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Extraction of zinc from polluted waters using bio-sorbents derived from *Prosopis cineraia, Tephrosia purpurea* and *Justicia adhatoda* plants

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ABSTRACT

Adsorbents derived from plant materials of *Prosopis Cineraia, Tephrosia purpurea and Justicia adhatoda, have been explored for their affinity towards Zinc ions from waste waters. Sorption natures of these adsorbents have been probed with respect to various physicochemical parameters and the conditions of extraction for the maximum removal of Zinc from polluted waters, have been optimized. In many of the sorbents, more than 70% extraction has been noted. % removal is found to be more with ashes as adsorbents, followed by stems powder and leaves powder. The effect of co-ions on the % of extraction is studied; anions, monovalent cations and many of the divalent cations commonly found in natural waters, have marginal effect. The procedures developed have been successfully applied to samples collected from industrial effluents and polluted lakes.*

Keywords: Bio-sorbents, Batch studies, Zinc removal

INTRODUCTION

Zinc toxicity is well known and its presence in drinking waters more than 5 ppm (1-3) causes health hazards due to the accumulation of Zinc in liver, kidney, pancreas and bones of human beings (3). Various industries pertaining to the manufacture of paints, batteries, electroplating, galvanization, pharmaceuticals and paper, are the main source of zinc contamination besides the contamination of waters due to over utilization of zinc salts in agriculture (4-7).

The control of heavy metal ions in drinking waters using bio-sorbents derived from flora and faunae materials is one of the major areas of research in pollution control methods and these methods are evoking hidden sorption abilities of bio-wastes towards the metal ions either in their native state or in the modified forms and thus, proving to be alternatives to traditional methods. In this aspect, our research group has been actively working and successfully developed methods in controlling some polluting ions [8-14].

Various bio-sorbents prepared bio-materials such as *Rice husk, Oil Palm, cork powder, Duckweed, maize stalks,* Neem *biomass, Moringa oleifera Lam. [horseradish tree] biomass, Biomass of Agaricus Bisporus, leaves of Araucaria cookie etc. have been tried by various researchers for the extraction of Zinc ions from polluted waters and in fact, a good review article is reported by* Haider M. Zwain et. al. (15-34). These methods one way other have disadvantages and the search for simple, eco-friendly and effective method is actively pursued by researchers.

Our pilot work has indicated that there is affinity between Zinc ions and bio-materials pertaining to Prosopis Cineraia, Tephrosia purpurea and Justicia adhatoda plants. In this work, the effect of various physicochemical *properties on the extraction of Zinc from polluted water has been probed and optimized. The methodologies developed have been applied to real polluted water sample.*

EXPERIMENTAL SECTION

(A) CHEMICALS: Analytical grade chemical were used.

- ***Stock solution of Zinc*:** 500 ppm of Zinc solution was prepared by dissolving a requisite amount of A.R. grade Zinc Sulphate in a known volume of double distilled water with the addition of few drops of dil. H_2SO_4. It was suitably dilute as per the need.
- Solution ascorbate, fine granular powder, USP.
- Potassium cyanide solution: 1.0 gm of KCN was dissolved in 50 ml of distilled water and the resulting solution was diluted to 100 ml.
- ***Buffer solution: pH: 9.0***: 8.4 gms of NaOH pellets were dissolved in 500 ml of water and then 31 gms of H_3BO_3 was added to the solution with stirring and the resulting solution was diluted to 1000 ml.
- ***Zincon reagent***: 100 g Zincon (2-carboxy-2f'-hydroxy-5'-sulfoformazyl benzene) was dissolved in 100 ml of methanol and the solution was allowed to stand for overnight.
- Cyclohexanone was purified
- Hydrochloric acid, HCl, conc. and 1N.
- Sodium hydroxide, NaOH, 6N and 1N.

(B) ADSORBENTS: The bio-materials of *Prosopis Cineraia, Tephrosia purpurea and Justicia adhatoda plants* have been found to have affinity towards Zinc ions.

A: Prosopis Cineraria ***B: Tephrosia purpurea*** ***C: Justicia adhatoda***

Fig No. 1: Plants showing affinity towards Zinc ions

Prosopis Cineraria are a species of flowering tree in the pea family, Fabaceae. It is native to arid portions of South Asia. It is a versatile species, providing fodder, fuel, timber and shade besides affecting the soil improvement and sand dune stabilization. It is commonly used in dry land agro forestry in India. It is also used in the preparation of some skin ointments

Tephrosia purpurea is an erect, spreading and short-lived perennial herb grows up to 40-80 cm. It belongs to Fabaceae family. It grows in tropical regions and it possesses medicinal and laxative properties.

