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REMOVAL OF PHOSPHATE FROM WASTEWATER USING LOW-COST ADSORBENTS

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Abstract:—A study was undertaken to investigate the removal of phosphorus from synthetic and industrial effluents by adsorption process in order to achieve the 100% removal efficiency. The study was conducted by using different adsorbents which includes alum sludge, coal ash, class'C' fly ash and ground granulated blast furnace slag (GGBS).The optimum pH; effective dosage and reaction time were optimized. As a result, pH of 5 and dosage of 10gm/100ml was found to be optimized condition for the phosphate removal by alum sludge, class'C'Flyash and GGBS and pH of 7 and 7.5gm/100ml was found to be the optimized condition for the phosphate removal by coal-ash adsorbents. Column studies were conducted in order to determine the saturation time by using column Break-through curve. From the column break-through curve, the saturation time for alum sludge, Coal-ash, Class'C'flyash and GGBS for synthetic sample of initial concentration 25mg/l was found to be 62,38,34 and 32 hours respectively. The saturation time for alum sludge, Coal-ash, Class'C'flyash and GGBS for synthetic sample of initial concentration 50mg/l was found to be 26, 20,20and 18 hours respectively. The experiments were carried out on industrial wastewater for the removal of Phosphorus with the optimum operating conditions which were obtained from batch studies. The results obtained on industrial wastewater showed the results were in par with the synthetic sample except for Coal-ash adsorbent.

Keywords:—Adsorption, phosphate removal, Class'C' Flyash, Alum sludge, coal-ash, GGBS

I. INTRODUCTION

Wastewater or contaminated water is a big environmental problem all over the world, in industrial plants; contaminants may be a result of side reactions, rendering the water stream an effluent status. These impurities are at low-level concentration but still need to be further reduced to levels acceptable by various destinations in the plant. Surface waters contain certain level of phosphorus (P) in various compounds, which is an important constituent of living organisms. In natural conditions the phosphorus concentration in water is balanced, i.e., accessible mass of this constituent is close to the requirements of the ecological system. Each person contributes about 2-3 g of phosphorus to wastewater each day [1]. When the input of phosphorus to waters is higher than it can be assimilated by a population of living organisms the problem of excess phosphorus content occurs. Regulatory control on phosphorus disposal is evident all over the world in recent years. Strict regulatory requirements decreased the permissible level of phosphorus concentration in wastewater at the point of disposal (i.e. 1 mg/L). This has made it very important to find appropriate technological solution for treatment of wastewater prior to disposal.

Phosphorus removal is considered as a major challenge in wastewater treatment, particularly for small-scale wastewater treatment systems. Processes available for P-treatment are generally classified into three general categories: chemical, physical or biological-based treatment systems. Among physical-chemical methods, phosphorus removal is achieved using ion exchange [2], dissolved air flotation [3], and membrane filtration [4]. Filtration has been used either alone or in conjunction with a coagulation process as a means to remove phosphorus from wastewater .High rate sedimentation has also been attempted in some studies [5]. Among the various physical-chemical methods, coagulation with chemical precipitation and adsorption are the most common techniques being used for removing phosphorus. Enhanced biological methods for removing phosphorus are also used with success. For small scale applications (e.g., aquaculture) biological methods may not be appropriate for phosphorus removal because of the low carbon concentrations, which increases cost and time involved in biological methods [6]. The major drawback of the chemical precipitation is that during phosphorus removal an additional amount of sludge is produced [7]. Alternatively, physical-chemical methods can offer advantages for small industries because of lower initial costs involvement. These methods are also easier to use and do not require high level of expertise to maintain. Physical-chemical methods can also accommodate recycling sludge to reduce further costs involved in handling sludge. However, finding an effective and feasible material is a significant challenge in physical chemical approach. This problem has not been addressed so far as a complete solution. The key problem is to find a suitable material, which is easily available and effective to remove phosphorus from small-scale wastewater applications.

