



## Extraction of aluminium (III) ions from polluted waters using bio-sorbents derived from *Acacia melanoxylon* and *Eichhornia crassipes* plants

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### ABSTRACT

The sorption abilities of thermally activated powders of leaves, stems and their ashes of *Acacia Melanoxylon* and *Eichhornia crassipes* plants have been probed for the extraction of Aluminum (III) ions from polluted waters. Various Physicochemical parameters such as pH, time of equilibration and sorbent dosage have been optimized for the maximum removal of Aluminum (III) ions. Procedures have been developed to remove more than 98% of Aluminum (III) ions from simulated waters using these bio-sorbents at optimum conditions of extractions. Common cations even in tenfold excess are almost not interfering with the extractability of Aluminum (III) ions at the experimental conditions. Sulphate, Nitrate and Carbonate have marginal effect while the Fluoride and Chloride are markedly interfering but Phosphate is enhancing the extractability of Aluminum (III) with some sorbents. The methodologies developed are applied to diverse waste water samples collected from industrial effluents and polluted lakes. The procedures are found to be remarkably successful in removing the Aluminum (III) ions from waste waters.

**Key Words:** Aluminum (III), pollution control, bio-sorbents, *Acacia Melanoxylon*, *Eichhornia crassipes*, applications

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### INTRODUCTION

Aluminum is the second most widely used metal after Iron in the modern industrialized world and its compounds are used in various industries such as food and beverages, drugs and in dyeing industry as mordant-fixative for natural fibers [1, 2]. Further, Aluminum salts have traditionally been used as coagulants and flocculants in the treatment of Municipal waters and after the treatment, there remains some residual Aluminum (III) which is considered to be undesirable aspect of the treatment process. [3,4]. Thus Aluminum and its salts are in contact with us in day to day activities. Moreover, the earth crust has 8% Aluminum. Volcanic eruptions and acidic environmental conditions resulting due to intensive human activity and improper disposal of effluents from industries, cause the leaching of Aluminum into the nearby water bodies in its trivalent state. [5, 6].

Al (III) ions are neurotoxins [7], effect the crop production in acid soils [8] and are reported in literature to be harmful to fish [9-11], zooplankton [12,13], cyanobacteria [14], algae [15] and water weeds [16] and it is implicated in dialysis dementia, Parkinson and Alzheimer's diseases<sup>17</sup>, bone softening [18], renal insufficiency, pulmonary fibrosis and microcytic anemia in human being [19].

Because of the harmful effects of Aluminum ions [17,20,21], various regulating agencies in different countries enforced strict legislation on the maximum permissible limit in drinking waters : 0.2 ppm as per WHO and US drinking water standards; and 0.1 ppm in the countries like Canada and Sweden [22,23].

Literature survey indicates that growing interest is being envisaged in developing the methodologies to remove or control Aluminum (III) from polluted waters. Methodologies have been developed based on Cation exchange, reverse osmosis and electro-dialysis phenomenon [24-26] but these methods suffer from high cost and are not viable in developing countries like India and are less encouraging for adoption for treating waters in large scale.

In this context 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 and it is stimulating the continuous and expanding research in this field [27-35].

B. Paul R Zimmik and Joseph Sneddon (1998) [27] studied the removal of Aluminum ions in water by an algal biomass. Adil Denizli *et al* (2003) [28] investigated the removal of Aluminum by Alizarin Yellow-attached magnetic poly(2-hydroxyethylmethacrylate) beads. Ghazy S.E. *et al* (2005) [30] worked on the kinetics of the removal of aluminum from water samples by adsorption onto powdered marble wastes.

Shaban El-Sayed GHAZY *et al* (2006) [31] investigated the removal of aluminum from some water samples by sorptive-flotation using powdered modified activated carbon as a sorbent and oleic acid as surfactant adopting batch sorption methods. Javaweera M W *et al* (2007) [32] studied the removal of aluminum by constructing wetlands with water hyacinth grown under different nutritional conditions. Septhum *et al* (2007) [33] probed the adsorption Al (III) from aqueous solution onto Chitosan using batch system of extraction. Mohamad Nasir Othman *et al* (2010) [34] studied the Aluminum removal by chelating ion exchange resin with Iontosorb (IO) and Polyhydroxamic acid (PHA). Tony Sarvinder Singh (2006) [35] investigated the sorption of Aluminum from drinking waters using a low-cost adsorbents such as rice husk char and activated rice husk char .

In the present work, the sorption abilities of bio-adsorbents derived from some plants have been explored towards the extraction of Aluminum (III) ions from polluted waters by optimizing the physicochemical parameters such as pH, time of equilibration and sorbent concentration.

## EXPERIMENTAL SECTION

**A: CHEMICALS:** All chemicals used were of analytical grade.

1. **Stock solution of Aluminum (III):** 75 ppm solution was prepared by dissolving the requisite amount of A.R. Aluminum Potassium Sulphate in double distilled water and it was suitably dilute as per the need.

2. **Buffer solution: concentrated:** 27.5 g of Ammonium Acetate and 11.0 g of Hydrated Sodium Acetate were dissolved in 100 ml water and then 1.0 ml of glacial Acetic acid was add and mixed well.

3. **Buffer solution: Diluted:** To one volume of concentrated buffer solution, five volumes of distilled water was added and the pH of the solution was adjusted to 6.0 by adding solutions of Acetic acid or Sodium hydroxide.

4. **Eriochrome cyanine R solution:** 0.1 g of solid Eriochrome Cyanine R was dissolved in 100 ml of distilled water and filtered through a Whitman No. 541 filter paper. This solution was prepared daily.

5. **Hydrogen Peroxide solution:** 5 volumes of H<sub>2</sub>O<sub>2</sub> solution was prepared.

**B: ADSORBENTS:**

*While we are making some pilot studies in exploring the sorption characteristics of some plant materials towards Aluminum (III) ions, we noticed strong affinity between Aluminium (III) ions and the leaves, stems or their ashes of Acacia Melanoxylon and Eichhornia crassipes*



*Acacia Melanoxylon*

*Eichhornia crassipes*

Fig No.1: Plants showing affinity towards Aluminum (III) ions

*Acacia Melanoxylon*, commonly known as the *Australian Blackwood*, is an *Acacia* species belongs to the family of *Fabaceae* and it is valued for its highly decorative timber. *Eichhornia crassipes*, known as *common Water Hyacinth*, is an aquatic plant belonging to the family of *Pontederiaceae* and its habitant ranges from tropical desert to subtropical or warm temperate desert to rainforest zones.

The leaves and stems of *Acacia Melanoxylon* and *Eichhornia crassipes* were cut, washed with tap water followed by distilled water and then sun dried. The dried materials were powdered to a fine mesh of size: < than 75 microns and activated at 105<sup>o</sup> C in an oven and then employed in this study. Further these leaves and stems were burnt to ashes and these ashes were also used in this work.