Justicia adhatoda is an herbal plant blossoms in cold season and is called Vaidyamata Singhee in Sanskrit. It belongs Acanthaceae family and grows wild in abundance all over India

Sorbent Preparation: The leaves or stems of the plants were cut freshly, washed with tap water, then with distilled water and then sun dried. The dried materials were powdered to a fine mesh of size: <75 microns and activated at 105^o C in an oven and then employed in this study. Further, the stems of the said plants were burnt to ashes, meshed and also used in this work.

C: ADSORPTION EXPERIMENT:

Batch system of extraction procedure was adopted [4, 36 and 37]. Carefully weighted quantities of adsorbents were taken into previously washed one lit/500 ml stopper bottles containing 500ml/250ml of Zinc ions 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, filtered and was analyzed for Zinc ions spectrophotometrically (3).

Estimation: To an aliquot of the sample in volumetric flak, 0.5 g sodium ascorbate, 5 ml of buffer solution, 2 ml of KCN solution and 3.0 ml of Zincon solution were added in sequence with thorough mixing after each addition. Then 1 ml of Cyclohexanone was added with shaking and the solution was allowed to stand for one minute. The developed color absorbance was measured against blank at λmax = 620 nm using UV-Visible Spectrophotometer (Systronics make). (3). The obtained O.D value for un-known solution was referred to standard graph (drawn between O.D and Concentration) prepared with known amounts Zinc solution by adopting method of Least Squares to find concentration of Zinc in unknown solutions.

The effects of various physicochemical parameters such as pH, time of equilibration and dosage of adsorbent on the extraction of Zinc have been studied and the obtained results have been presented in the Graph No. A: 1-9; B: 1-3 and C: 1-3.

***(D)* EFFECT OF OTHER IONS (INTERFERING IONS):**

The effect of co-ions commonly found in natural waters viz. Sulphate, Fluoride, Chloride, Nitrate, Phosphate, Carbonate, Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, Fe^{2+} , Mn^{2+}, Cu^{2+}, *Ni^{2+} and Al^{3+} on the % of extraction , has been assessed by studying the extraction Zinc from the synthetic mixtures prepared by keeping the concentration of co-ions five fold excess than the Zinc ions* as noted in the Table: 1. These synthetic solutions were taken in stopper bottles and then subjected to extraction of Zinc at optimum pH, equilibration time and sorbent dosage as decided by the Graph Nos A:1-9; B:1-3 and C:1-3 and the obtained results have been presented in the Table: 1.

(E)APPLICATIONS OF THE DEVELOPED BIO-SORBENTS:

The success of these new procedures have been tested by applying these extraction procedures to the real industrial sewage samples collected from the industries related to battery, electroplating and pharmaceuticals in and around Hyderabad and also from Lakes polluted with Zinc due to over-utilization of Zinc salts in agricultural procedures in the Bapatla area of Guntur District of Andhra Pradesh. The obtained resulted have been given in the Table. 2.

RESULTS AND DISCUSSION

The affinity of Zinc ions towards the adsorbents pertaining to *Prosopis Cineraia, Tephrosia purpurea and Justicia adhatoda plants have been studied at varying parameters and the results have been presented in the Graph Nos. A:1-9; B:1-3 and C: 1-3. The significant observations are:*

1. ***Time of equilibration***: As the time allowed for the equilibration between the sorbent and the sample solution at a fixed pH and sorbent dosage increases, % removal of Zinc also increases until a certain time interval and then onwards, % of extraction remains constant. The same observations have been noted with all the sorbents probed in this work (vide Graph Nos.A:1-9).

