

Full Length Research Paper

Phosphate pollution control in waste waters using new bio-sorbents

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Thermally activated barks/stems and their ashes of *Ficus religiosa*, *Cassia auriculata*, *Punica granatum* and *Calotropis gigantean* are found to have remarkable affinity towards phosphate ions. The sorption characteristics of these bio-products towards phosphate from synthetically prepared waste waters have been studied with respect to various physicochemical parameters such as pH, sorption concentrations and equilibration times. Phosphate removal is found to be pH sensitive and also depends upon equilibration time and sorption concentration. Conditions have been optimized for the maximum extraction of phosphate; not less than 87% removal is noted in these sorbents. The sorption concentration needed for the maximum removal of phosphate is less for ashes of bark/stems than powders of bark/stem. The interferences of ten fold excess of foreign anions like chlorides, sulphates, nitrates, fluorides and carbonates are marginal. Cations namely Ca^{2+} , Mg^{2+} , Cu^{2+} , Zn^{2+} , Fe^{2+} and Ni^{2+} , are synergizing the extraction of phosphate and hence % removal of phosphate is enhanced in their presence. The variations of D.O., BOD, COD, color and turbidity of the water samples after extractions with the successful sorbents developed in this work, are found to be within the permissible limits of water quality standards.

Key words: Phosphate pollution control, bio-sorbents, *Ficus religiosa*, *Cassia auriculata*, *Punica granatum* and *Calotropis gigantean*.

INTRODUCTION

Phosphate pollution in natural waters bodies is attributed to agricultural run offs, domestic and industrial sewages (Gerard, 1998; Tchobanoglous et al., 2003). Excess concentrations of phosphate, cause eutrophication in lakes. This process leads to the depletion of dissolved oxygen levels in water, resulting in the loss aquatic life (Ames et al., 1970; Batchelor et al., 1987; Zhao and Sengupta, 1998; Kofinas and Kioussis, 2003).

Phosphate pollution is recognized as a major pollution problem throughout the world and some countries introduced phosphate control acts and in fact, the Switzerland banned the use of phosphate in detergents. Hence, increasing research interest is being envisaged in developing new methodologies in controlling phosphate

pollution (Gerard, 1998; Tchobanoglous et al., 2003).

Traditionally phosphate is removed by chemical precipitation (Ames et al., 1970; Brattebo et al., 1986; Batchelor et al., 1987; Huang, 2000; Yee, 1966; Sona et al., 2004). Biological treatment methods coupled with active sludge processes are thoroughly being investigated in controlling the problem of phosphate pollution and in fact, a number of patents exist in this regard (Kioussis et al., 1999; Unnithan et al., 2002; Gerard, 1998; Baker et al., 1998; Huang and Chiswell, 2000; Tchobanoglous et al., 2003; USA Patents: 7285215, 2007; 4183808, 1980 and 6881346, 2005).

The use of biomasses or bio-wastes of flora or fauna origin in controlling the pollution either in their native state or chemically modified, by evoking their surface sorption phenomenon, is another new trend in this aspect of research (Amir et al., 2005; Chubar et al., 2003; Dakiky et al., 2002; Iqbal et al., 2002; Shrihari and Raghavendra,

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2003; Majeti and Kumar, 2000; Oklieimen and Onyenkpa, 1989; Orhan et al., 1993; Thomas et al., 2005; Urano et al., 1991; Srinivasan et al., 1988; Singh et al., 2000; Shrihari et al., 2003; Shukla et al., 2002; Sandhya, 2003; LuzE and Yohr, 2004; Cesar and Marco 2004; Imran, 2006). Imran (2010) discussed the increasing quest for active carbon adsorbents for controlling the toxic pollutants in wastewaters. Inglezakis et al. (2003) have explored the surface properties of clinoptilolite in removing simultaneously metal ions: Cu^{2+} , Fe^{3+} and Cr^{3+} with anions: SO_4^{2-} and HPO_4^{2-} . Dinesh et al. (2006) have studied the phosphate removal by refined aspen wood fiber treated with carboxymethyl cellulose and ferrous chloride. Wood processing residues like sawdust, bark etc and some other agricultural residues like corncobs have been explored as bio-sorbents for controlling phosphate pollution (Shukla et al., 2002; Tshabalaka et al., 2004; Vaughan et al., 2001; Boujelben et al., 2008; Khan and Moheman, 2006; Han et al., 2003; Thomas et al., 2006). LuzE and Yoav (2004) discussed in their review article on the recent advances in removing phosphorus from waste water. Activated red mud has been used to remove phosphates from aqueous solutions (Shiao and Akashi, 1997; Yanzhong et al., 2006; Xin et al., 2011).

Bioremediation methods have been explored by various authors for the control of phosphate in polluted waters (Biswas et al., 2007; Heng et al., 2009; Akpor and Muchie, 2010; Lu and Huang, 2010; Ning et al., 2011; Zhang et al., 2011; Wilaiwan et al., 2010).

In the present work, barks or stems and their ashes of different plants for the removal of phosphates from polluted waters have been studied with respect to various physico chemical parameters and we tried to develop simple methodologies in controlling the phosphate pollution by evoking the sorption abilities of these bio-materials.

MATERIALS AND METHODS

Chemicals

All chemicals used were of analytical grade.

- 1) Stock solution of phosphate of 100 ppm concentration was prepared by dissolving requisite amount of A.R. grade potassium dihydrogen phosphate in a definite volume of double distilled water and it was suitably diluted as per the need.
- 2) Sodium molybdate solution: 12.5 g of sodium molybdate was dissolved in 500 ml of 10N. H_2SO_4 .
- 3) Hydrazine Sulphate solution: 1.5 g of Hydrazine Sulphate solution was dissolved in 1L of double distilled water.

Adsorbents

Diverse adsorbents of flora origin were used in this work. The stems/barks or their ashes of *F. religiosa*, *C. auriculata*, *P. granatum* and *C. gigantea* have been found sensitive to

phosphate ions (Figure 1). The methodology described hereunder pertains only to these sorbents.

F. religiosa plant is considered sacred by the followers of Hinduism, Jainism and Buddhism and it belongs to Moraceae family and is used in traditional medicine for about 50 types of disorders. *C. auriculata* is evergreen Indian shrub with vivid yellow flowers, belongs to *C. piniaceae* family and it grows in dry stony hills and is widely spread in central part of India and it possesses many medicinal properties. *C. gigantea* is a large shrub having traditional medicinal values, growing to 4 m tall and it belongs to Apocynaceae family and is widely grown in all types of soils. *P. granatum* is a fruit bearing deciduous shrub or small tree growing between five and eight meters tall and it belongs to Lythraceae family.

Barks or stems of *F. religiosa*, *C. auriculata*, *P. granatum* and *C. gigantea* were cut, washed with tap water and then with distilled water. Thus obtained plant extracts were air dried and powdered to a fine mesh of size: less than 75 microns and the powders were activated thermally at 120°C for four hours in an oven and were employed in this work. Further, these barks/stems were burnt to ashes and these ashes were also used in this work.