**C: ADSORPTION EXPERIMENT:** *Batch system of extraction procedure was adopted [36-38].* Weighted quantities of adsorbents were taken in to previously washed 1 lit/500 ml stopper bottles containing 500 ml/250 ml of Aluminum Potassium Sulphate 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 Aluminum determination. Aluminum (III) was determined spectrophotometrically by using "Eriochrome cyanine R" method [39].

**Estimation of Aluminum (III) :** An aliquot amount of Aluminum (III) solution was taken in a 250 ml beaker. To it 5 ml volume H<sub>2</sub>O<sub>2</sub> solution was added and mixed well and the pH of the resulting solution was adjusted to 6.0 using either 0.2 M Sodium hydroxide or 0.2 M Hydrochloric acid with the help of pH-meter. At this stage 5 ml of Eriochrome cyanine R solution was added and mixed well. Then 50 ml of the dilute buffer solution was added and the solution was quantitatively transferred to a 100 ml volumetric flask with the help distilled water and thus resulting solution was diluted to 100 ml. Thus obtained solution was well shaken to ensure thorough miscibility. Red to Pink color was developed depending on the concentration. After 30 minutes, the O.D. of the developed color was measured against blank at 535 nm using U.V. and Visible Spectrometer (Systronics Make). Thus obtained O.D value was referred to standard graphs (drawn between O.D and concentration) prepared with known amounts of Aluminum by adopting method of Least Squares to find concentration of Aluminum in unknown solutions.

The sorption characteristics of the adsorbents were studied with respect to various physicochemical parameters. At a fixed sorbent concentration, the % removal of Aluminum ions from sample waters was studied with respect to time of equilibration at various pH values. The results obtained were presented in the Graph Nos. A: 1-a to 1-d, A-2-a to 2-d and B: 1&2. To fix the minimum dosage needed for the maximum removal of the Aluminum ions for a particular sorbent at optimum pH and equilibration times, extraction studies were made by studying the % of extraction with respect to the sorbent dosage. The results obtained were presented in the Graph Nos. C: 1&2.

**D: EFFECT OF OTHER IONS (*Interfering Ions*):** The interfering ions chosen for study were the common ions present in natural waters viz. Sulphate, Fluoride, Chloride, Nitrate, Phosphate, Carbonate, Calcium (II), Magnesium (II), Copper(II), Zinc(II) and Nickel (II). The synthetic mixtures of Aluminum and of the foreign ions were so made that the concentration of the foreign ion was maintained at the concentrations cited in the Table: 1. 500ml of these solutions were taken in stopper bottles and then correctly weighted optimum quantities of the promising adsorbents (*as decided by the Graph Nos. A, B and C*) were added. Optimum pH was adjusted with dil. HCl or dil. NaOH using pH meter. The samples were shaken in shaking machines for desired optimum periods and then small portions of the samples were taken out, filtered and analyzed for Aluminum (III). % of extraction was calculated from the data obtained. *The results were presented in the Table: 1.*

#### **E: APPLICATIONS:**

The adoptability of the methodologies developed with the new bio-sorbents derived from *Acacia Melanoxylon* and *Eichhornia crassipes* plants in this work for removing Aluminum (III), is tried with some real sewage/effluent samples of some industries polluted lake waters. For this purpose, three samples were collected from Alum manufacturing industries in Hyderabad and three from Aluminum sulphate manufacturing industries in Chennai and these samples were analyzed for the actual concentration of Aluminum (III). Further, three more natural samples from three polluted lakes at different places in Bapatla Mandalam of Guntur Dt of Andhra Pradesh were collected and these sample were fed with known amounts of Aluminum (III).

Then these samples were subjected to extraction for Aluminum (III) using the bio-sorbents developed in this work at optimum conditions of extraction as cited in the Table 2. The results obtained were presented in the Table 2.

## RESULTS AND DISCUSSION

The extraction characteristics of leaves, stems and their ashes of *Acacia melanoxylon* and *Eichhornia crassipes* towards Aluminium (III) at varying physicochemical parameters such as pH, time of equilibration and sorption concentration are presented in the GraphNo.A:1-a to 1-d, A:2-a to 2-d, B:1&2, C :1&2. The following observations are significant:

1. **Time of equilibration:** Percent of extraction increases with time of agitation for a fixed adsorbent at a fixed pH and after certain duration, the extractability remains constant, i.e. an equilibrium state has been reached (vide GraphNos.A: 1-a to 1-d, 2-a to 2-d). As for example, in the case of the powders of leaves of *Acacia melanoxylon* as adsorbent, the % of extraction is found to be : 75% at 10minutes, 80 % at 20 minutes, 88% at 30 minutes, 95% at 60 minutes, 96% for 90 minutes, 100% at 120 minutes and above, at optimum pH:6 and sorption concentration :2.0 gm/lit (vide Graph No.A:1-a) . The same trend is noticed in the case of other sorbents

2. **Effect of pH:** %of extraction is found to be pH sensitive and is maximum in the pH range 4 to 8; below and above this pH range, the extraction decreases. As for example, with the powders of *Acacia melanoxylon* leaves, the % of maximum extractability is found to be 55% in 1N HCl ; 60% in 0.5N HCl; 75% at pH: 1; 85% at pH:2; 94% at pH:4; 96 % at pH:6; 98 % at pH:8 ; and decreased to 80% at pH:10, after an equilibration time of 120minutes and at sorption concentration of 2.0 gm/lit. With the ashes of leaves of *Acacia melanoxylon*, the maximum extractability of Aluminum (III) is found to be 65% in 1N HCl; 79% in 0.5N HCl; 84% at pH: 1; 90% at pH:2; 96% at pH:4; 98% at pH:6; 100% at pH:8; 84% only at pH:10 after an equilibration time of 90 minutes and with sorption dosage of 2.0gm/lit. With stem powders of *Acacia melanoxylon*, the maximum extractability is found to be 50% in 1 N HCl; 64% in 0.5N HCl; 71% at pH: 1; 80% at pH:2; 90% at pH:4; 98 % at pH:6;100% at pH:8; 81%only at pH:10 after an equilibration time of 120minutes with sorbent concentration of 2.0gm/lit With stem ashes of *Acacia Melanoxylon*, the maximum extractability is found to be 57% in 1N HCl; 66% in 0.5N HCl; 74% at pH: 1;83 % at pH:2; 96% at pH:4; 98 % at pH:6;100% at pH:8; 78% only at pH:10 after an equilibration time of 90minutes and with sorbent dosage 1.5gm/lit . Similarly in the case of the powders of *Eichhorni crassipes* leaves, the maximum extractability has been found to be: 45% at 1N HCl; 52% at pH: 0.5N HCl; 58% at pH: 1; 62% at pH: 2;85 % at pH: 4; 94% at pH: 6; 98% at pH: 8 and decreased to 82% at pH: 10 after an equilibration period of 120 minutes and with sorption concentration of 4.0gm/lit. With the ashes of leaves of *Eichhornia crassipe* the maximum extractability after 120 minutes is found to be 60% at 1N HCl; 65% at pH: 0.5N HCl; 74% at pH: 1; 89% at pH: 2; 94% at pH:4; 100% at pH:6; 100% at pH:8; and decreased to 78% at pH:10 with the sorbent concentration of 2.5gm/lit. With the stem powders of *Eichhornia crassipes*, the maximum extractability has been found to be: 59% in 1N HCl; 65% in 0.5NHCl; 70% at pH: 1; 78% at pH: 2; 88% at pH: 4; 100% at pH: 6; 100% at pH: 8 and 82% at pH: 10 after 150 minutes of agitation and with sorbent dosage of 2.5gm/lit. In the case of stem ashes of *Eichhornia crassipes*, the maximum extractability has been found to be 62% in 1N HCl ; 72% in 0.5N HCl; 80% at pH: 1; 92% at pH:2; 96% at pH:4; 100% at pH:6; 100% at pH:8; and 80% at pH:10 after an equilibration period of 120 minutes, with the sorbent dosage of 2.0gm/lit.

