameter of the pores. During activation, the textural properties of materials may also change. (C Namasivayam 2006) Two most commonly employed activation techniques are chemical activation and physical activation.

Coir pith is an agricultural solid waste indigenously available in coconut fibre industries. It is a light fluffy material, which is generated in the separation process of the fiber from coconut husk. Annual production of coir pith is around 7.5 million tons. Coir pith accumulation around coir fiber industries is creating a menace. Surface modification is a recent technique, by which the uptake capacity of the adsorbent materials can be considerably and desirably

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increased. Surface modification implies the functionalisation of surface groups on the solid surface of the adsorbent with or without carbonization. The newly produced charged sites provide new sites for adsorption of solute from aqueous solutions. Treated coir pith was found to be two times more effective compared to that of raw coir pith in removing phosphate. Adsorption isotherms were drawn and the results better fitted with the Freundlich adsorption isotherm.

II. LITERATURE SURVEY

Anoop Krishnan and Ajit Haridas 2008 conducted a study on removal of phosphate using iron impregnated coir pith and concluded about 87% of phosphate removal efficiency. D A Georgantas 2007 conducted a study using alum and aluminium hydroxide for phosphate removal and reached a conclusion that alum is much more efficient in phosphorous removal than aluminium hydroxide with an efficiency of 87%. The optimal pH values are 5-6 in both cases, alum and aluminium hydroxide, although alum is efficient in a wider pH range (4-7) and a mechanism was proposed to interpret these results. C Namasivayam and D Sangeetha 2006 conducted a study on phosphate removal using zinc chloride activated coir pith and got an efficiency of about 74%. M M Mortula 2007 found that coir pith and oven dried alum sludge showed good phosphate adsorbing capacity. The objective of the study is to analyse the potential of aluminium impregnated coir pith on phosphate adsorption and also to study the effect of factors such as pH, initial concentration and contact time. The effect of bed depth on break through curve was also investigated. In this study a column reactor with raw and treated coir pith (used as adsorbents) is used for the removal of phosphorous and the effect of pH, initial phosphate concentration and contact time were analysed. In this study, surface modification was carried out using Al (III) salt solution.

III. MATERIALS AND METHODS

COIR PITH

Coconut coir pith was collected from a local coir pith unit, Kollam, (Kerala). The coir pith used in this study contains 29.6% of lignin and 35% of cellulose which is responsible for adsorption and is tabulated in Table 1.

Table 1 : Characteristics of coir pith

Parameter	Value
Lignin (%)	29.6
Cellulose (%)	35
Bulk density (g/cc)	0.097
Particle density (g/cc)	0.985
Particle size (micron)	344
Fat content (%)	1.8
Ash content (%)	8.7

The coir pith was given proper treatment such as washing, drying and sieving. Fresh wet coir pith was washed properly with water to remove adhered as well as soluble impurities. Then it was sun dried, slightly crushed and sieved to

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remove fibre particles so as to obtain Coir Pith (CP) for the modification process. In order to remove the coir fibres, it was sieved through 4.75mm sieve and then passed through 1.18mm for making it uniform in size. The raw coir pith thus obtained was then treated with 1M K_2HPO_4 in order to improve adsorption capacity. The treated coir pith thus obtained was finally dried at 70°C for 2 hours and preserved at room temperature in sealed bottles. The Scanning electron microscope (SEM) analysis of coir pith was done.

IV. ADSORBENT PREPARATION

The coir pith was soaked in aluminium sulphate solution for aluminium adsorption. About 600g of coir pith was soaked in one litre of 1N $Al_2(SO_4)_3$ solution and provided timely mixing for 24 hours for aluminium impregnation. For drying purpose, the beaker containing the pith was placed inside the oven for 4 hours at a temperature of about 160°C. It was washed with distilled water and filtered several times until all the physically adhered aluminium was removed. Finally the treated coir pith was stored in an air tight container.

Standard Phosphate solution

The stock solution of phosphate was prepared with $NaH_2PO_4 \cdot 2H_2O$ in distilled water. The experimental solution was prepared by diluting the stock solution to desired concentration using distilled water. HCl and NaOH solutions were used for pH adjustments. (APHA 2002)

Industrial waste water

The industrial waste water used in the study was collected from a Soap treating industry, in Quilon [Kerala]. The sample was alkaline due to the presence of strong alkalis such as NaOH and KOH and the sample was found to be highly turbid. The characteristics of the collected sample were determined using standard methods for the examination of water and waste water in the environmental engineering lab.