Adsorption experiment

The batch system of extraction procedure was adopted (Gerard, 1998; Tchobanoglous et al., 2003; Trivedy, 1995). Weighted quantities of adsorbents were taken into previously washed 1 L/500 ml stopper bottles containing 500/250 ml of potassium dihydrogen phosphate solution of predetermined concentrations. The various initial pH values of the suspensions were adjusted with dil. HCl or dil. NaOH solution using pH meter. The samples were shaken vigorously in mechanical shakers and were allowed to be in equilibrium for the desired time. After the equilibration period, an aliquot of the sample was taken for phosphate determination. Phosphate was determined spectrophotometrically by "molybdenum blue" method (Vogel, 1961).

Estimation of phosphate: An aliquot amount of phosphate sample was taken in a 50 ml volumetric flask. To it 5 ml each of molybdate solution and hydrazine sulphate solution were added successively and the solution was then diluted to the volume and mixed well. The flask was immersed in a boiling water bath for 10 min, removed and cooled rapidly. The flask was shaken and adjusted the volume. Blue color was developed. Optical density was measured at 830 nm against a reagent blank using U.V and visible spectrophotometer (Systonics make). Thus obtained optical density value was referred to standard graph (drawn between optical density and concentration) prepared with known amounts of phosphate by adopting method of least squares to find concentration of phosphate in unknown solutions.

Effect of interfering ions

The interfering ions chosen for study were the common ions present in natural waters, viz. Sulphate, fluoride, chloride, nitrate, carbonate, calcium, magnesium, copper, zinc, ferrous and nickel. The synthetic mixtures of phosphate and of the interfering ions were so made that the concentration of the interfering ion was maintained at 10 fold excess (500 ppm) than the conc. of Phosphates (50 ppm). 500 ml of these solutions were taken in stopper bottles and then correctly weighted optimum quantities of the promising adsorbents (as decided by the Graphs A1 to 8; B1 and 2; C1 and 2) were added. Optimum pH was adjusted with dil. HCl or dil. NaOH using pH meter. The samples were shaken in

*Ficus religiosa**Cassia auriculata**Calotropis gigantean**Punica Granatum***Figure 1.** Plants explored for their affinity towards sorption of phosphates.

shaking machines for desired optimum periods and then small portions of the samples were taken out, filtered and analyzed for Phosphate. Percentage of extraction was calculated from the data obtained.

Effect of extractions on the other parameters

The synthetic water samples after extraction of phosphate with the successful sorbents developed in this work, at the optimum conditions of pH, time of equilibration and sorbents concentration, were filtered. Thus filtered water samples were analyzed for DO, BOD, COD, color and turbidity using standard procedures described elsewhere (APHA: 1998). The results are presented in the 4 to 7 columns of Table 1.

RESULTS AND DISCUSSION

The percentage removal of phosphate is studied under various parameters viz., time of equilibration, pH and

interfering ions with the promising adsorbents: thermally activated barks/stem powders or ashes of *F. religiosa*, *C. auriculata*, *P. granatum* and *C. gigantean*. The results obtained are presented in the Graphs A1 to 8; B1 and 2; C1 and 2 and Table 1.

The following observations are significant:

Effect of equilibration time: Percentage of extraction of phosphate increases with time for a fixed adsorbent at a fixed pH and after certain duration, the extractability remains constant, that is, an equilibrium state has been reached. In other words, there will not be any further adsorption after certain time of equilibration (Graphs A1 to 8).

Effect of pH: The extractions are found to be pH sensitive. As pH increases, the maximum extractability of

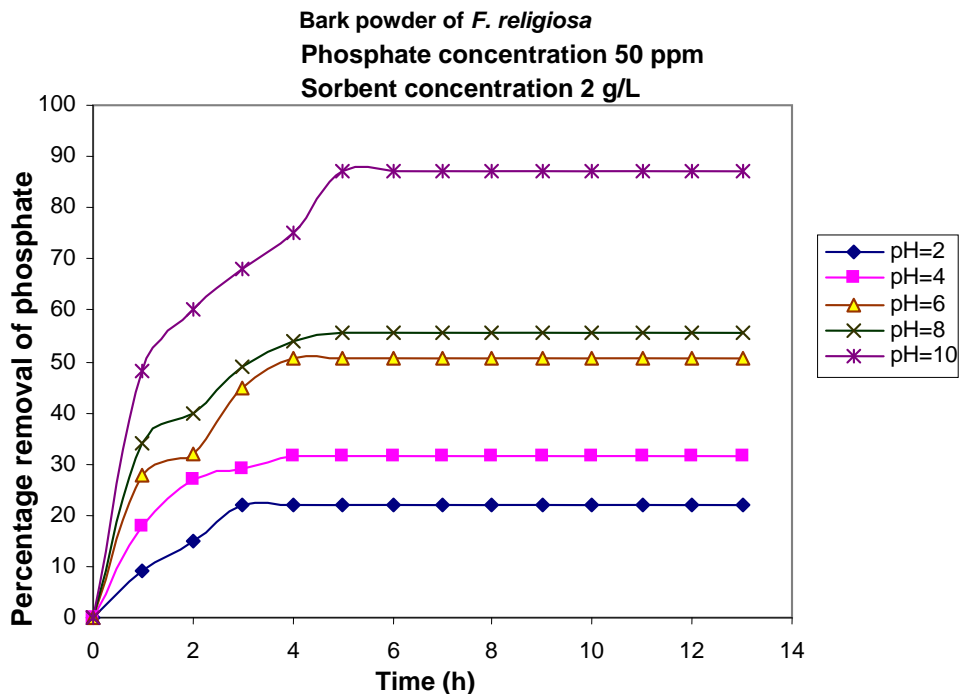
Table 1. Effect of interfering Ions on the extractability of phosphate.