3. In most of the sorbents the optimum time of agitation for maximum extraction Aluminum is found to be less for ashes than with the raw powders of leaves and stems. In the case of *Acacia melanoxylon*, the agitation time is 120 minutes for leaves powders and 90 minutes for their ashes; 120 minutes of stems powders and 90 minutes for their ashes. With *Eichhornia crassipes*, the optimum time is: 150 minutes for stems and 120 minutes with their ashes (videGraphNos.A:1-2).

4. **Sorbent Concentration:** The optimum sorbent dosage needed for maximum extractability of the Aluminum (III) is found to be more in the case of leaves and stem powders than with their ashes. With the stem powders of *Acacia melanoxylon*, it is 2.0 g/lit but reduced to 1.5 g/lit with the ashes of the same. Similarly, with the powders of leaves of *Eichhornia crassipes*, the optimum dosage is found to be 4.0 gm/lit, while with its ashes it is only: 2.5 g/lit; with the stem powders it is 2.5 g/lit while with its ashes it is : 2.0 gm/lit. (Vide GraphNo.C:1 and 2).

5. The % of maximum extractability of Aluminum(III) is found to be more than 98% in all the sorbents developed at optimum conditions of pH, equilibration time and sorbent dosage from the simulated waste waters (vide Graph Nos. A: 1 &2).

6. **Interfering ions:** The extractability of Aluminum (III) in presence of tenfold excess of common ions found in natural waters, namely Sulphates, Nitrates, Chlorides, Phosphates ,Fluorides, Carbonates, Calcium, Magnesium, Copper, Zinc and Nickel ions are summarized in the Table No.:1.

- Cations marginally effected.
- Anions like of  $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$  and  $\text{CO}_3^{2-}$  has marginal effect, while the  $\text{Cl}^-$  and Fluoride are markedly interfering. Phosphate have no effect on the extraction of Aluminum and more over there is an enhancement of extraction in the case the powders of leaves of *Acacia melanoxylon* and *Eichhornia crassipes* from 98% to 100%.

### DISCUSSION

The surface morphology of bio-sorbents derived from plant materials plays an important role in influencing extraction Characteristics. The surface functional groups present in these biomaterials are either  $-\text{OH}$ -or  $-\text{COOH}$  groups. The pH sensitive dissociation or association of these groups imports charge on the inter surface and thereby an urge for oppositely charged ions prevails on the surface of the sorbents. At low pH values, protonation of the functional groups may occur and due to it, there is an electrostatic thrust for anions. But at high pH values, the functional groups dissociate imparting negative charge to the interface and thereby a thrust for positively charges ions prevails.

At low pH values ( $\text{pH} < 5$ ), the main species for Aluminum (III) is  $\text{Al}[(\text{H}_2\text{O})_6]^{3+}$ . However, as the pH increases,  $\text{Al}(\text{OH})^{2+}$ ,  $\text{Al}(\text{OH})_2^+$  are gradually formed and at neutral pH amorphous  $\text{Al}(\text{OH})_3$  precipitates; at basic pH this precipitate dissolves to form  $\text{Al}(\text{OH})_4^-$ . In the pH range 6 to 8, the Aluminum essentially exists as hydrated  $\text{Al}(\text{OH})_3$  but it is not precipitated from dilute solutions of  $\text{Al}(\text{OH})_2^+(\text{H}_2\text{O})_3$  in spite of insolubility, because the formation of  $\text{Al}(\text{OH})_3$  is inhibited [40]. The bio-sorbents having functional groups  $\text{OH}/\text{COOH}$  bind the *hydrated* Aluminum hydroxide either due to *electrostatic interactions* or *via hydrogen bonding* resulting in the increase in the % of extraction. As the pH is increased to 10, the species exists is anion,  $\text{Al}(\text{OH})_4^-$  [33,40] and is having less affinity towards the sorbent. Hence, % of extraction is decreased.