The adsorption characteristics of different adsorbents for phosphate removal from aqueous solutions were evaluated in small-scale experiments. The scope included the effect of initial phosphate concentration, pH, and adsorbent dosage on the adsorption of phosphate. The adsorption isotherms were evaluated in batch tests by using orthophosphate solutions. Such work could contribute to understanding the phosphate removal process using different adsorbents.

II. MATERIALS AND METHODS

2.1 Materials:

In the present study, four different materials were used as low-cost adsorbents. Alum sludge was collected from T.K.Halli water treatment plant, Bangalore, India. Coal-ash was collected from Raichur Thermal Power Plant, Raichur, India. Class'C'Flyash was procured from South Indian Sponge Iron Industry, Malur, India.The GGBS for the work was procured from a typical Iron and Steel industry, Hubli. The alum sludge obtained was oven-dried and was powdered to pass through a sieve of size 2.36mm.

2.2. Batch phosphate sorption experiments:

Batch experiment was carried out to measure the phosphate adsorption by different adsorbents. Different adsorbent dosages were added to 100ml of synthetic phosphate solutions prepared from KH_2PO_4. The mixture was shaken for various times at room temperature. After shaking, the mixture was filtered and the supernatant was measured for phosphate concentration by the Vanado-molybdo phosphoric acid method with a UV–Vis spectrophotometer.

2.3. Column phosphate sorption experiments:

Column adsorption experiments were used to determine the effect of inflow phosphate concentration and adsorption capacity of various adsorbents. Column studies are important because sewage is a continuously flowing system. Columns were designed to determine the breakthrough curve for the adsorption of phosphate from aqueous phase onto various adsorbents. The following experimental set up has been made for the continuous removal of phosphate from water and wastewater. A column, 2.5 cm diameter and 20 cm bed height, filled with various adsorbents was employed for this study. The column was operated in up-flow mode without effluent recycle.

III. RESULTS AND DISCUSSION

3.1 Batch study:

3.1.1 Effect of pH:

The pH of the aqueous solution is an important variable, which influences the sorption of both anions and cations at the solid-liquid interface. The anion exchange capacity is strongly governed 1by the pH of the solution and by the surface chemistry of the solids.

To study the influence of pH on the adsorption capacity of Alum sludge, Coal-ash, Class'C'Flyash and GGBS adsorbents for phosphate, experiments were performed at room temperature, for several contact times, using various initial solution pH values 3,5 and 7 and phosphate solution with initial concentrations 25 and 50 mg/L .

Fig 1-Fig 4 and Fig 5-Fig 8 shows the effect of various pH values, i.e. 3, 5 and 7 on the sorption of PO^4-P on Alum sludge, Coal-ash, Class'C'Flyash and GGBS adsorbents for initial concentration of 25mg/l and 50mg/l respectively at optimum contact time of 20 minutes for Coal-ash and 30 minutes for the rest of the adsorbents respectively.

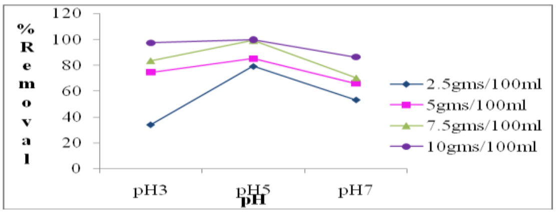

Fig 1: Effect of pH on phosphorus removal for initial concentration of 25mg/l at contact time 30mins using alum sludge

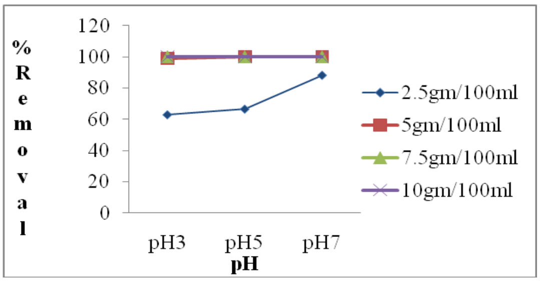

Fig 2: Effect of pH on phosphorus removal for initial concentration of 25mg/l at 20mins contact time using Coal-ash