S/No.	Adsorbent	Max. extraction at optimum conditions	D.O/ BOD/ COD (ppm)	BOD÷COD Ratio	Color in Hazen Units	Turbidity	Extractability of phosphate in presence ten fold excesses (500 ppm) of interfering ions at optimum conditions phosphate concentration :50 ppm										
							SO ₄ ²⁻	NO ₃ ⁻	Cl ⁻	F ⁻	CO ₃ ²⁻	Ca ²⁺	Mg ²⁺	Cu ²⁺	Zn ²⁺	Fe ²⁺	Ni ²⁺
1	Bark powder of <i>F. religiosa</i>	87.0%	4.5,	0.70	18	5.2 NTU	83.2%	84.9%	84.0%	85.9%	86.2%	90.3%	91.6%	95.9%	94.0%	96.5%	97.4%
		pH:10, 5.0 h	20.1 and 28.6				pH:10, 3.5 h	pH:10, 2.5 h	pH:10, 1.5 h	pH:10, 1.5 h	pH:10, 2.5 h	pH:10, 2.0h	pH:10, 3.0 h	pH:10, 3 h	pH:10, 2.0 h	pH:10, 2.5 h	pH:10, 4.5 h
2	Bark powder of <i>C. auriculata</i>	97.0%	5.1,	0.73	20	6.2 NTU	93.4%	93.5%	94.6%	95.0%	95.0%	98.5%	98.8%	99.2%	98.9%	99.0%	98.9%
		pH:10, 5.0 h	18.2 and 25.1				pH:10, 4.5 h	pH:10, 1.5 h	pH:10, 2.5 h	pH:10, 2.5 h	pH:10, 3.5 h	pH:10, 2.5 h	pH:10, 2.0 h	pH:10, 3.5 h	pH:10, 2.5 h	pH:10, 2.5 h	pH:10, 4.0 h
3	Bark powder of <i>P. granthusm</i>	89.0%	5.6,	0.68	17	3.8 NTU	85.0%	85.6%	86.0%	87.5%	87.2%	90.8%	91.9%	94.8%	93.4%	97.5%	94.9%
		pH:10, 5.0 h	16.1 and 23.6				pH:10, 3.0 h	pH:10, 2.5 h	pH:10, 2 h	pH:10, 2.5 h	pH:10, 2.0h	pH:10, 3.0 h	pH:10, 2.0 h	pH:10, 2.0 h	pH:10, 2.5 h	pH:10, 2.0 h	pH:10, 2.0 h
4	Stem powder of <i>C. zygantia</i>	90.0%	3.9,	0.59	23	6.1 NTU	84.6%	85.7%	86.7%	87.3%	86.4%	91.2%	92.2%	93.7%	94.8%	95.6%	94.2%
		pH:10, 5.0 h	15.4 and 26.2				pH:10, 2.0 h	pH:10, 2.0 h	pH:10, 3.0 h	pH:10, 3.5 h	pH:10, 3.0 h	pH:10, 2.5 h	pH:10, 4.0 h	pH:10, 1.5 h	pH:10, 3.5 h	pH:10, 2.0 h	pH:10, 2.5 h
5	Bark ash of <i>F. religiosa</i>	93.0%	4..9,	0.77	12	3.2 NTU	89.6%	90.5%	91.0%	92.1%	92.6%	93.8%	94.2 %	95.2%	95.8%	96.4%	95.7%
		pH:10, 5.0 h	7.1 and 9.2				pH:10, 3.0 h	pH: 10, 2.5 h	pH:10, 2.0 h	pH:10, 3.0 h	pH:10, 2.0 h	pH:10, 3.5 h	pH:10, 3.0 h	pH:10, 2.0 h	pH:10, 3.5 h	pH:10, 2.0 h	pH:10, 2.5 h
6	Bark ash of <i>C. auriculata</i>	100.0%	6.1,	0.86	13	2.1 NTU	95.3%	96.0%	96.5%	97.5%	97.5%	100.0%	100.0%	100.0%	100.0%	100%	100%
		pH:10, 4.0 h	5.2 and 6.6				pH:10, 1.5 h	H:10, 3.5 h	pH:10, 3.0 h	pH:10, 3.5 h	pH:10, 2.5 h	pH:10, 1.5 h	pH:10, 2.0 h	pH:10, 3.5 h	pH:10, 1.5 h	pH:10, 1.5 h	pH:10, 3.0h
7	Bark ash of <i>P. granthusm</i>	93.0%	6.4,	0.88	10	4.6 NTU	89.7%	91.0%	92.0%	92.6%	92.7%	94.8%	95.5%	96.7%	97.2%	98.3%	98.2%
		pH:10, 5.0 h	4.9 and 5.6				pH:10, 2.0 h	pH:10, 1.5 h	pH:10, 2.0 h	pH:10, 3.5 h	pH:10, 3.0 h	pH:10, 3.5 h	pH:10, 2.0 h	pH:10, 2.0 h	pH:10, 3.0 h	pH:10, 1.5 h	pH:10, 1.5 h
9	Stem ash of <i>C. gigantean</i>	94.0%	5.1,	0.90	15	5.3 NTU	91.2%	92.5%	92.3%	93.2%	93.4%	96.2%	96.8%	97.2%	98.8%	96.4%	97.5%
		pH:10, 5.0 h	4.6 and 5.1				pH:10, 3.5 h	pH:10, 2.0 h	pH:10, 1.5 h	pH:10, 2.0h	pH:10, 3.5 h	pH:10, 3.5 h	pH:10, 3.5 h	pH:10, 3.0 h	pH:10, 2.5 h	pH:10, 1.5 h	pH:10, 3.5 h

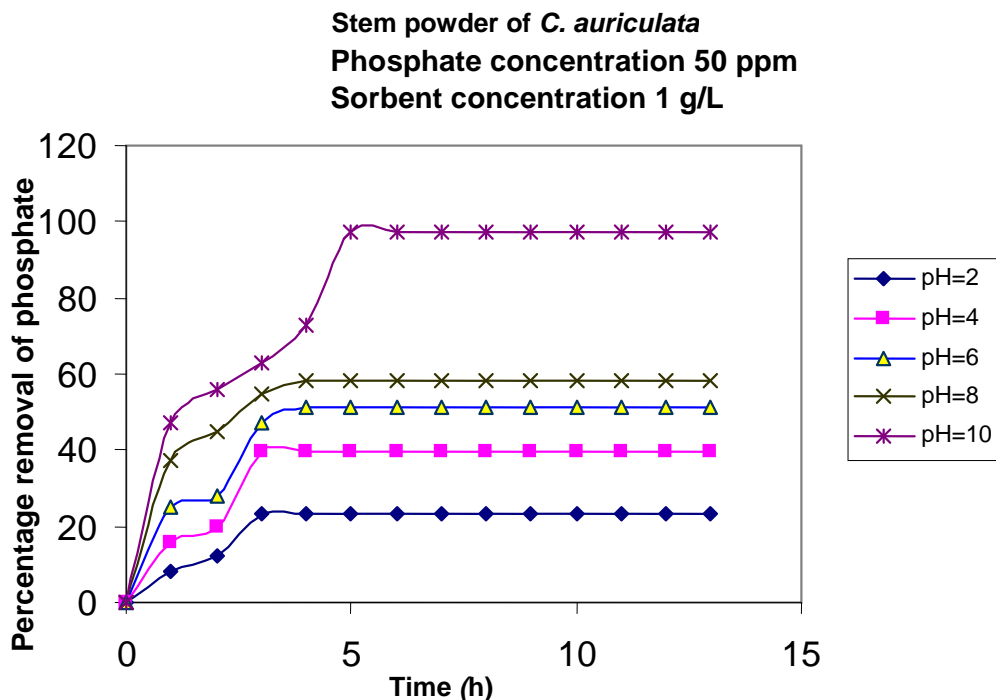
phosphate at optimum equilibration times, is increasing for a fixed adsorbent concentration (Graphs A1 to 8; B1 and 2).

a) In the case of bark powders of *F. religiosa*, the extraction is found to be 21.9% at pH 2; 31.6% at pH 4; 50.7% at pH 6; 55.6% at pH 8 and 87.0% at

pH 10 after 5 h of equilibration. The bark powder of *C. auriculata* is found to extract 23.5% at pH 2; 39.8% at pH 4; 51.2% at pH 6; 58.4% at pH 8 and