Experimental Setup

Column adsorption experiments were carried out to determine the effect of pH, initial phosphate concentration and contact time of Aluminium impregnated coir pith (CP-Al-I). The experimental setup is shown in fig. 1 which consists of a square glass column whose edges are filled inside with cementing material, having size of 2.5 cm in width and 40 cm in height was used in the study. The column was uniformly filled with dried CP-Al-I. The inlet of the column was supported by wire gauze stacked on an adaptor to prevent the loss of adsorbent.

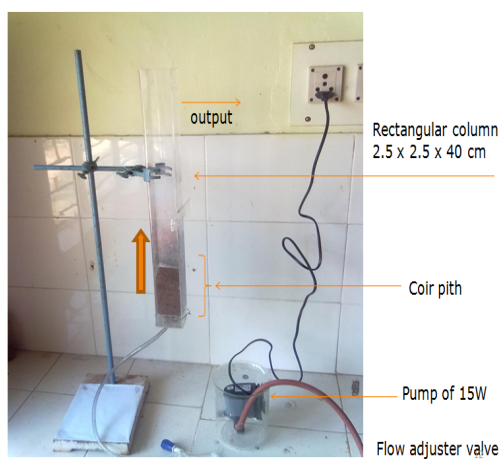


Fig. 1: Experimental Setup

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The coir pith was packed in the column between glass wool and glass beads, which prevented the wash out of coir pith. Up flow mode was used for the study using a pump of capacity 15W. A flow adjustor valve was also used for the study which was connected between the pump and the reactor. The top portion of the column was packed with glass wool material to prevent the escape of the adsorbent during the up flow mode.

Before operation, the bed was rinsed with distilled water and left overnight to ensure closely packed arrangement of particles with no void, channels, or cracks. The adsorbent was filled with a bed depth of 10cm and filling weight of 24.4 g in the column. The flow to the column was continued until the effluent concentration (C_t) approached the influent concentration (C_0), $C_t/C_0=0.9$. The study was conducted for varying depths up to 30 cm. The effluent samples were collected at specified time intervals and measured for the remaining phosphate by Spectrophotometer.

V. RESULTS AND DISCUSSIONS

Influence of pH on Phosphate adsorption

pH of the waste water is an important variable that influences the adsorption of anions and cations at the solid liquid interface. Fig. 2 shows the variation of pH in phosphate adsorption. Using treated coir pith, as the pH increased the percentage removal of phosphorous also increased. At higher pH, the phosphate removal efficiency reduced and at lower pH, more Al^{3+} ions were liberated and the phosphate molecules were absorbed into the active sites of the adsorbent. Maximum phosphate removal efficiency of 75% was obtained at pH of 6. The above said conditions were maintained for raw coir pith also, and it showed better phosphate removal efficiency at pH values between 5 and 7. Comparing both the results it was found that treated coir pith was around two times more efficient compared to that of raw coir pith.

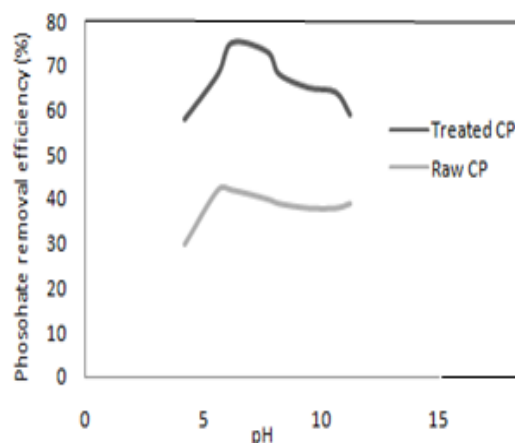


Fig. 2: Influence of pH on phosphate adsorption

Influence of Initial phosphate concentration on phosphate adsorption

Effect of initial phosphate concentration in the adsorption phenomenon was studied using different phosphate concentration varying from 10 mg/L to 60 mg/L. The effect of initial phosphate concentration on phosphate removal is shown in Fig. 3. Using treated coir pith, phosphate removal efficiency was found to be 83%. The effective initial phosphate concentration ranged between 15 mg/L to 30 mg/L. For the removal efficiency to be maximum the pH was optimised at 6.2 and further studies showed that the removal efficiency reached upto 83%. Raw coir pith showed removal efficiency of only 49% due to the non exposure of active sites of adsorbent

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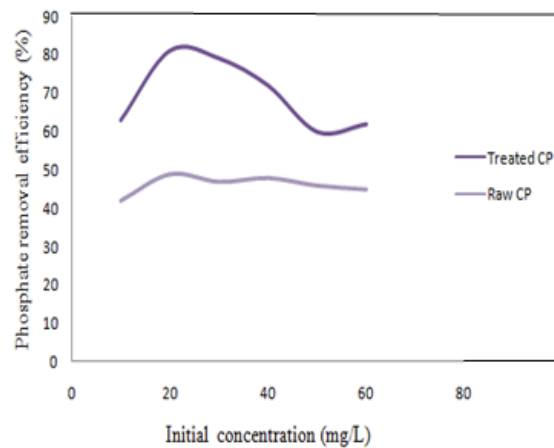