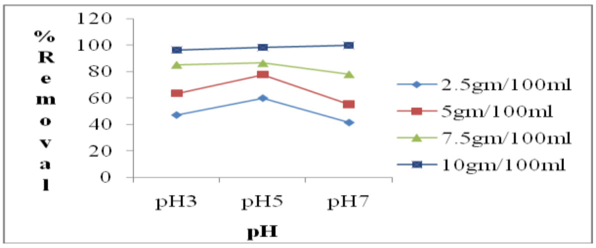

Fig 3: Effect of pH on phosphorus removal for initial concentration of 25mg/l at 30mins contact time using Class'C'Flyash

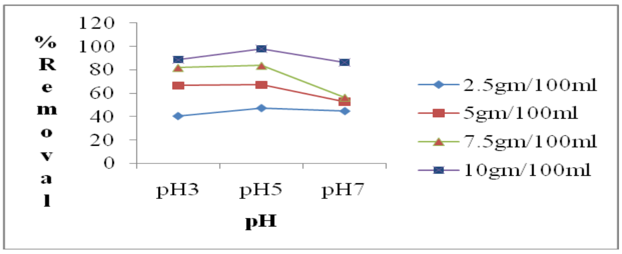

Fig 4: Effect of pH on phosphorus removal for initial concentration of 25mg/l at 30mins contact time Using GGBS

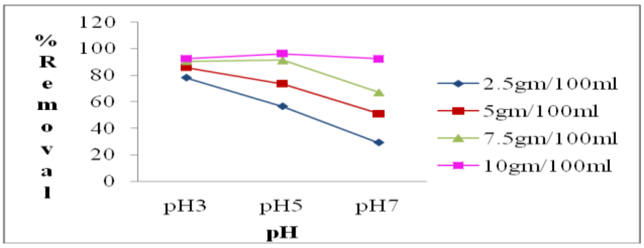

Fig 5: Effect of pH on phosphorus removal for initial concentration 50mg/l at contact time 30mins using Alum sludge

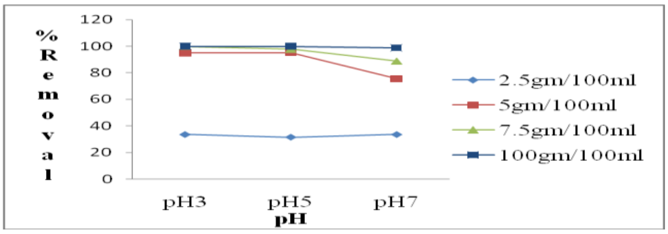

Fig 6: Effect of pH on phosphorus removal for initial concentration of 50mg/l at 20mins contact time using Coal-ash

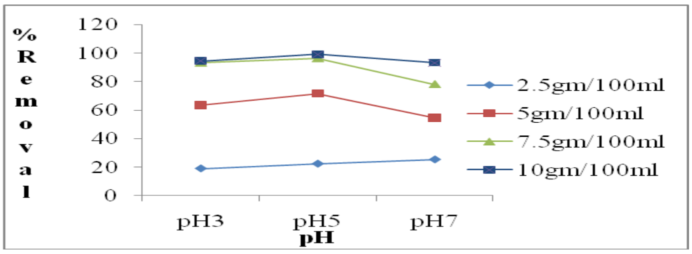

Fig 7: Effect of pH on phosphorus removal for initial concentration of 50mg/l at 30mins contact time using Class'C'Flyash