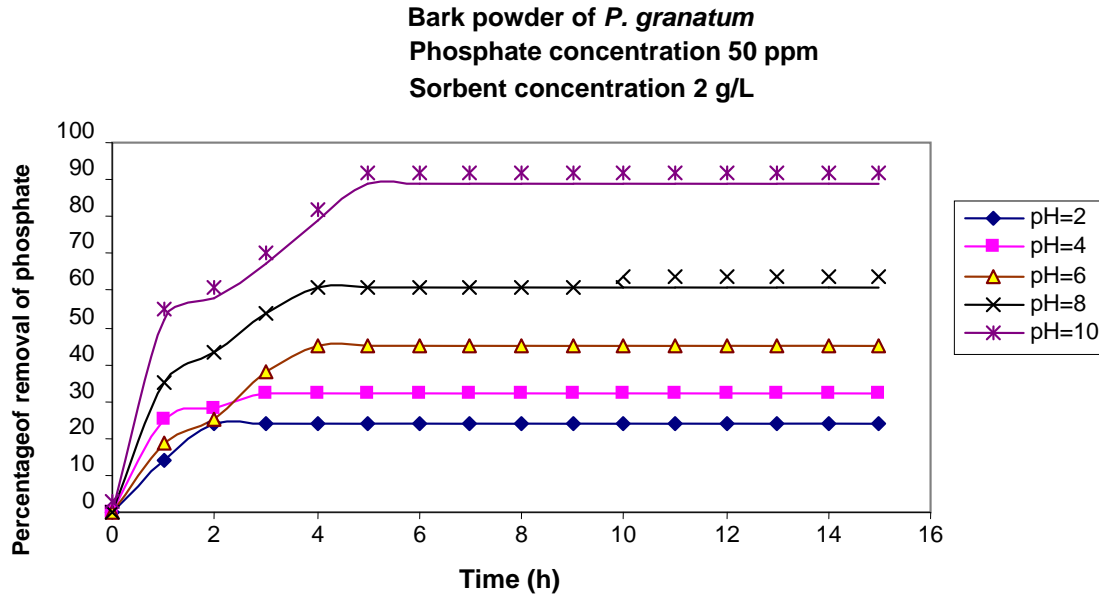
Graph A1. Time Vs percentage of removal of phosphate.



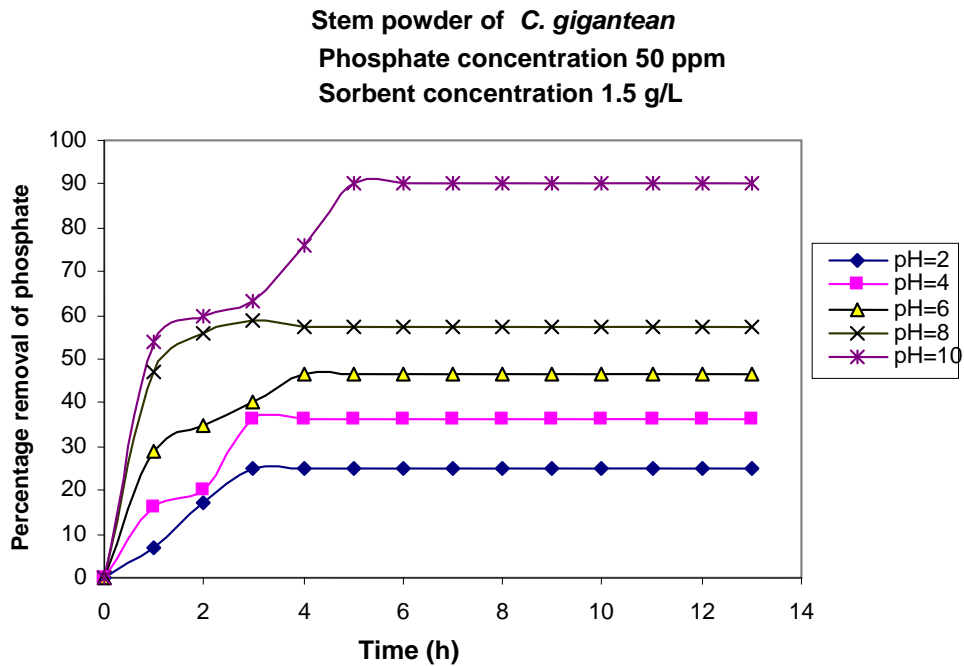
Graph A2. Time vs. percentage of removal of phosphate.

97.0% at pH 10 after 5 h. The stem powders of *C. gigantean* is found to extract 24.9% at pH 2; 36.2% at pH 4; 46.8% at pH 6; 57.5% at pH 8 and 90.0% at pH 10

after 5h. Bark powder of *P. granatum* is found to extract 23.7% at pH 2; 32.3% at pH 4; 44.9% at pH 6; 60.9% at pH 8 and 89.0% at pH 10 after 5 h.



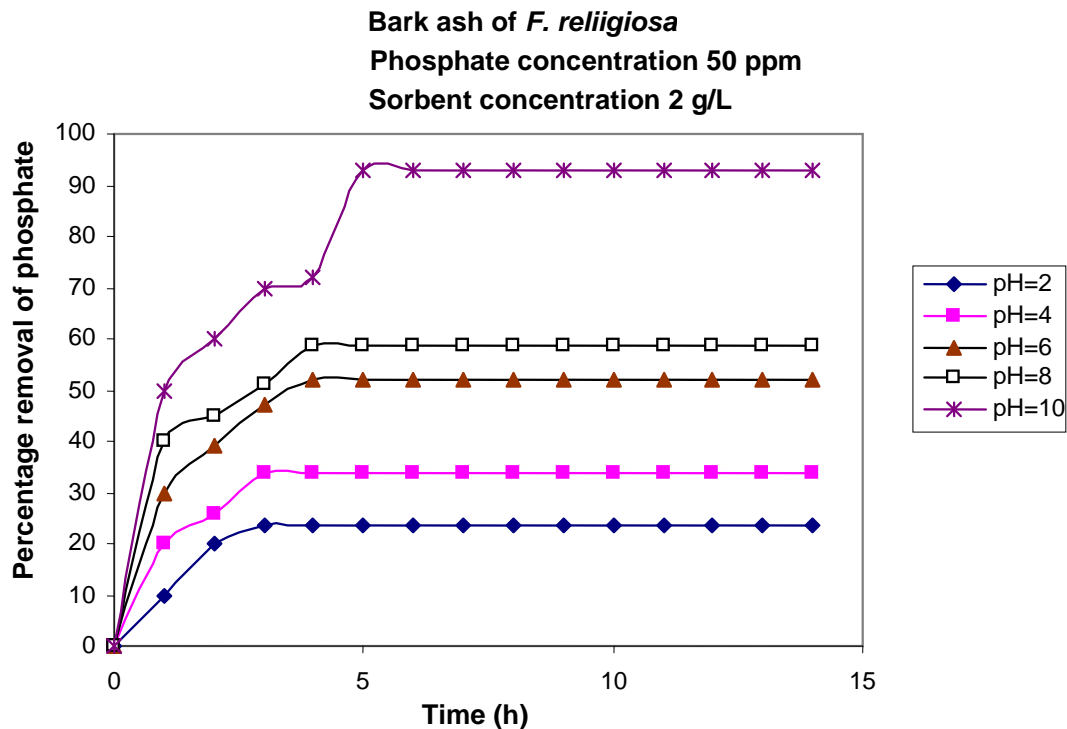
Graph A3. Time vs. percentage of removal of phosphate.