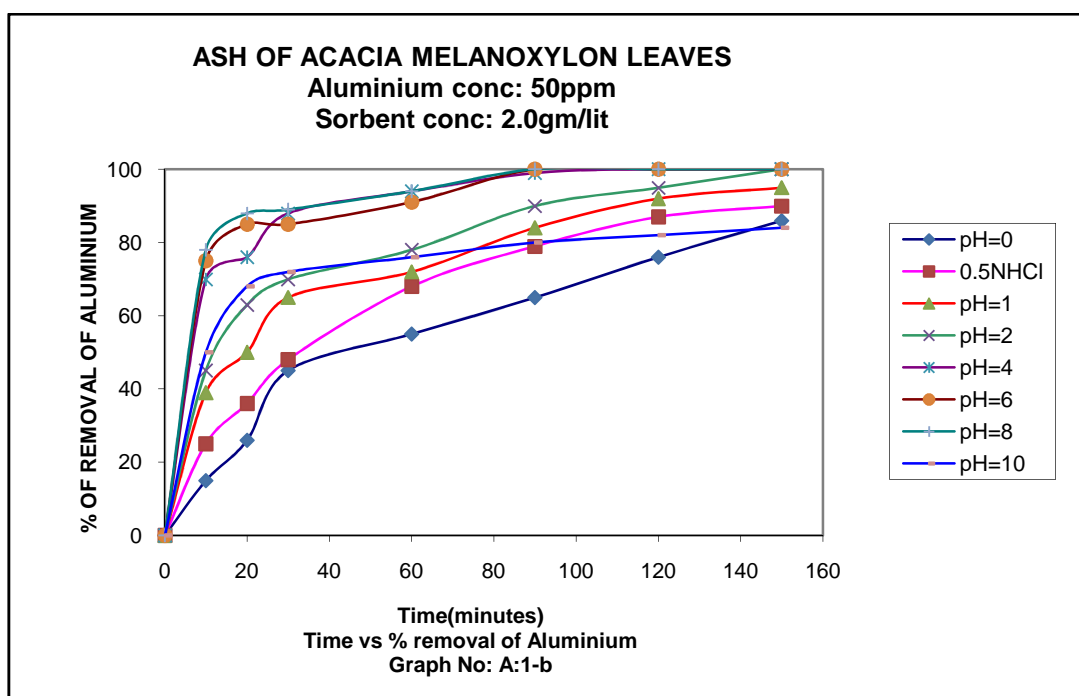
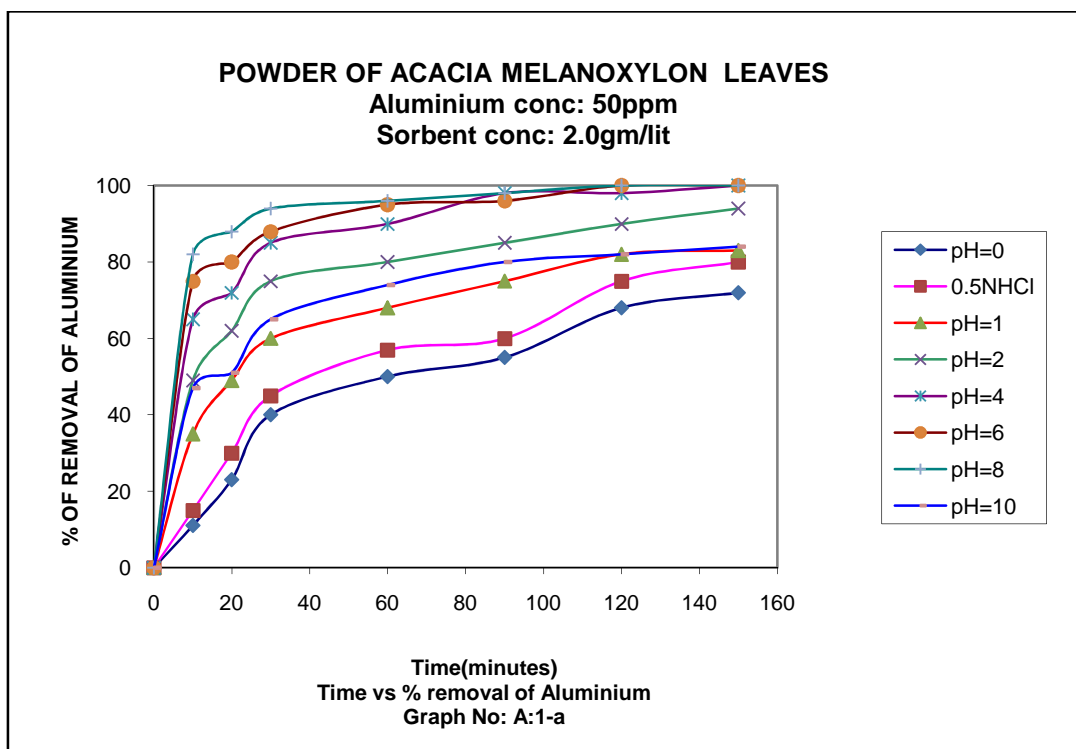
Ashes are the oxides of some heavy metals containing large amounts of silica. The ashes, contains ' $-\text{OH}$ ' groups and ' $-\text{O}-$ '. The observed behaviors of extractability as pH varies may be understood in the same lines as described in the case of raw leaves or stem powders. In fact, in the literature it is reported that the transition pH from anion exchanging nature to cation exchange nature is: 3 [41-43] and this supports the proposed logic for the observed behavior.

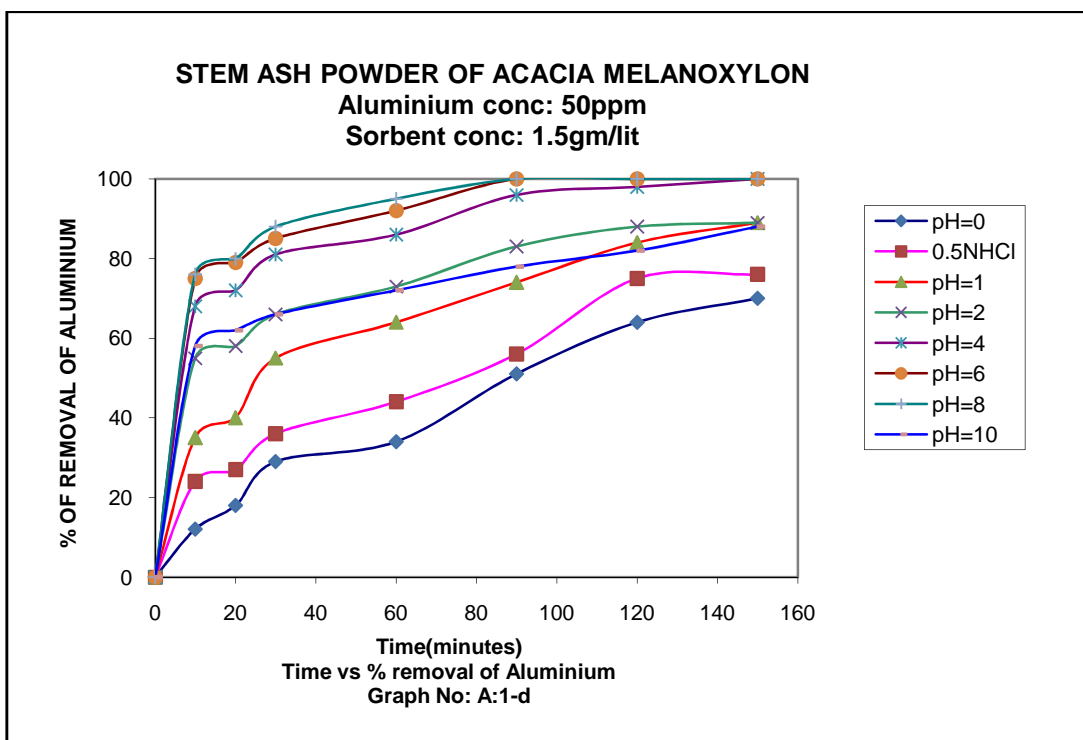
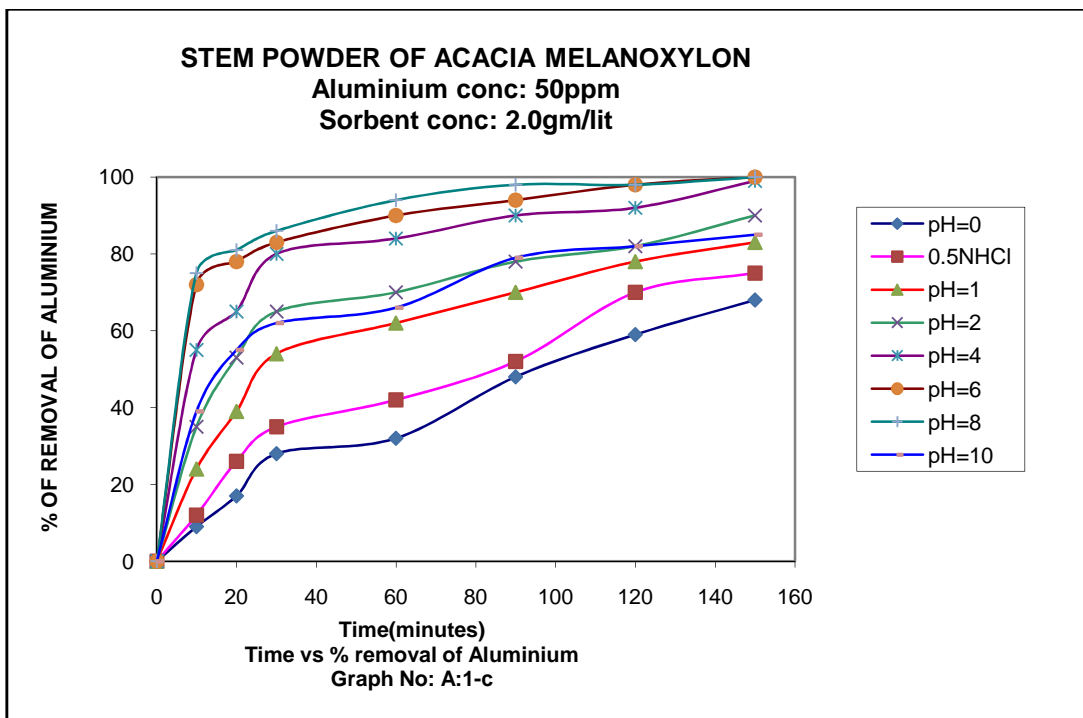
The decrease in the rate of adsorption with the progress in the equilibration time may be attributed to the more availability of adsorption sites initially and are progressively used up with time due to the formation of adsorbate film on the active sites.