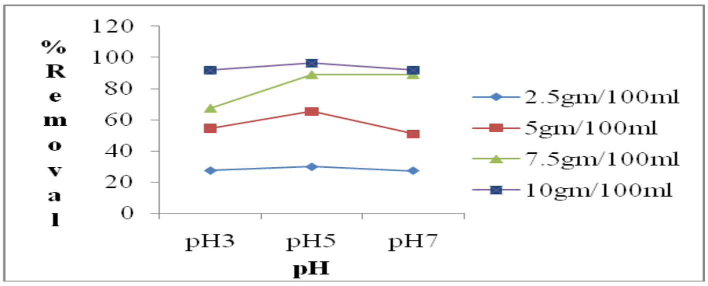

Fig 8: Effect of pH on phosphorus removal for initial concentration of 50mg/l at 30mins contact time using GGBS

3.1.2. Effect of adsorbent dose

To investigate the effect of adsorbent dose on the phosphate adsorption onto various adsorbent surfaces, experiments were carried out with initial phosphate concentration of 25 and 50 mg/L and varying adsorbent dose at room temperature and at a constant stirring speed of 185 rpm for different contact time. The results show that the percent removal increased with increasing adsorbent dose due to the increase in the total available surface area of the adsorbent particles. Fig 9-Fig 12 and Fig 13-Fig 16 shows the effect of adsorbent dosage on the sorption of PO_4-P on Alum sludge, Coal-ash, Class'C'Flyash and GGBS adsorbents for initial concentration of 25mg/l and 50mg/l respectively at optimum contact time of 20 minutes for Coal-ash and 30 minutes for the rest of the adsorbents respectively.

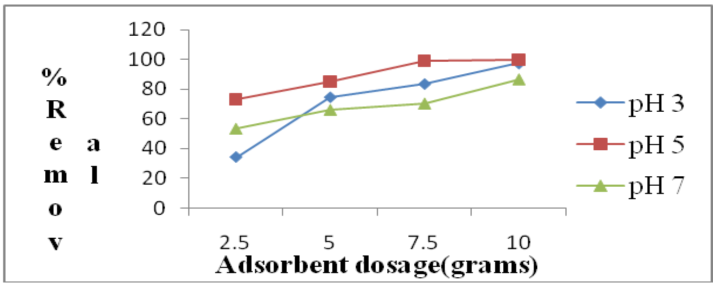

Fig 9: Effect of dosage of alum sludge on phosphorus removal for initial concentration 25mg/l at optimum contact time of 30 Mins

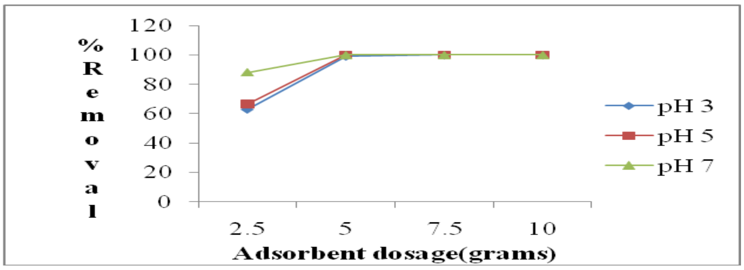

Fig 4.10: Effect of dosage of coal-ash on phosphorus removal for initial concentration of 25mg/l at optimum contact time of 20 mins

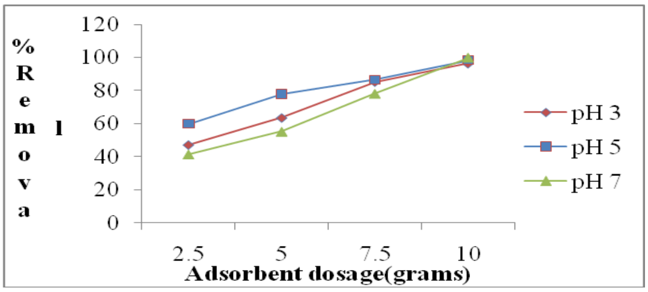

Fig 4.11: Effect of dosage of class'C'Flyash on phosphorus removal for initial concentration of 25mg/l at optimum contact time of 30 mins