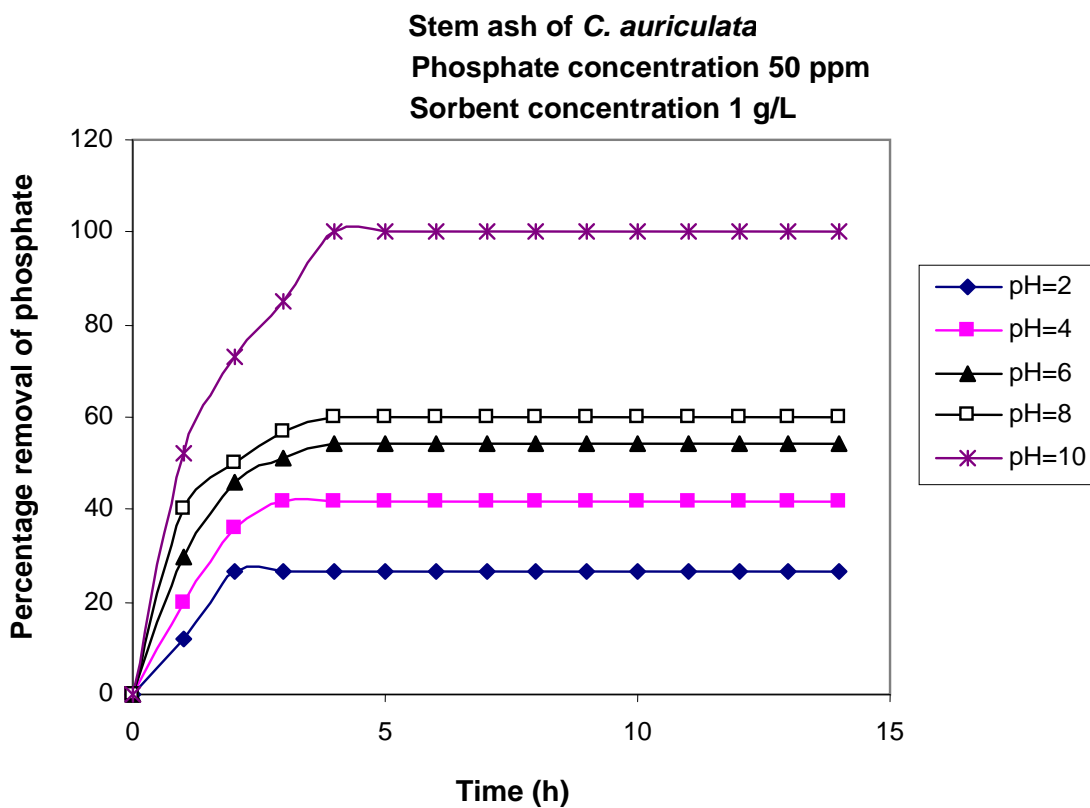
Graph A4. Time vs. percentage of removal of phosphate.

b) With ash of barks of *F. religiosa*, percentage of phosphate extractability is found to be 23.4% at pH 2; 33.7% at pH 4; 51.9% at pH 6; 58.7% at pH 8 and 93.0% at pH 10 after 5 h of equilibration time. Ash of barks of *C. auriculata* is found to extract 26.7% at pH: 2; 41.9% at pH 4; 54.3% at pH 6; 59.8% at pH 8 and 100.0% at pH 10

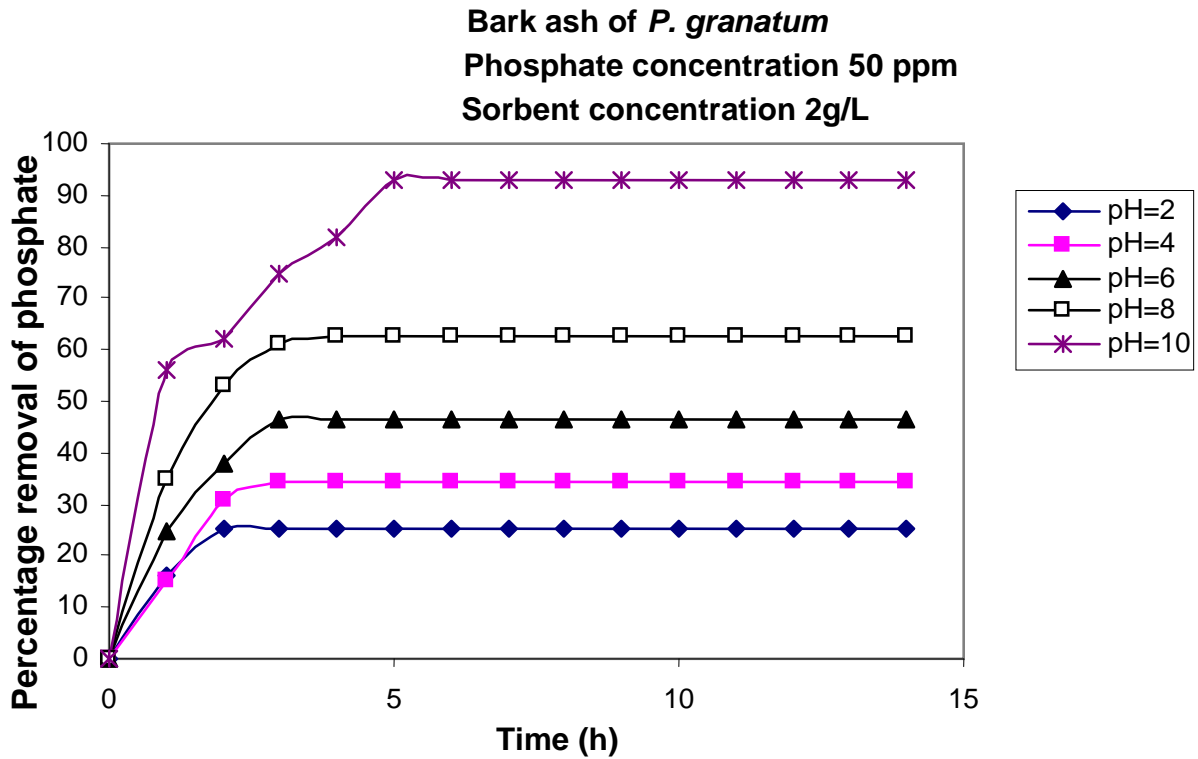
after 4 h. Ash of barks of *Punica granatum* is found to extract 25.5% at pH 2; 34.4% at pH 4; 46.7% at pH 6; 62.4% at pH 8 and 93.0% at pH 10 after 5 h. *Calotropis gigantean* ash is found to extract 26.3% at pH 2; 38.3% at pH 4; 48.9% at pH 6; 58.7% at pH 8 and 94.0% at pH: 10 after 5 h of equilibration.