As for example, with powders of leaves of *Prosopis Cineraia, % of extraction of Zinc ions at pH :6 has been found to be 12.5% at 0.25 hrs, 13.5% at 0.5 hrs, 26.2% at 0.75 hrs, 43.5% 1.0 hrs, 53.0% at 1.25 hrs, 59.5% at 1.5 hrs, 60.1% at 1.75 hrs, 62.1 % at 2.0 hrs, 70.0% at 2.25 hrs and above (vide Graph No. A: 1). Similarly, with, the adsorbents derived from the leaves of Tephrosia purpurea plant, % of removal at pH: 4 is found to be : 13% at 0.25 hrs, 35.8% at 0.5 hrs, 40.5% at 0.75 hrs, 49.0% at 1.0 hr, 54.9% at 1.25 hrs, 63.4% at 1.5 hrs, 65.8% at 1.75 hrs, 68.9% at 2.0 hrs, 73.2% at 2.25 hrs and above (vide Graph No. A: 2). The same trend is observed in case of leaves powders of Justicia adhatoda plants at pH: 4 with the maximum Zinc extractability of 62.3% at equilibration time 2.0 hrs or above.(vide Graph No. A:3)*

Similar trend of sorption has been observed with the sorbent derived from the stems of Prosopis Cineraia with 76.5% maximum removal of Zinc at 2.0 hrs of equilibration time, at pH: 6 and with the sorbent dosage of 6.0 g/lit.(vide Graph No. A:4). With the stems powder of Tephrosia purpurea, 70.2% of maximum extraction at 2.0 hrs of equilibration time, at pH: 4 and with the sorbent dosage of 5.0g/lit (vide Graph No.A:5). With stems powder of Justicia adhatodaplant, 82% of removal of Zinc after an equilibration period of 1.75 hrs at pH: 4 and with sorbent concentration of 5.0 g/lit have been observed. (vide Graph No. A: 6).

With the ashes of stems of Prosopis Cineraia, Tephrosia purpurea and Justicia adhatodaplants, the optimum equilibration time have been found to be 1.25 hrs with the mamimum extraction of 74.5% at pH: 6 for Prosopis Cineraia, 75.0% at pH: 4 for Tephrosia purpurea and 85.0% for Justicia adhatodaplants , Vide Graph No. A: 7-9.

It may be inferred from the data that the optimum time of equilibration for the maximum removal of Zinc ions from the waters is of the order: leaves powder > stems powders > ashes of stems for the said three plants. For the sorbents derived from *Prosopis Cineraia plant, the optimum time has been found to be 2.25 hrs for leaves powders, 2.0hrs for stem powders and 1.25 hrs for stems ash. In the case of sorbents pertaining to Tephrosia purpurea, 2.25 hrs for leaves powders, 2.0 hrs for stems powder and 1.25 hrs for ashes of stems. For Justicia adhatoda plant sorbents, 2.0 hrs for leaves powder, 1.75 hrs for stems powder and 1.25 hrs for ashes of stems.*

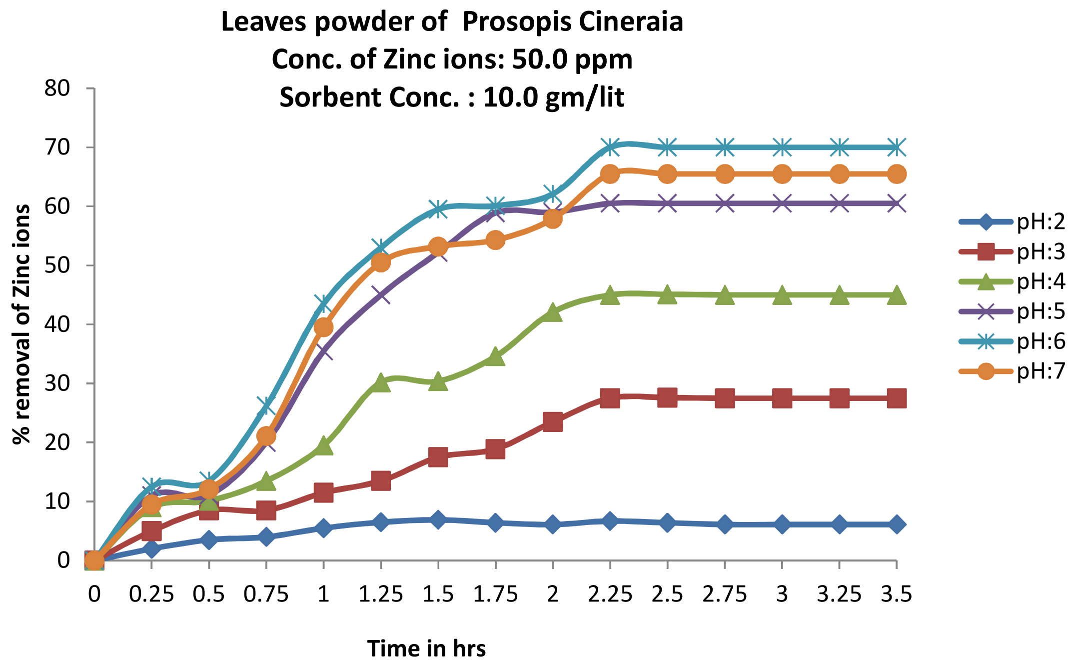
2. ***Effect of pH****:* The extractions are pH sensitive. Sorption nature has been studied in the pH range: 2 to 7. At pH: 6, the maximum removal has been observed (at other standard conditions of extraction), for the sorbents derived from *Prosopis Cineraia plant materials. The optimum pH has been found to be 4 in the case of sorbents pertaining to Tephrosia purpurea and Justicia adhatoda plants (Vide Graph No. B: 1-3).*