Fig. 3: Influence of initial phosphate concentration on phosphate adsorption

Influence of contact time on phosphate adsorption

Studies were further conducted by applying the optimum conditions for pH and initial phosphate concentration. Figure 4 shows the effect of contact time on phosphate removal efficiency for both treated and raw coir pith. Treated coir pith showed a removal efficiency of about 87% in 40 minutes. As contact time increased more phosphate molecules got adsorbed into the coir pith particles. Raw coir pith also showed better results of phosphate removal. Raw coir pith showed a maximum removal efficiency of 53% at 50 minutes.

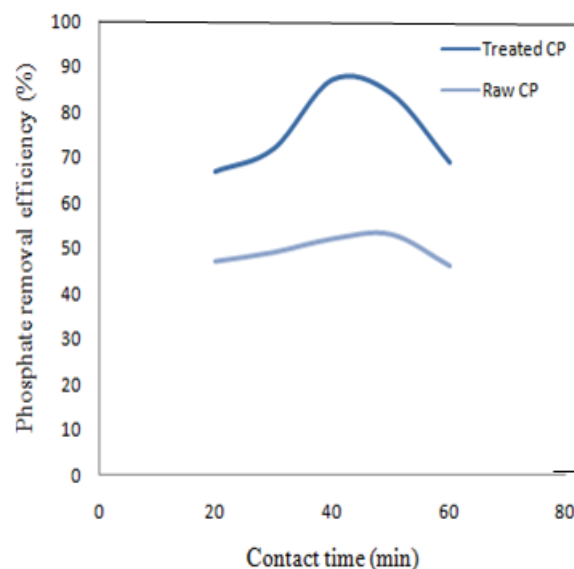


Fig. 4 Influence of contact time on phosphate adsorption

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Effect of bed depth on break through curves

The column experiments were conducted with 10 ppm solutions at bed depths (z) of 10, 20 and 30 cm respectively maintaining a constant flow rate of 10 ml/min. The effect of depth on the break through curve was investigated. The results show that the shape as well as gradient of the break through curve varies slightly with the variation in depth. The break through time (t_b) corresponds to $C_t/C_0=0.05^{21, 22}$.

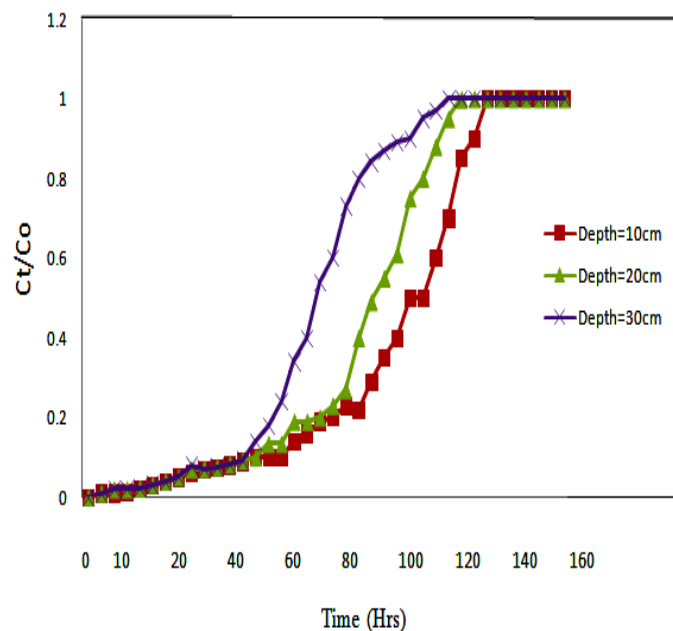


Fig. 5 Breakthrough curve for Raw coir pith

As seen in Figure.5, the break through time occurred at 2, 4.5 and 7 hrs for 10, 20 and 30 cm depth respectively when raw coir pith was used as adsorbent. An increase in bed depth increased the break through time. The lower the breakthrough time, the diffusion process becomes less effective resulting in lower adsorption. Thus adsorbent requires more time to bond the metals more efficiently.