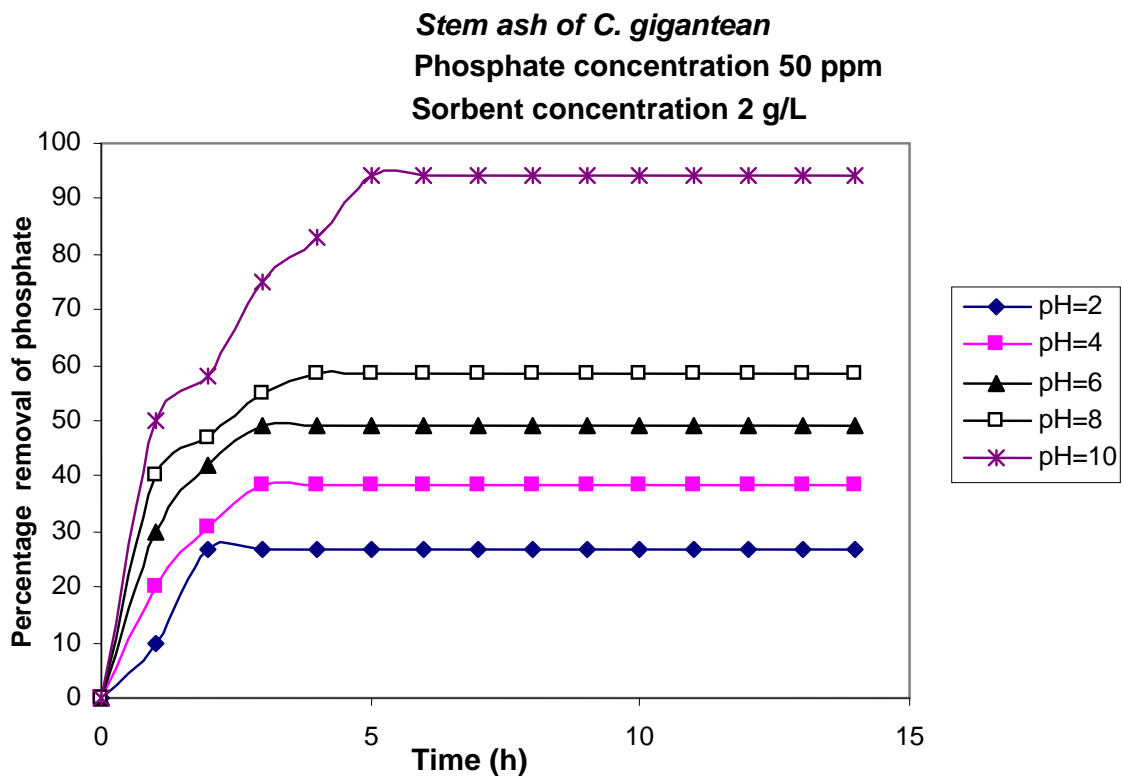
Graph A5. Time vs. percentage of removal of phosphate.



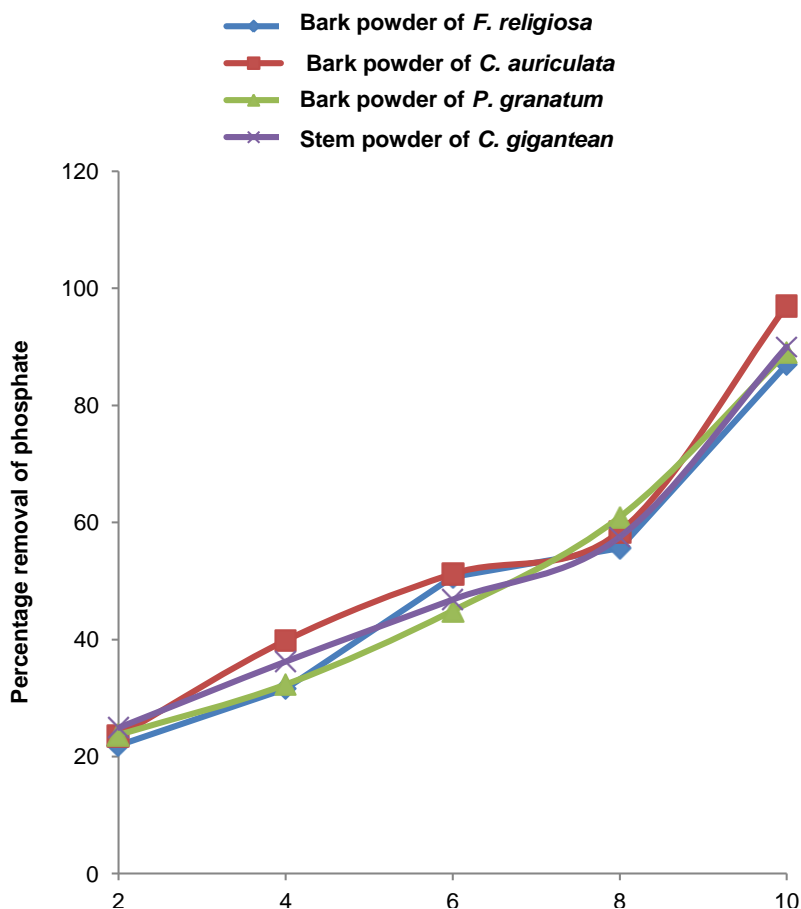
Graph A6. Time vs. percentage of removal of phosphate.



Graph A7. Time vs. percentage of removal of phosphate.



Graph A8. Time vs. percentage of removal of phosphate.



Graph B1. pH vs. percentage removal of phosphate.

When percentage removal is studied with respect to adsorbent dosage at fixed optimum pH: 10 and at optimum equilibration times, the graphs increase up to certain dosage and from then onwards plateaus are obtained (Graphs C1 and 2). The optimum dosage is found to be 1.0 g/L for barks/stems powders of *F. religiosa*; 1.5 gm/L for *C. gigantean*; 2.0 g/L for *P. granatum* and *C. auriculata* (Graph C1).