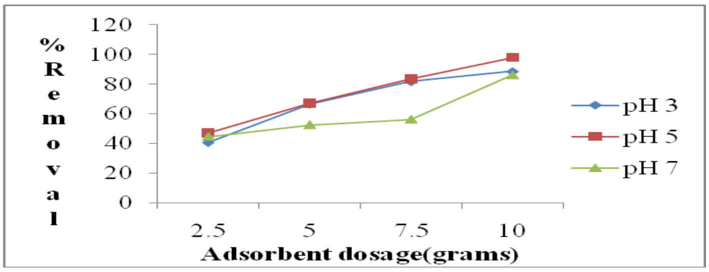

Fig 4.12: Effect of dosage of GGBS on phosphorus removal for initial concentration of 25mg/l at optimum contact time of 30 mins

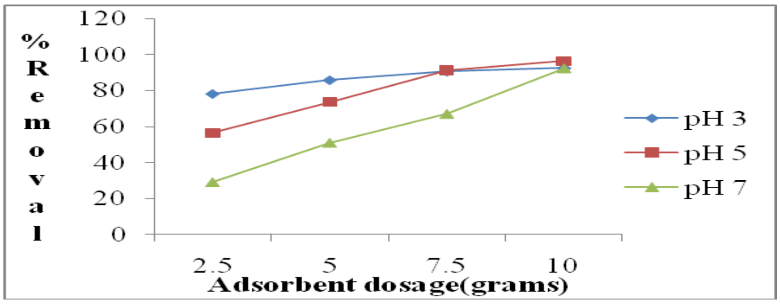

Fig 4.13: Effect of dosage of alum sludge on phosphorus removal for initial concentration 50mg/l at optimum contact time of 30 Mins.

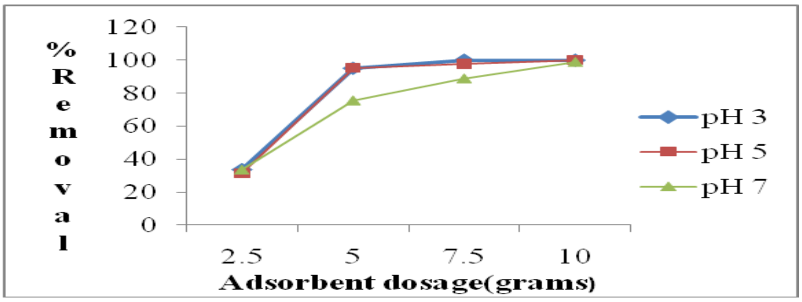

Fig 4.14: Effect of dosage of coal-ash on phosphorus removal for initial concentration of 50mg/l at optimum contact time of 20mins

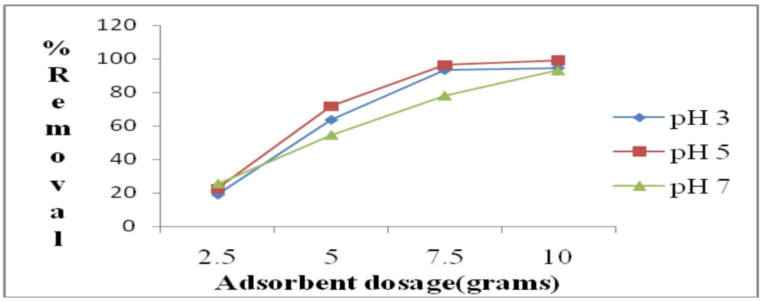

Fig 4.15: Effect of dosage of class'C'Flyash on phosphorus removal for initial concentration of 50mg/l at optimum contact time of 30 mins