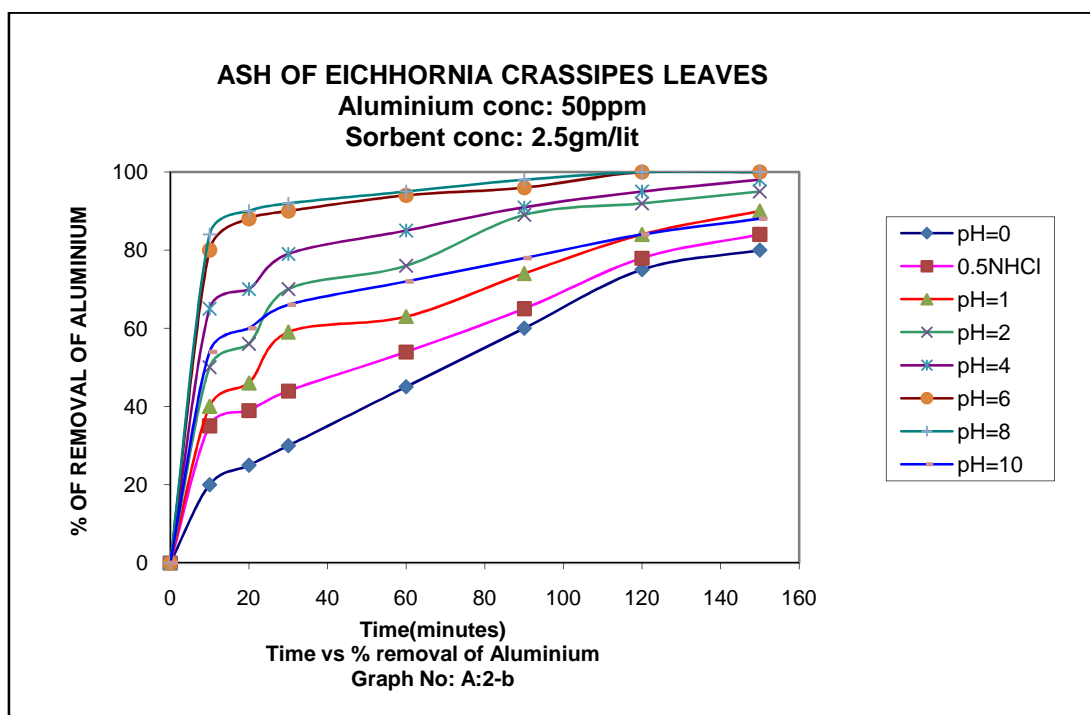
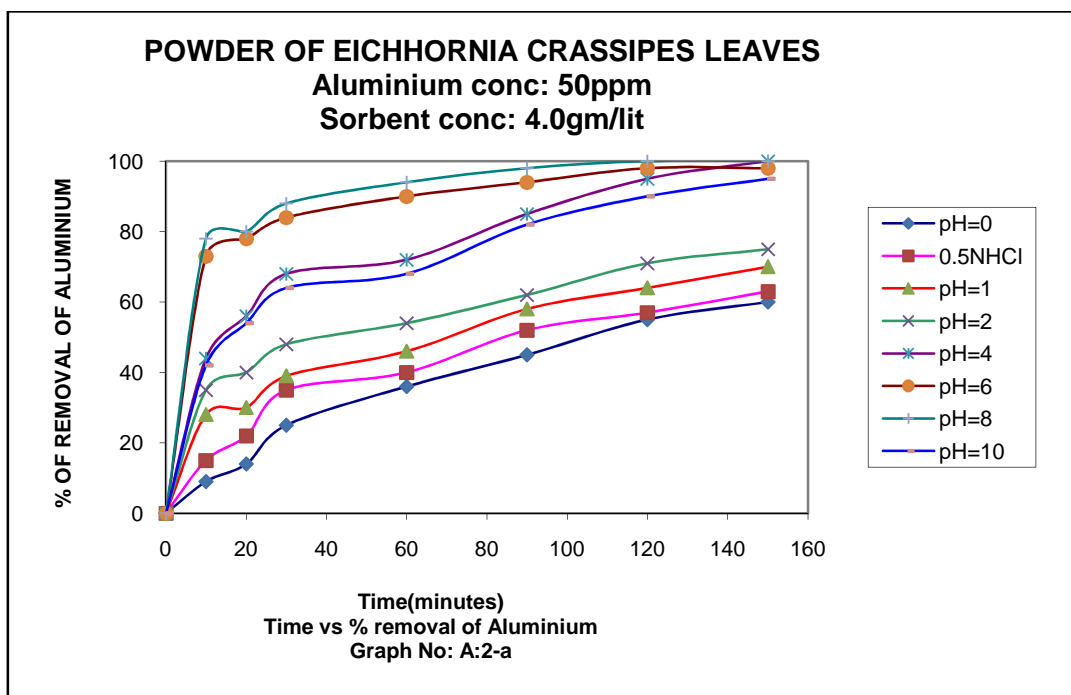
The interference of chlorides and fluorides on the extraction of Aluminum ions may be due to the formation of anionic complexes,  $\text{AlF}_4^-$  and  $\text{AlCl}_4^-$  which are less held on the negatively charged surface of the sorbent at the optimum pH: 6-8. The enhancement of % of extraction in the presence of phosphate, may be accounted due to the formation of sparingly soluble Aluminum Phosphate,  $\text{AlPO}_4$  which is gelatinous in nature and is trapped or occluded in the matrix of the sorbents.