With bark/stem ashes, the optimum sorbent dosage needed for maximum removal of phosphate, is found to be markedly less than with powders of barks or stems. The optimum sorbent concentration is found to be 0.75 g/L in the case of ashes of *F. religiosa*; 1.0 g/L for the ashes of *C. auriculata*; 1.25 g/L for the ashes of *C. gigantean*; and 1.5 g/L for ashes of *P. granatum* (Graph C2)

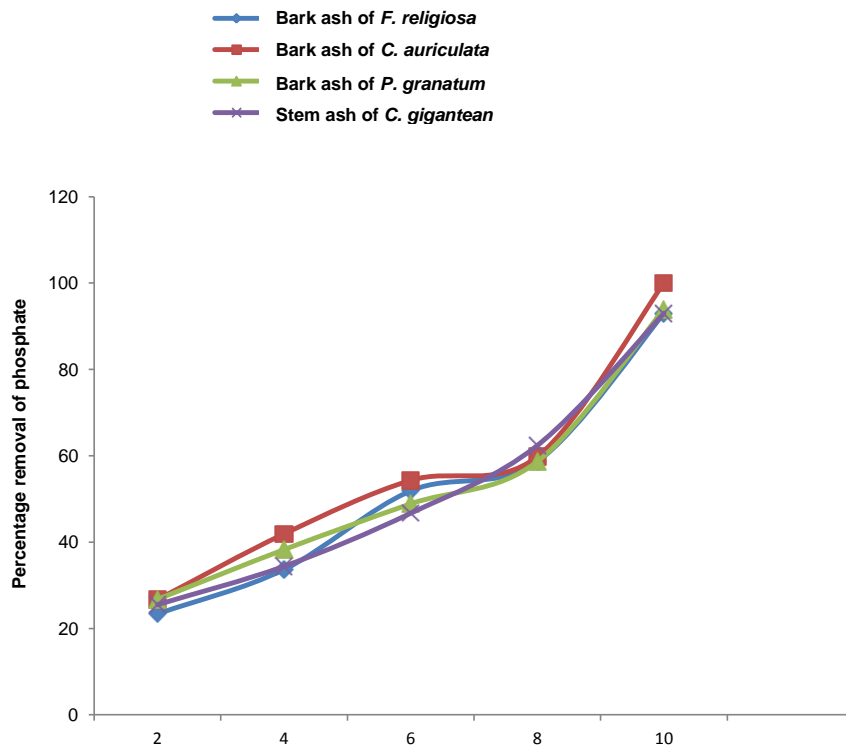
Effect of interfering ions

The extractability of phosphate ions in presence of ten fold excess (500 ppm) of the common ions found in

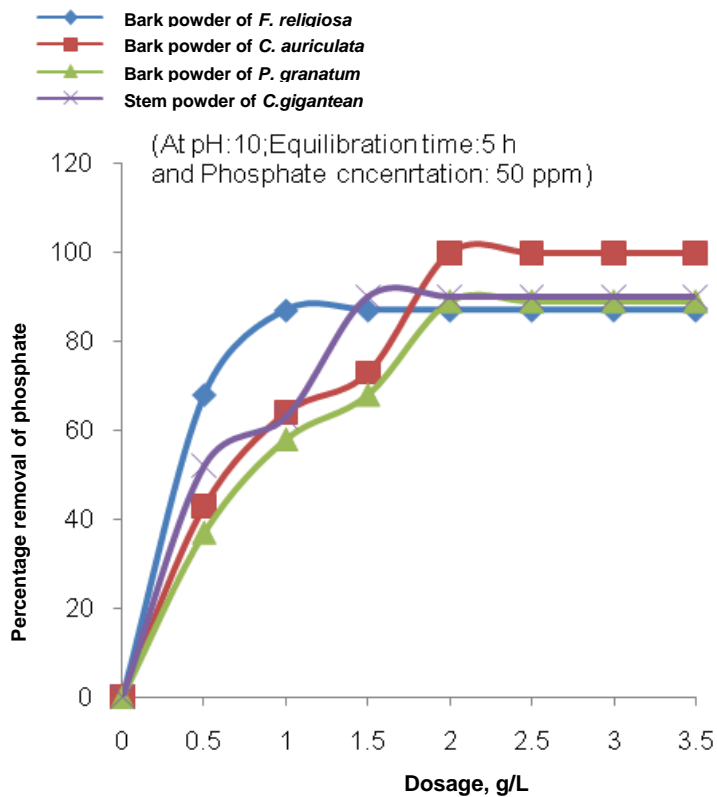
natural waters, namely chlorides, fluorides, sulphates, carbonates, nitrates, calcium, magnesium, copper, ferrous and zinc ions, has been studied with the sorbents at optimum conditions of maximum extraction. The results are presented in the Table 1.

The following observations are significant:

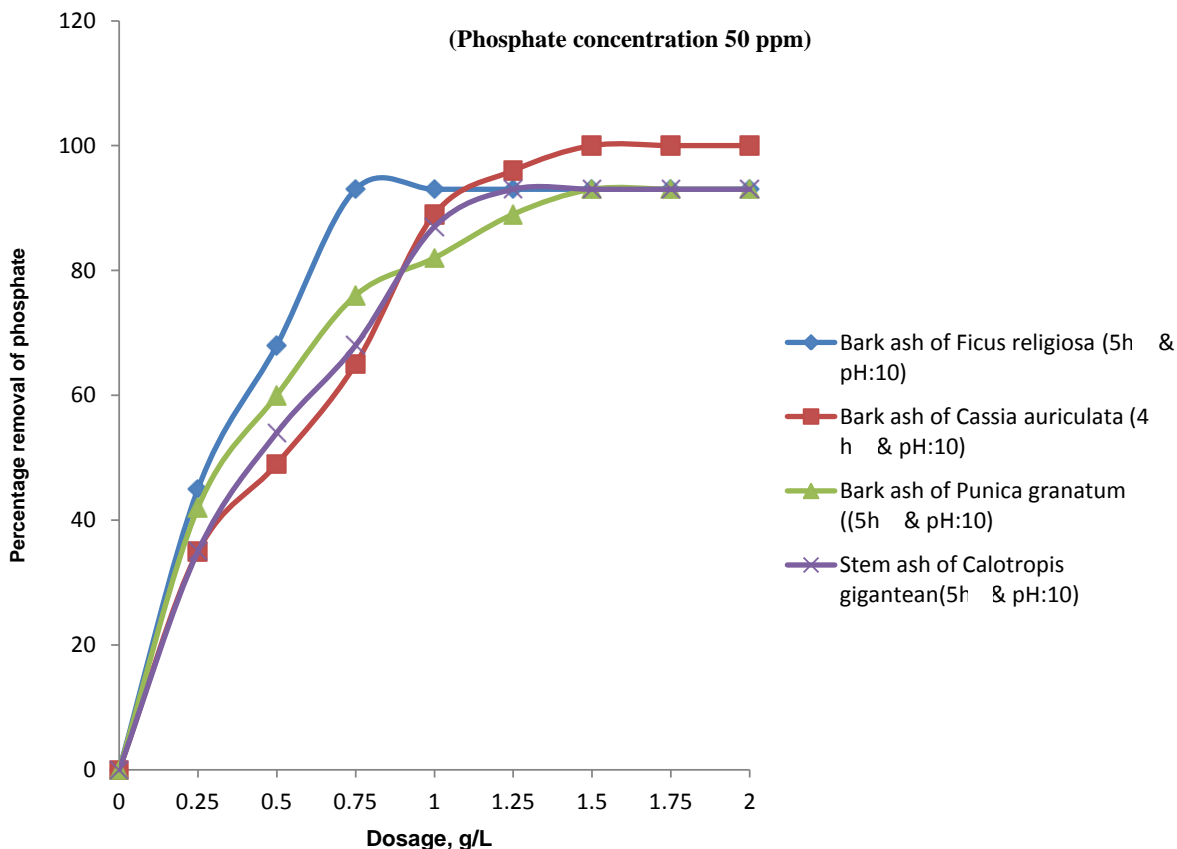
- 1) Chlorides, sulphates, nitrates, fluorides and carbonates have marginal effect on the percentage of extraction of phosphates.
- 2) Ca^{2+} , Mg^{2+} , Cu^{2+} , Zn^{2+} , Fe^{2+} and Ni^{2+} have markedly enhanced the percentage of extraction of phosphates. As for example: the percentage of extraction is 87.0% at pH:10 after 5 h of equilibration time with bark powder of *F. religiosa* while in the presence of Ca^{2+} , Mg^{2+} , Cu^{2+} , Zn^{2+} , Fe^{2+} and Ni^{2+} ions, the percentage of extraction phosphate is enhanced to 90.3, 91.6, 95.9, 94.0, 96.5 and 97.4% respectively (Table 1: item 1). The same trend was observed in the case of remaining adsorbents; further, it is interesting to note that the extraction time is