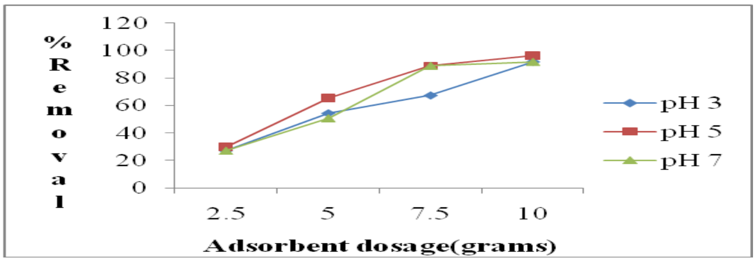

Fig 4.16: Effect of dosage of GGBS on phosphorus removal for initial concentration of 50mg/l at optimum contact time of 30 mins

3.1.3 Effect of initial concentration

To investigate the effect of initial concentration on the phosphate adsorption, experiments were carried out with initial phosphate concentration of 25 and 50 mg/L and varying adsorbent dose at room temperature and at a constant stirring speed of 185 rpm for different contact time.

Fig 17- Fig 20 shows the effect of varying initial PO_4^{3-} concentration of 25 and 50mg/L on the sorption capacity of various adsorbents. It was observed that lower initial concentration (25 mg PO_4^{3-}/L) resulted in higher removal efficiency compared to the higher concentration (50 mg PO_4^{3-}/L). This is due to the greater relative availability of sorption sites on the adsorbent for PO_4^{3-} removal. In the case of higher initial PO_4^{3-} concentration, the total number of available sorption sites was exceeded by the moles of PO_4^{3-} which caused the decrease in the phosphate adsorption rate. Fig 21 shows the comparision of various adsorbents efficiency in phosphate removal and varying initial phosphate concentration of 25mg/L and 50mg/L.

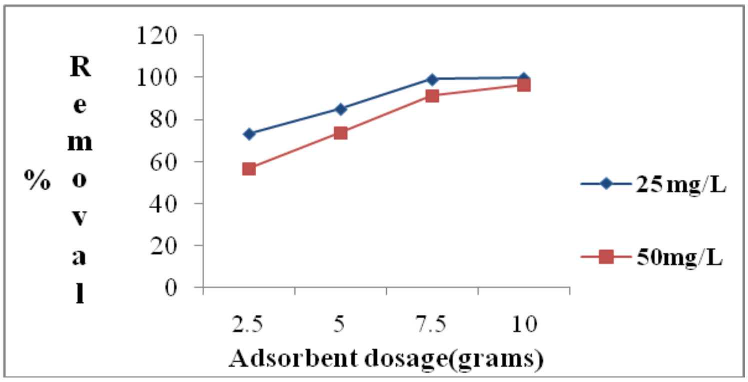

Fig 17: Effect of initial concentration on adsorption on alum sludge at optimum contact time of 30 mins and optimum pH 5

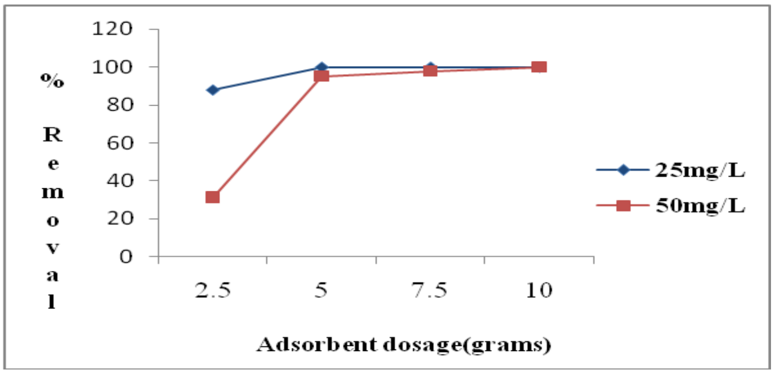

Fig 18: Effect of initial concentration on adsorption on Coal-ash at optimum contact time of 20 mins and optimum pH 7