### Applications

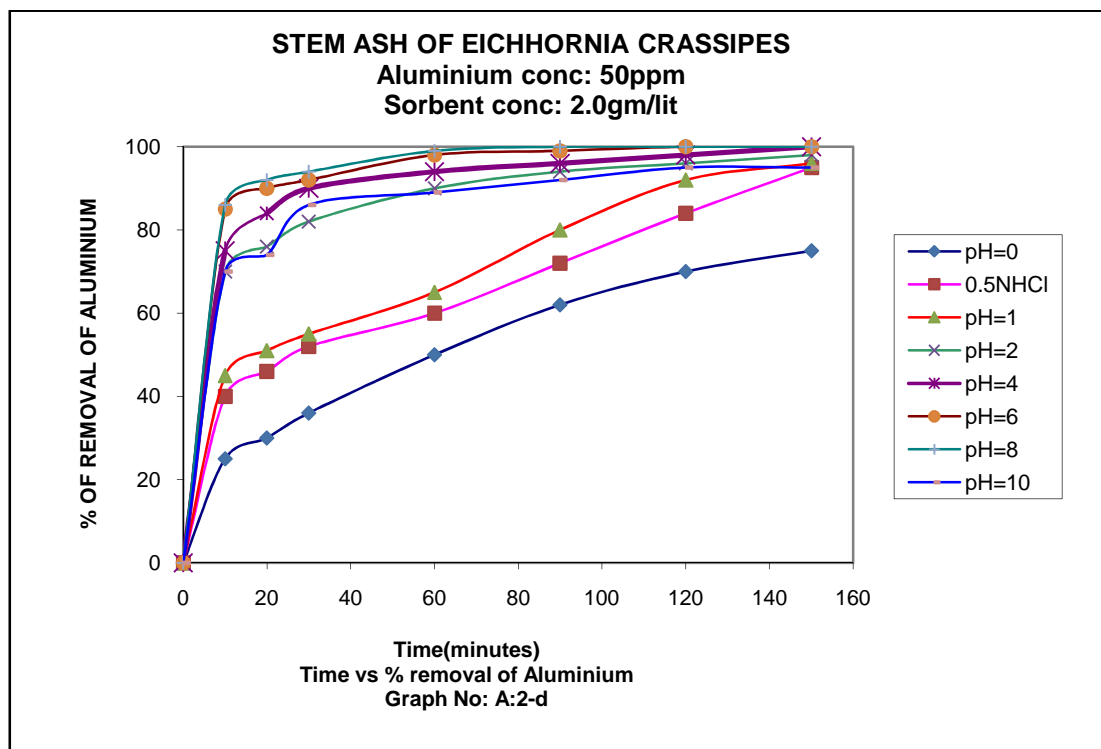
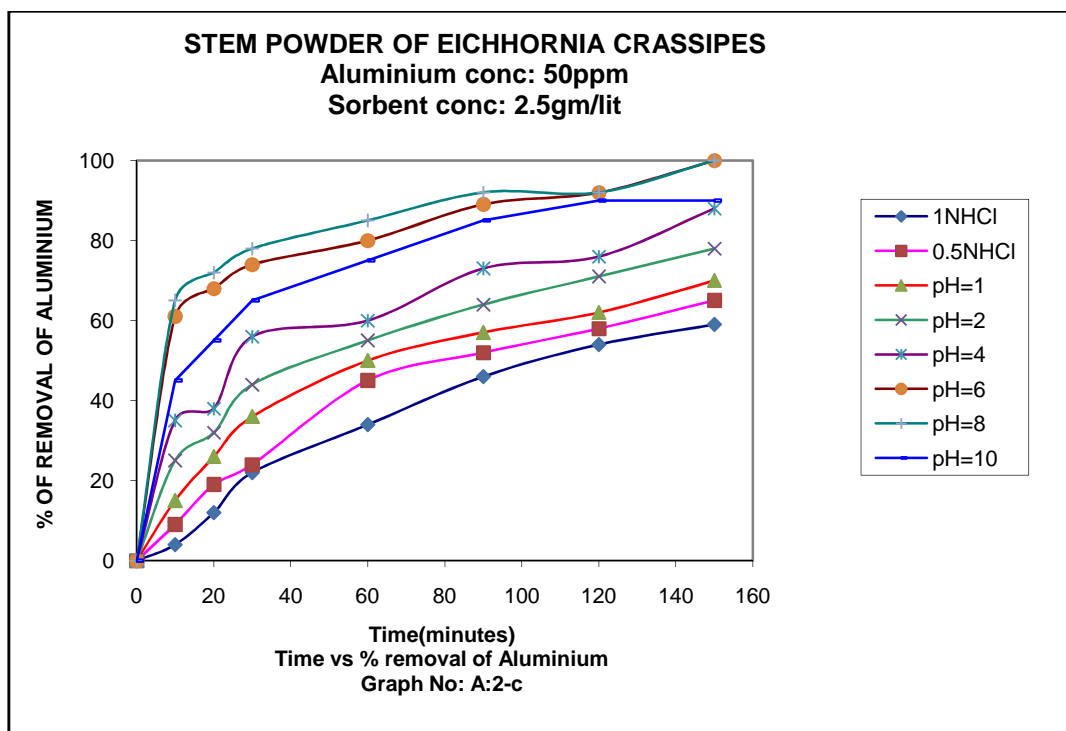
The methodologies developed in this work are applied to the real samples of diverse nature that have been collected from the sewages/effluents of Aluminum based industries and polluted lakes. The results are presented in *the Table 2*. It can be inferred that the sorbents developed can successfully remove *more than 95%* of Aluminum from the samples at the optimum conditions of extraction as cited *in the Table 2*.