Graph B2. Ph vs. percentage removal of phosphate.



Graph C1. Sorbent dosage vs. percentage removal of phosphate.



Graph C2. Sorbent dosage vs. percentage removal of phosphate.

also decreasing considerably (Table 1).

Effect of extractions on the other physicochemical parameters of waters

The variations of DO; BOD, COD and their ratio; color; and turbidity at the optimum conditions of extraction with the successful sorbents, have been studied and the obtained results are presented in the 4 to 7 columns of Table 1. The observations are:

- 1) With the activated stem/bark powders of *F. religiosa*, *C. auriculata*, *P. granatum* and *C. gigantean*, D.O is found to be respectively 4.5, 5.1, 5.6 and 3.9 and with their ashes, 4.9, 6.1, 6.4 and 5.1 ppm, at the optimum conditions of extraction (4th column of Table 1).
- 2) BOD/COD ratios are found to be less for sorbents derived from bark powders than for their respective ashes. As for example, the BOD/COD value with bark powders of *P. granatum* is found to be 0.68 ppm while with their ashes 0.88 ppm (5th column of Table 1).
- 3) BOD and COD values are within the permissible limits of water quality standards.

4) The turbidity values are found to be within permissible limits of 10 NTU. The maximum turbidity is found to be 6.2 NTU in all the sorbents of study. The low values of turbidity are due to the fact that the solutions after the optimum period of equilibration are filtered.

5) The color of the treated sample of water is relatively more with bark powder based sorbents than with their respective ashes as sorbents. The maximum color is found to be 23 units in the case of bark powders of *C. gigantean* and 10 units in the case of ashes of *P. granatum* (vide column number 6 in Table 1). However all these values are within the permissible limits of 25 units. Even these trace colors can be removed by just treating water with chlorine solution or chloramines.

DISCUSSION

The available data is inadequate to propose sound theoretical explanations for each observation made as it needs surface studies of "adsorbent and adsorbate interactions" using more sophisticated instruments and methodologies and it is beyond the aims of this work.

H_3PO_4 is a tribasic acid having $pK_1 = 2.15$; $pK_2 = 7.20$;

pK3 = H₃PO₄ is a tribasic acid having pK1 = 2.15; pK2 = 7.20; pK3 = 12.3 yielding three series of salts, NaH₂PO₄, Na₂HPO₄ and Na₃PO₄. The acid vs. base titration curve shows three steps with inflexions at pH: 4.5; 9.5; 12.35; the first inflexion, correspond to the formation of NaH₂PO₄ and second corresponding to Na₂HPO₄. The optimum pH found in our experiments is: 10 and at this pH, the phosphate exists as HPO₄²⁻.

The barks or stems of the bio-sorbents may be having some natural compounds which have affinity towards phosphate at high pH values that is when the phosphate exists as HPO₄²⁻ form. Further, these natural materials may have of metal ions like Ca, Mg, Cu, Zn, Fe, Al and these di/trivalent metal ions form sparingly soluble salts with of HPO₄²⁻ which are gelatinous in nature and are being trapped in the matrixes of the bio-adsorbents and thus resulting in the increase of percentage removal of phosphate. This is more so in the case of ashes as adsorbents, which are oxides of some metal ions.

The decrease in the rate of adsorption with the progress in the equilibration time may be due to the more availability of adsorption sites initially and are progressively used up with time due to the formation of adsorbate film on the sites of adsorbent and thus resulting in decrease in capability of the adsorbent.

The observations made with respect to the foreign ions are also confirming as per the expected nature of extraction. Percentage of extractability is less affected in the presence anions chosen for study viz., chlorides, sulphates, nitrates, fluorides and carbonates while with the divalent cations, the percentage extraction of phosphate is increased. This kind of synergic effect may be due to the formation of sparingly soluble gelatinous precipitates of metal phosphates which are trapped or occulted in the matrix of the sorbents.

CONCLUSIONS

- 1) The sorption abilities of thermally activated bark powders of *F. religiosa*, *C. auriculata*, *P. granatum* and stem powders of *C. gigantean* and their ashes, have been studied with respect to pH, sorption dosage and equilibrium time.
- 2) It is found that phosphates have remarkable affinity towards these sorbents.
- 3) The extractability is pH sensitive and the maximum extraction is found at pH: 10 in all the sorbents; further, it depends on time of equilibration and sorption concentration.
- 4) The minimum dosage needed for the maximum removal of phosphate is found considerably less for bark/stem ashes than for bark/stem powders
- 5) We claim that the removal of phosphate with bark powders of *F. religiosa*, *C. auriculata*, *P. granatum* and stem powders of *C. gigantean* is 87.0, 97, 89 and 90.0%

respectively at pH 10, 5 h of equilibration and with optimum dosages of sorbents.

6) With the ashes of barks/stems, percentage of removal of phosphate is enhanced: 93% for *F. religiosa*, 100% for *C. auriculata*, 93% for *P. granatum* and 94% for *C. gigantean*, at pH 10 after an equilibration period of 5 h with optimum sorbent dosages.

7) Inteference: Tenfold excess of anions like chlorides, sulphates, nitrates, fluorides and carbonates have less affected the percentage of extraction of phosphate at the optimum conditions cited in Table 1. while ten fold excesses of cations viz., Ca²⁺, Mg²⁺, Cu²⁺, Zn²⁺, Fe²⁺ and Ni²⁺ ions are synergizing the extraction of phosphate and thereby percentage removal of phosphate is increased. Further, it is noted that the time of equilibration needed for maximum extraction of phosphate is less in presence of ten fold excess of cations than without the said cations.

8) D.O., BOD, COD, color and turbidity of the water samples after extraction, with the successful sorbents of this work at optimum conditions of pH, equilibration time and sorbent concentration, are found to be within the permissible limits of water quality standards.

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