The maximum extractability in the case of sorbents of Prosopis Cineraia is found to be: 6.7% at pH:2, 27.5% at pH:3, 45.0% at pH:4, 60.5% at pH:5, 70.0% at pH:6 and 65.5% at pH:7 for leaves powders; 9%, 49.8%, 62.0%, 68.0%, 76.5%, 64.5% for stems *powder; and 12.0% at pH:2, 55.0% at pH:3, 65.0% at pH:4, 74.5% at pH:5, 80.0% at pH:6, and 74.0%at pH:7 with the stems ashes, at other optimum conditions of extraction. With* Tephrosia purpurea plant materials, the % of maximum extraction is found to be 12.2% at pH: 2, 52.5% at pH:3, 73.2% at pH:4, 68.9% at pH:5, 60.5% at pH:6 and 58.2% at pH:7 with the leaves powder; 4.0% at pH: 2, , 52.0% at pH: 3, 70.2% at pH:4, 65.1% at pH: 5, 54.7% at pH: 6 and 50.0% at pH: 7 with the *stems powder;* and 13.0% at pH:2 , 54.5% at pH:3 , 75.0% at pH: 4, 65.5% at pH:5, 58.9% at pH: 6 and 54.2% at pH: 7 with stems ashes. In the case of *Justicia adhatoda plant, the maximum removal is found to be* 2.1% at pH: 2, 50.2% at pH: 3, 62.3% at pH: 4, 54.2% at pH: 5, 46.4% at pH: 6 and 40.3% at pH: 7; 10.0% at pH: 2, 49.0% at pH: 3, 82.0% at pH: 4, 73.4% at pH: 5, 67.1% at pH: 6 and 60.4% at pH: 7 for stems powder; and 15.0% at pH: 2, 54.5% at pH: 3, 85.0% at pH: 4, 74.5% at pH: 5, 65.4% at pH: 6 and 57.4% at pH: 7 for stems ash.

3. ***Sorbent dosage*** The optimum sorbent dose for the maximum removal of Zinc from waters is of the order: leaves powder < stems powders < ashes of stems for a particular plant (vide Graph: C: 1–3). For *Prosopis Cineraia plant*, the dosages is found to be: 9 gm/lit for leaves powder, 6 gms/lit for stems powder and 4 gm/lit for ashes.

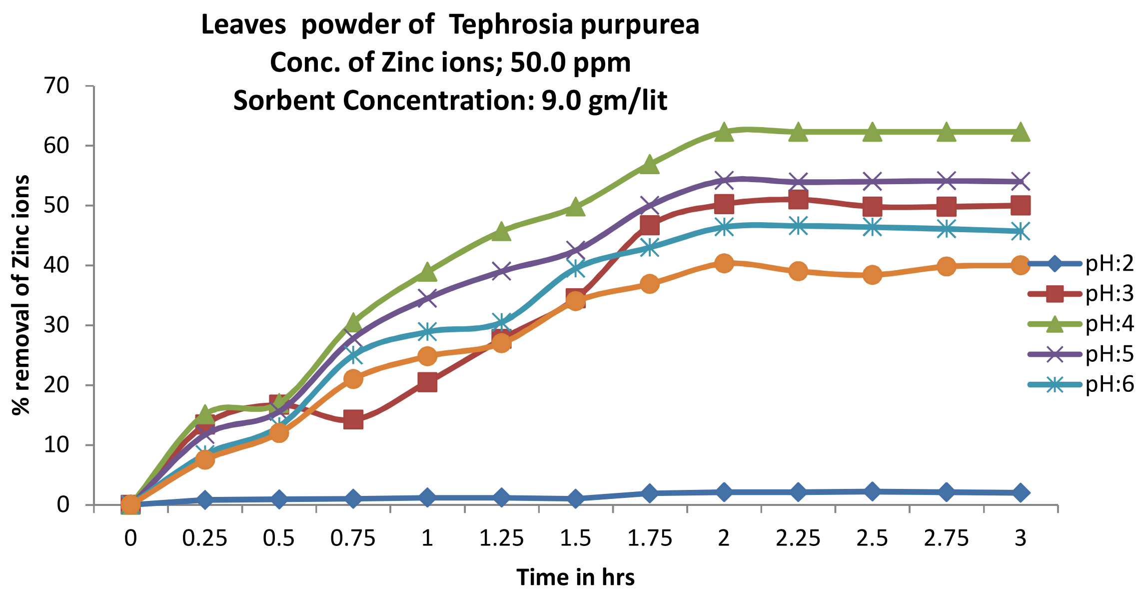
In the case of Tephrosia purpurea plant, the optimum concentration have been found to be 8.0 gm/lit for leaves powder, 5 gms/lit for stems powder and 4 gms/lit for ashes of stems while with *Justicia adhatoda* plant, the optimum concentration is found to be 7.0gm/lit, 5.0 gm/lit and 4.0 gms/lit for leaves powder, stems powder and ashes of stems respectively.