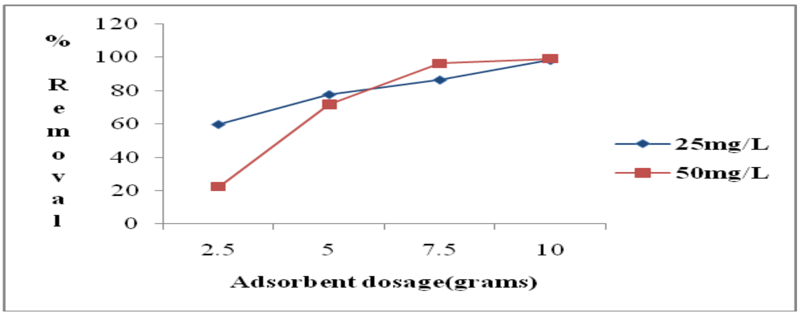

Fig 19: Effect of initial concentration on adsorption on Class'C'Flyash at optimum contact time of 30 mins and optimum pH 5

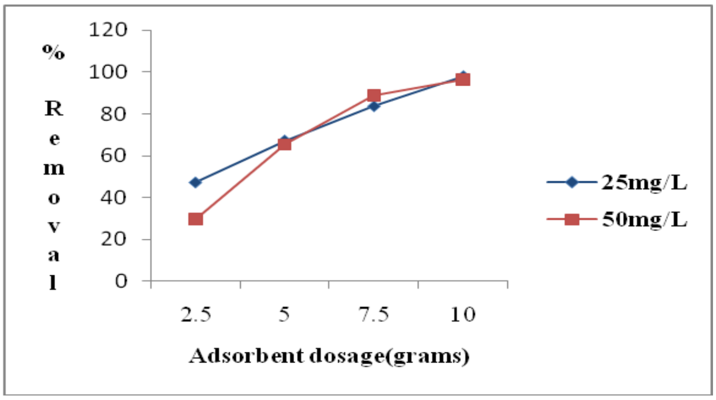

Fig 20: Effect of initial concentration on adsorption on GGBS at optimum contact time of 30 mins and optimum pH 5

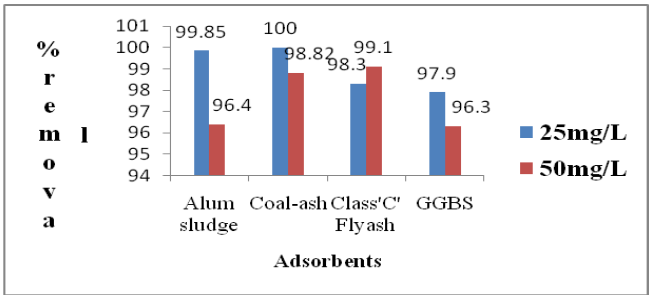

Fig 21: Variation in % Removal of PO_4^{3-} in synthetic sample of varying concentration after treatment at optimum conditions for different adsorbents

3.2 Column study:

Phosphate breakthrough curves were used to quantify P adsorption under continuous loading. The ratio of effluent concentration (*Ce*) to influent concentration (*C0*) was plotted against the column operation time with a constant flow rate of 10ml/min. From the column break-through curve, the saturation time for alum sludge, Coal-ash, Class'C'flyash and GGBS for synthetic sample of initial concentration 25mg/l was found to be 62, 38, 34 and 32 hours respectively.

IV. CONCLUSIONS

The present study aimed to investigate the adsorption of PO_4^{3-} using four different low-cost adsorbents, Alum sludge, Coal-ash, Class'C'Flyash and GGBS. In batch studies, the optimum pH, effective dosage and reaction time were optimized. As a result, pH of 5 and dosage of 10gm/100ml was found to be optimized condition for the phosphate removal by alum sludge, class'C'Flyash and GGBS and pH of 7 and 7.5gm/100ml was found to be the optimized condition for the phosphate removal by coal-ash adsorbents. Increase in adsorbent dosage increased the percentage removal of orthophosphate. Results from the column study showed that higher initial concentration resulted in shorter column saturation time.

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