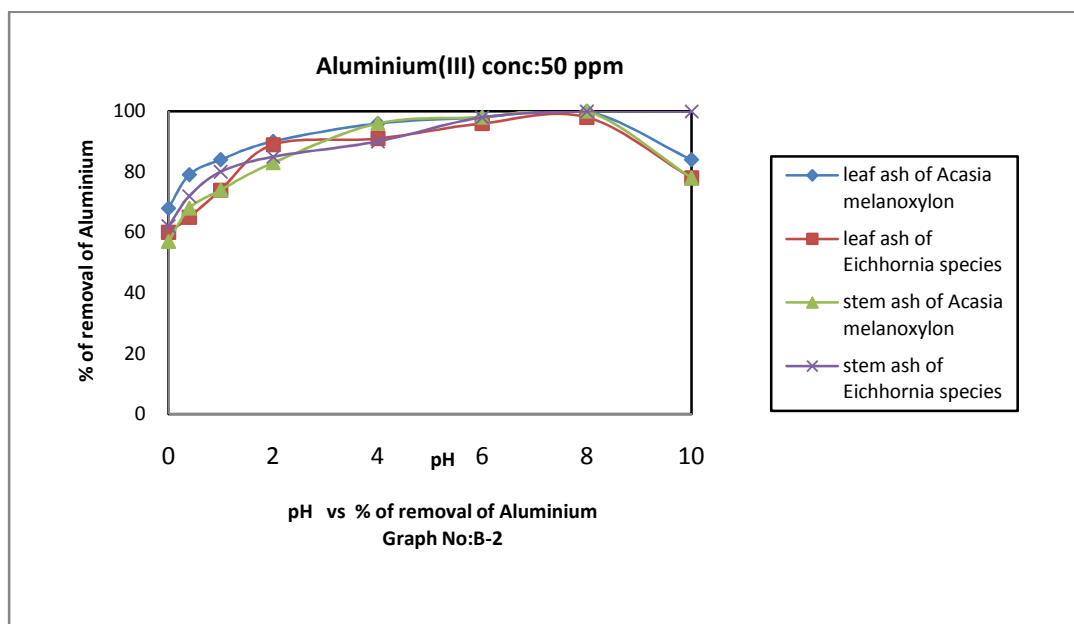
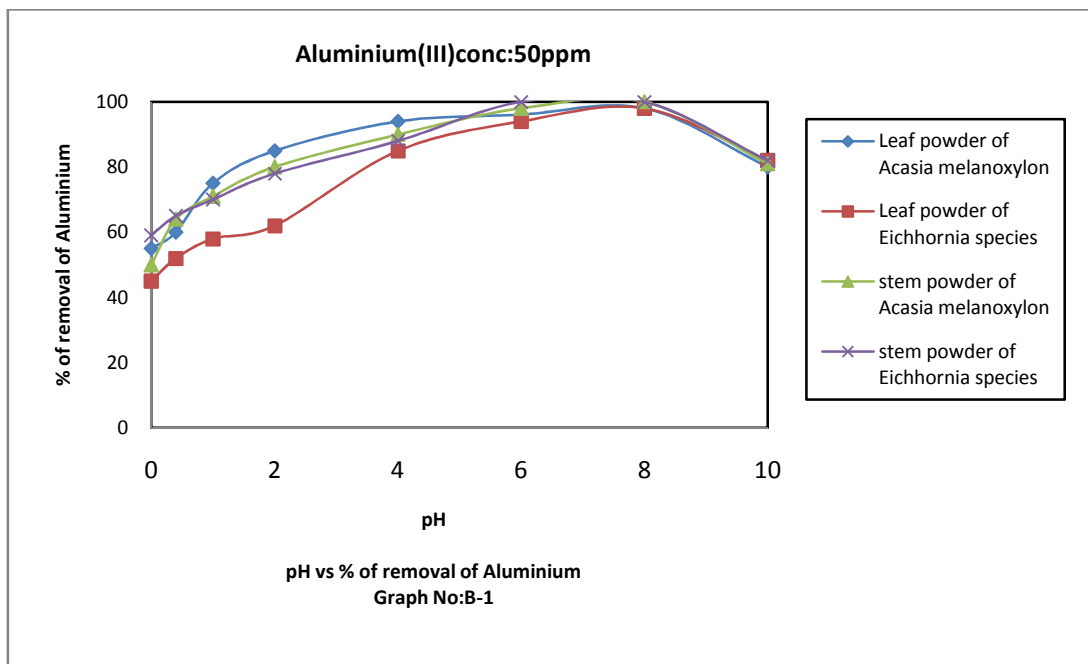












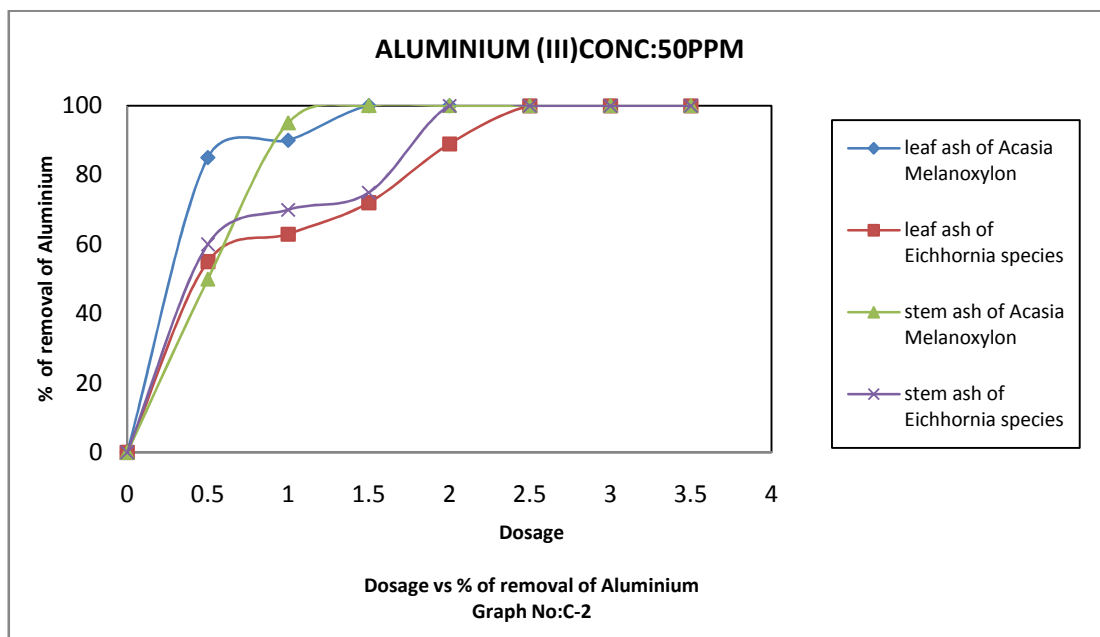
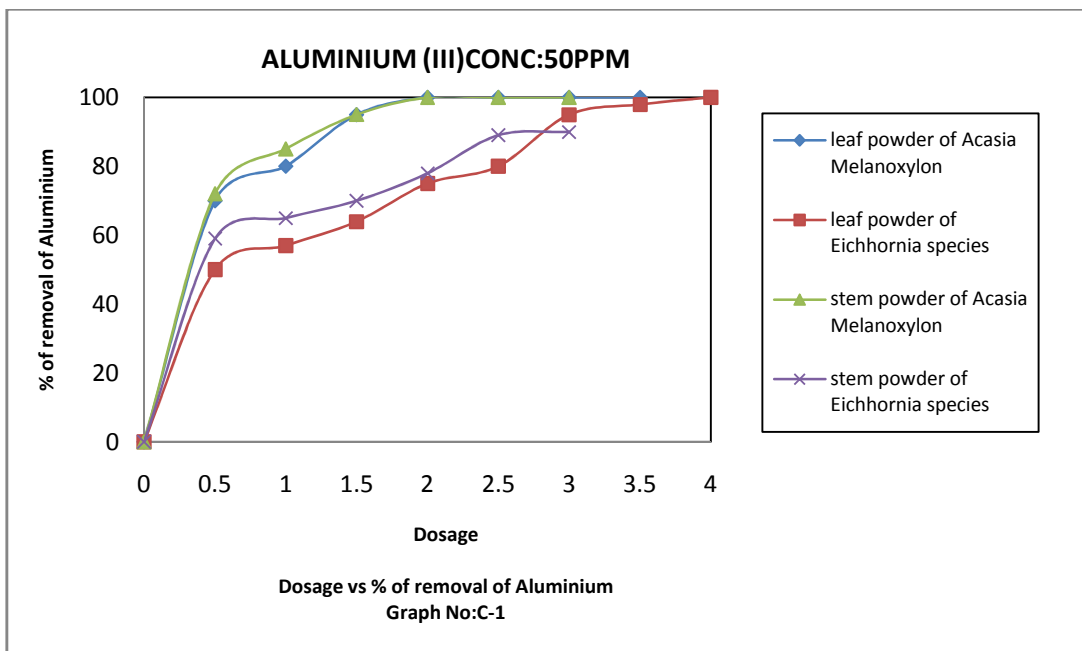