4. ***Interfering Ions*****:** Common anions such as Sulphate, Fluoride, Chloride, Nitrate, Phosphate and Carbonate have marginal effect on the % of extraction of Zinc ions from waters even when they present in Fivefold excess (vide Table 1). Common Cations like K^{+}, Ca^{2+}, Mg^{2+}, Fe^{2+} & Mn^{2+} have also not effected the % of extraction of Zinc ions at the standard conditions of extractions as cited in the Table 1. However, Cu^{2+} *and* Ni^{2+} *have interfered to some extent while* Al^{3+} *interfered markedly (vide Table No. 1)*



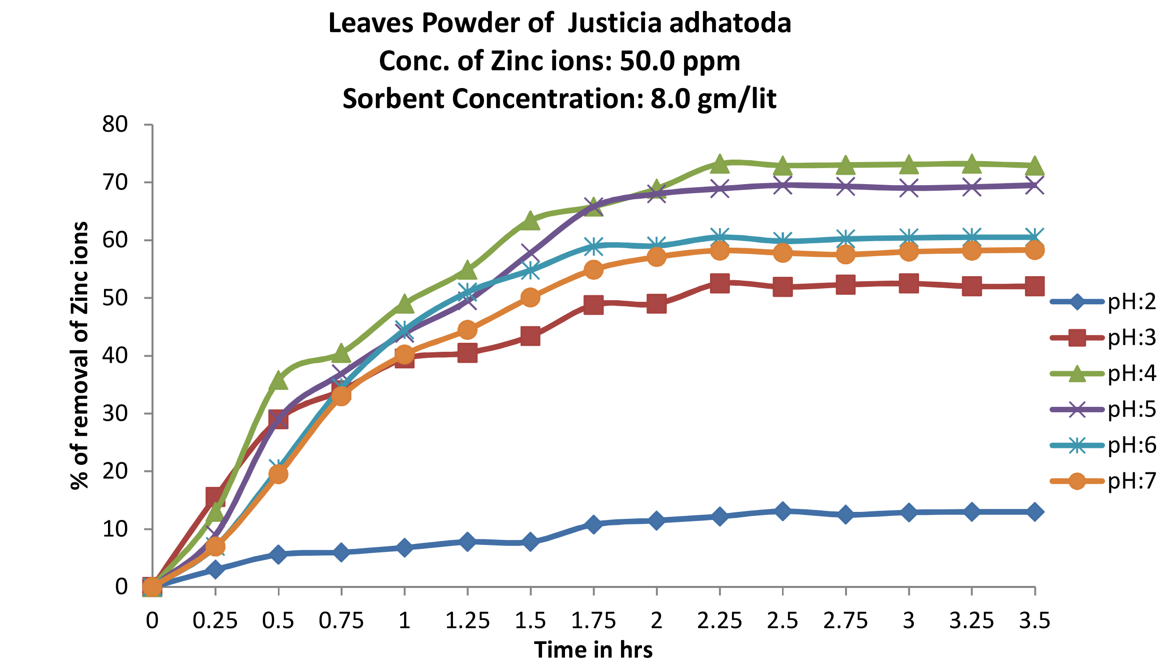
Time Vs % or removal of Zinc ions

Graph No.A: 1



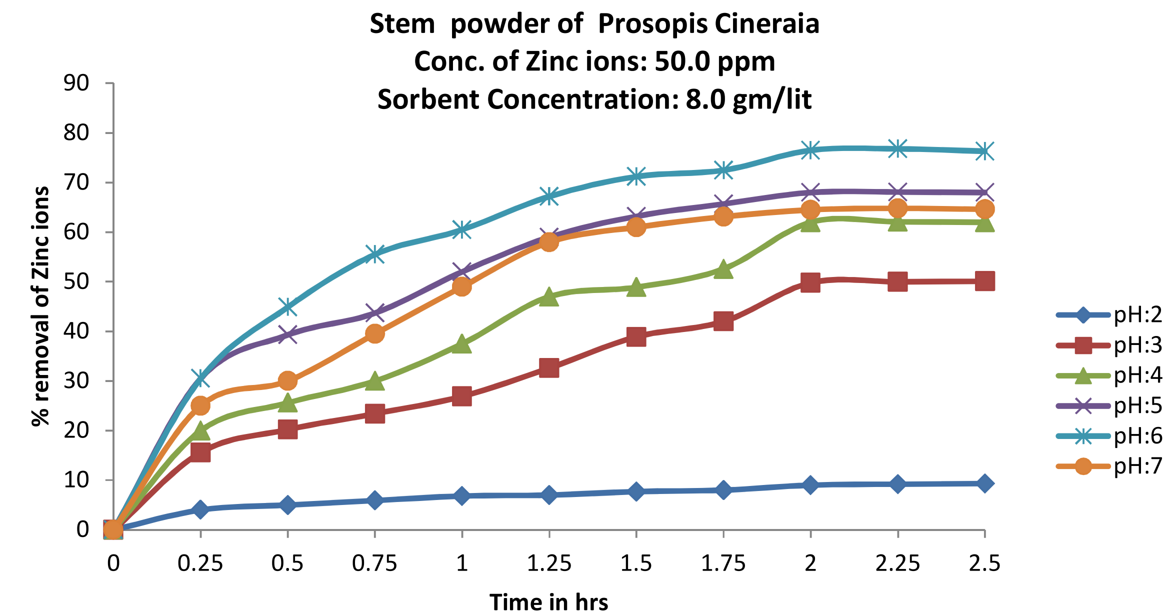
Time Vs % of removal of Zinc ions

Graph No. A:2



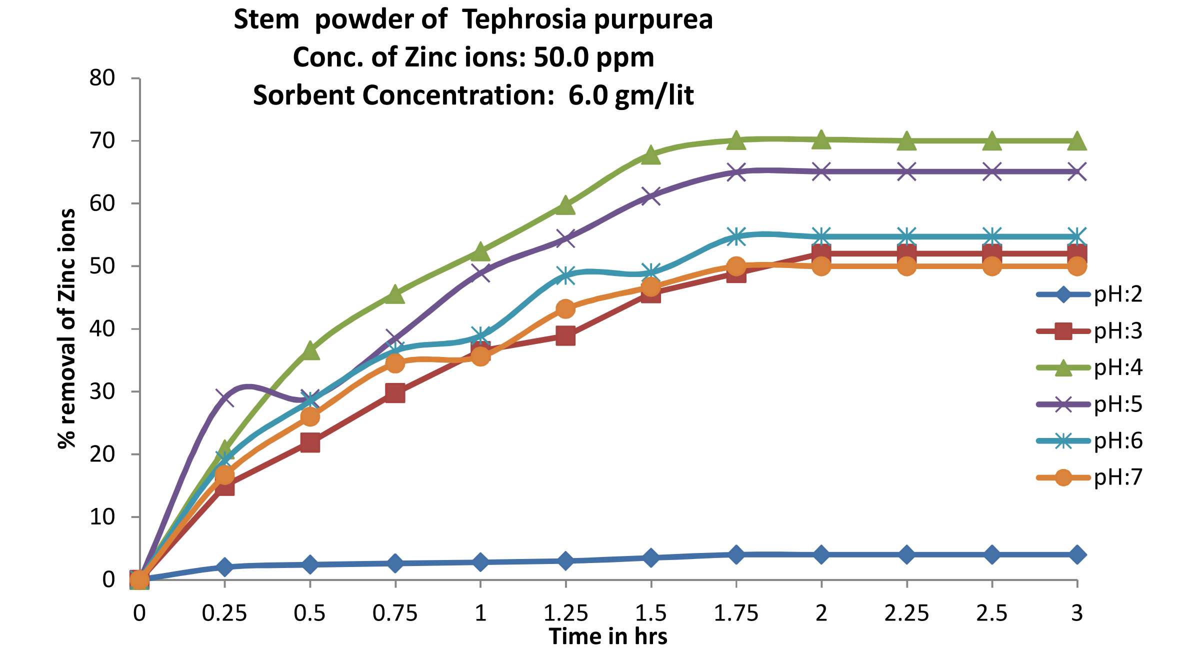
Time Vs % of removal of Zinc ions

Graph No. A: 3