The break through time was at 3, 7 and 10 hours for corresponding depths when treated coir pith was used as adsorbent as in Fig.6. The result indicated that the break through time (t_b) increased with increase in bed depth. For the same depth, break through time and exhaustion time (at $C_t/C_0= 0.9$) were found still increased by the use of treated coir pith. (Runping Han 2009)

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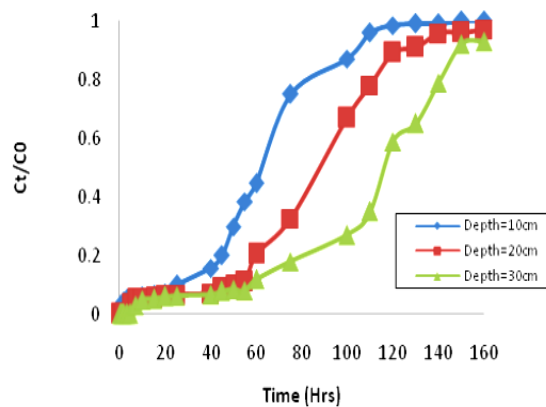


Fig. 6 Breakthrough curve for treated coir pith

Phosphate Adsorption Kinetics

Freundlich adsorption isotherm and Langmuir adsorption isotherm were used to study the adsorption kinetics of phosphate removal. The results better fitted with Freundlich adsorption isotherm for the study. Fig. 7 shows Freundlich adsorption isotherm for the study and the general relation for the same is given as equation (1).

$$\text{General form of the equation is } x/m = k C_e^{(1/n)} \text{ -----(1)}$$

Where x = adsorbed quantity
 m = adsorbent quantity
 x/m = mass of adsorbate adsorbed per unit mass of adsorbent
 c = unadsorbed concentration left in the solution.

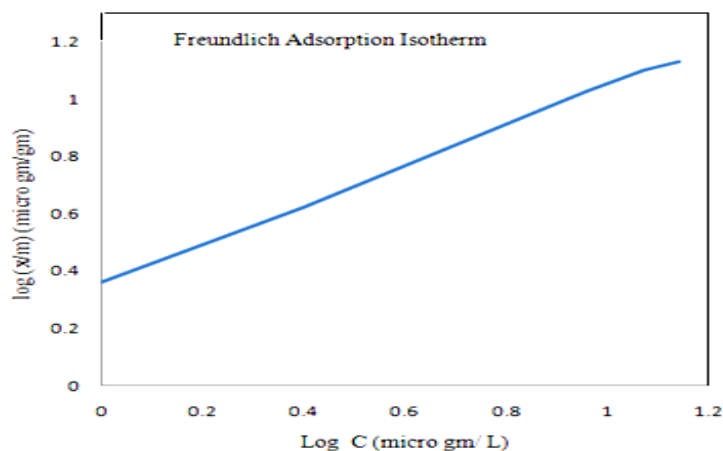


Fig. 7: Freundlich adsorption isotherm

$$\log k = 0.36, k = 2.30, 1/n = 1.13, x/m = k C^{(1/n)}, x/m = 2.30 C^{(1.13)}$$

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VI. CONCLUSIONS

Aluminium impregnated coir pith was found to be a suitable adsorbent for the removal of phosphate from both aqueous solutions and industrial waste water. The adsorption process is dependent on pH of the solution and phosphate removal efficiency was obtained at pH 6. The adsorption mechanism for the removal of phosphate can be described by ligand exchange reaction between the coordinated OH groups and the phosphate ions. Column adsorption was found to be very effective in the removal of phosphate from aqueous solutions. Using treated coir pith, the maximum phosphate removal efficiency was obtained as 86% at pH of 6, initial phosphate concentration of 15 – 25 mg/L and contact time of 40 minutes. Using raw coir pith, the same was obtained as 53% at pH of 7, initial phosphate concentration of 15 mg/L – 30 mg/L and contact time of 50 minutes respectively. The breakthrough time increased with increase in bed depth. For same bed depth, treated coir pith shows higher breakthrough time as compared with that of raw coir pith. The above data better fitted with Freundlich adsorption isotherm compared to Langmuir adsorption isotherm which indicates double layer adsorption. Comparing the results of this experimental study with other case studies, it was found that aluminium impregnated coir pith showed almost similar phosphate removal efficiency with that of iron and zinc impregnated coir pith. Coir pith as a low cost, easily available and comparatively high heavy metal removal efficiency not only reduces the cost of waste water management but also adds value to waste.

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BIOGRAPHY



KAILAS S is a Post Graduate in Environmental Engineering, from College of Engineering Trivandrum, currently working as Assistant Professor in Department of Civil Engineering at Vidya Academy of Science and Technology Technical campus Kilimanoor, Trivandrum. He has more than five years of teaching experience. His Research interests are Bioremediation, Adsorption of heavy metals etc.



DEEPIKA S is a Post Graduate in Environmental Geotechnology from National Institute of Technology Calicut, currently working as Assistant Professor in Department of Civil Engineering at Vidya Academy of Science and Technology Technical campus Kilimanoor, Trivandrum. Her research interests are in the field of Geotechnical Investigation methods and Environmental Engineering.