TABLE: 1 Effect of Interfering Ions on the Extractability of Aluminum (III) with Different Bio-sorbents

S.No	Adsorbent	Maximum extractability at optimum condition	% of Extraction of Aluminum (III) in the presence of tenfold excess of interfering ions at optimum extraction conditions										
			SO <sub>4</sub> <sup>2-</sup>	NO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	PO <sub>4</sub> <sup>2-</sup>	F <sup>-</sup>	CO <sub>3</sub> <sup>2-</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Cu <sup>2+</sup>	Zn <sup>2+</sup>	Ni <sup>2+</sup>
1.	Powder of Acacia melanoxylon leaves	100.0%, pH:6, 120 minutes, 2.0gm/lit	99.3%	99.9%	78.2%	100.0%	64.3%	98.9%	96.2%	99.3%	97.6%	98.4%	96.9%
2.	Powder of Eichhornia crassipes leaves	98.0%, pH:6, 120 minutes, 4.0gm/lit	97.5%	97.2%	70.0%	100.0%	62.2%	96.1%	94.2%	97.8%	96.1%	97.0%	94.6%
3.	Powder of Acacia melanoxylon stems	98.0%, pH:6, 120 minutes, 2.0gm/lit	97.2%	96.9%	69.9%	100.0%	61.9%	95.9%	93.8%	97.6%	95.8%	96.9%	94.7%
4.	Powder of Eichhornia crassipes stems	100.0%, pH:6, 150 minutes, 2.5gm/lit	99.1%	100.0%	77.9%	100.0%	64.1%	98.9%	95.9%	99.4%	97.1%	99.1%	97.3%
5.	Ash of Acacia melanoxylon leaves	100.0%, pH:6, 90 minutes, 2.0gm/lit	99.1%	100.0%	77.7%	100.0%	63.9%	98.7%	95.7%	99.2%	97.4%	98.7%	96.8%
6.	Ash of Eichhornia crassipes leaves	100.0%, pH:6, 120 minutes, 2.5 gm/lit	97.3%	97.1%	70.3%	100.0%	62.3%	96.4%	94.3%	97.7%	96.2%	97.1%	94.3%
7.	Ash of Acacia melanoxylon stems	100.0%, pH:6, 90 minutes, 1.5 gm/lit	99.4%	100.0%	78.3%	100.0%	64.4%	98.8%	96.3%	99.4%	97.7%	98.5%	96.8%
8.	Ash of Eichhornia crassipes stems	100.0%, pH:6, 120 minutes, 2.0gm/lit	99.2%	100.0%	78.1%	100.0%	64.2%	98.6%	96.1%	99.2%	97.5%	98.3%	96.6%

Table No: 2: Applications: Extraction of Aluminum (III) from Different Industrial Effluents and Natural polluted Lake Samples using Bio-sorbents developed in this work

SAMPLES COLLECTED AT DIFFERENT PLACES	Conc. of Al(III) in the Sample	% of Maximum extraction of Aluminum(III)							
		Acacia melanoxylon				Eichhornia crassipes			
		Leaves Powders (mesh:<75 μ) :pH:6; 120 min & 2.0 g/lit	Leaves Ashes pH: 6;90 min & 2.0 g/lit	Stems Powders (mesh:<75 μ) pH:6;120 min & 2.0 g/lit	Stems Ashes pH: 6;90 min & 1.5 gms/lit	Leaves Powders (mesh:75 μ) :pH:6;120 min& 4.0 g/lit	Leaves Ashes pH: 6;120 min & 2.5 g/lit	Stem Powders (mesh:75 μ) pH:6;150 min& 2.5 g/lit	Stem Ashes pH: 6;120 min & 2.0 g/lit
Alum manufacturing Industrial effluents:									
1	8.0 ppm	96.5%	95.4%	93.5%	94.1%	98.2%	95.5%	96.0%	95.2%
2	12.5 ppm	98.0%	94.5%	94.0%	95.2%	96.3%	96.0%	97.2%	96.5%
3	14.5 ppm	95.5%	96.0%	96.5%	95.3%	95.6%	97.5%	98.3%	97.5%
Aluminum Sulphate manufacturing Industrial effluents:									
1	15.5 ppm	97.5%	94.4%	94.5%	97.3%	95.5%	96.3%	94.5%	95.0%
2	18.5 ppm	98.0%	95.2%	96.7%	96.8%	96.3%	97.6%	90.5%	96.5%
3	22.8 ppm	97.0%	93.8%	94.2%	95.8%	97.4%	95.4%	91.5%	96.7%
Natural polluted Lake Samples(fed with known amounts of Aluminum (III)):									
1	7.2 ppm	98.5%	95.5%	96.5%	97.6%	97.4%	95.4%	95.5%	96.5%
2	12.0 ppm	96.8%	97.0%	97.4%	98.6%	96.5%	96.8%	96.5%	97.5%
3	20.0 ppm	97.5%	96.5%	96.5%	96.8%	98.6%	97.5%	95.0%	98.0%

## CONCLUSION

1. Bio-adsorbents derived from leaves and stems of *Acacia melanoxylon* and *Eichhornia crassipes* are found to be effective in the removal of Aluminum (III) species from waste waters at optimum conditions of pH (6-8), sorbent dosage and time of equilibration.
2. The optimum conditions for the maximum extraction of Aluminum (III) ions with minimum dosage and agitation time from simulated water have been studied.
3. Methodologies developed have been found to be successful in extracting more than 98% of Aluminium.
4. Most of the common cations, even at tenfold excess, envisaged marginal effect on the % of extraction of Aluminum (III) at optimum extraction conditions. Anions like Sulphate, Nitrate and Carbonate have least affected the % of extraction while Chlorides and Fluorides markedly affected the % of extraction but Phosphates synergistically increased the % of extraction.
5. The procedures developed are successfully applied for some industrial and polluted lake samples in extracting more than 95% of Aluminum.

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