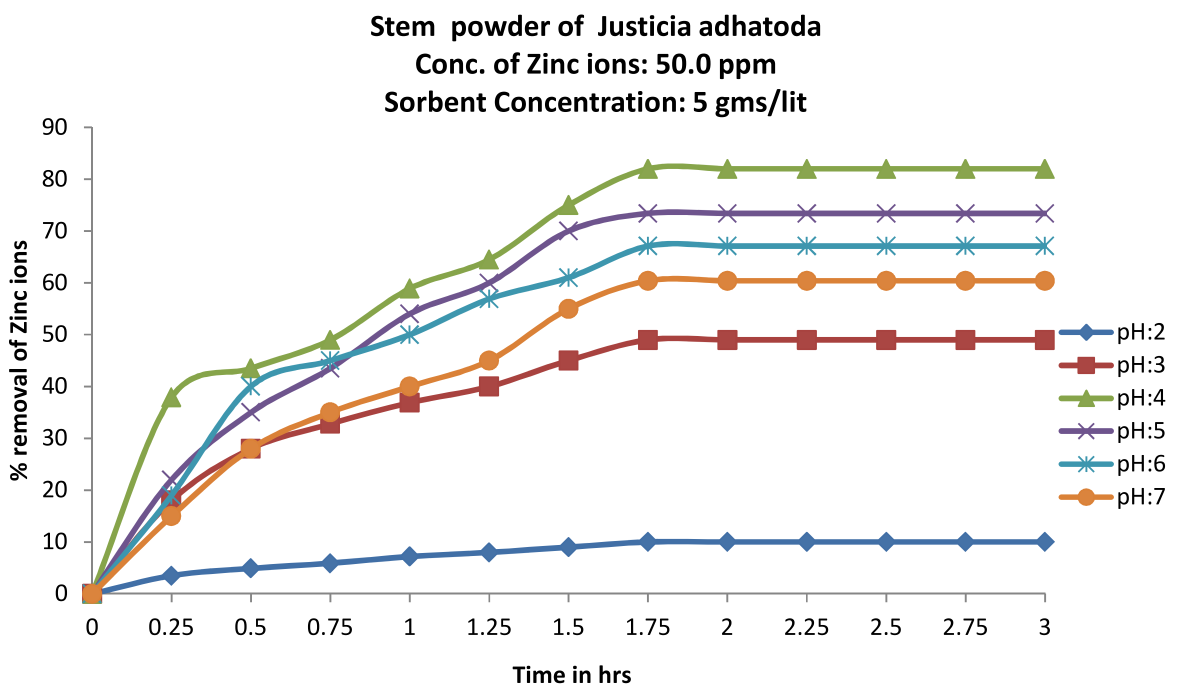
Time Vs % of removal of Zinc ions

Graph No. A:4



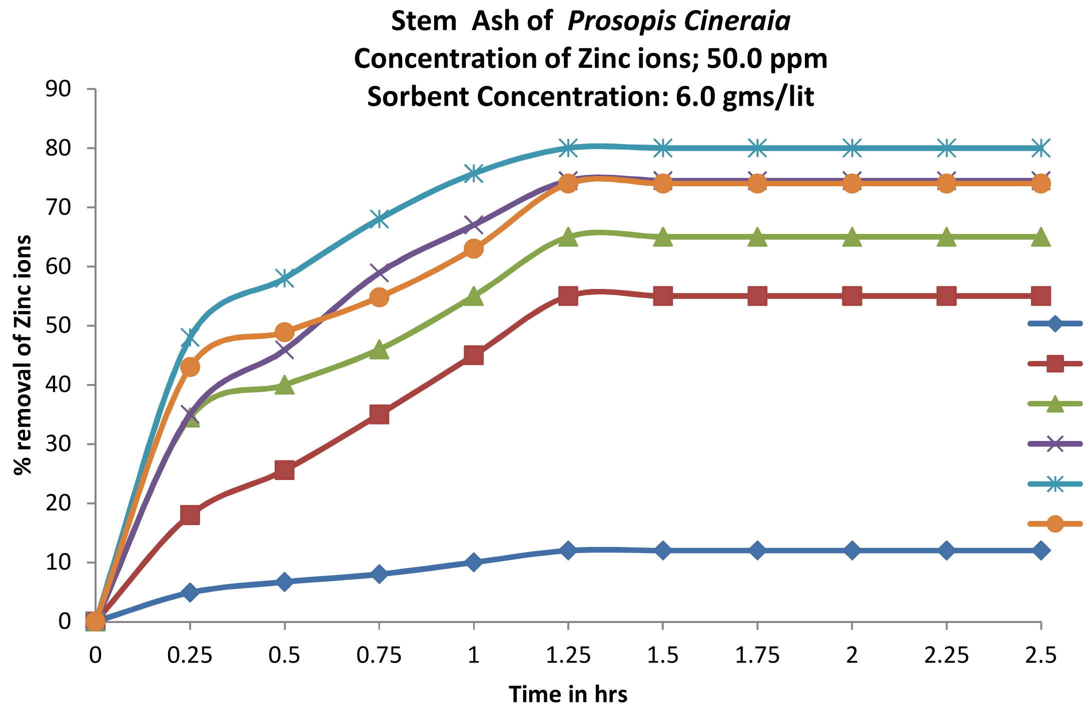
Time Vs % of removal of Zinc ions

Graph No. A:5



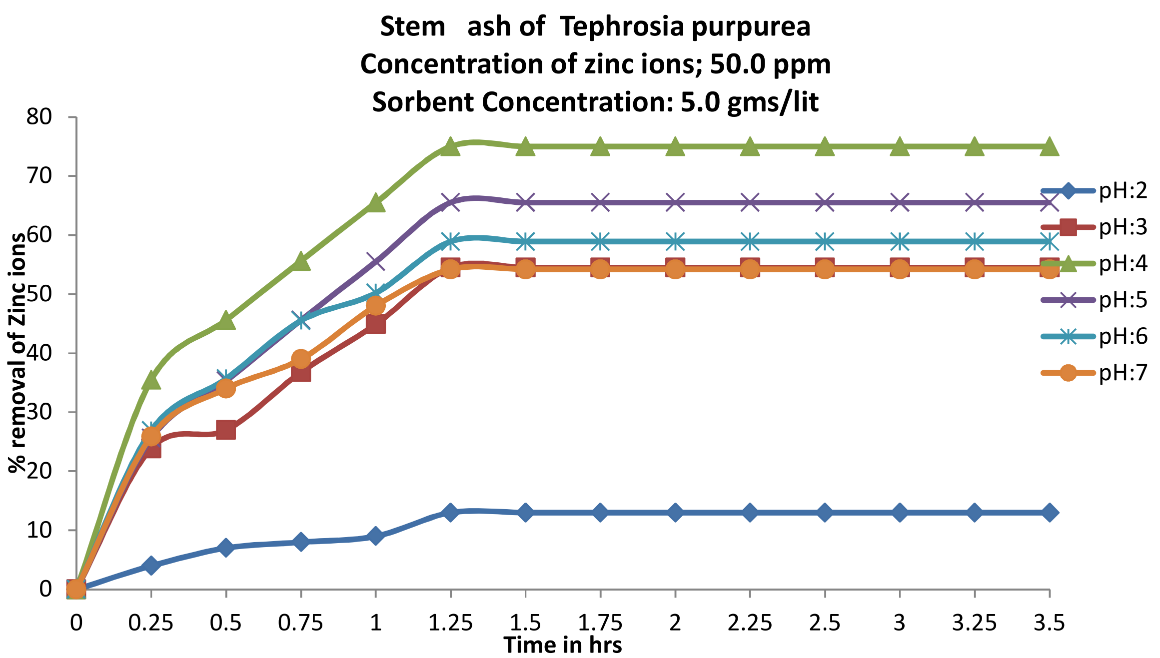
Time Vs % Removal of Zinc ions

Graph No. A: 6



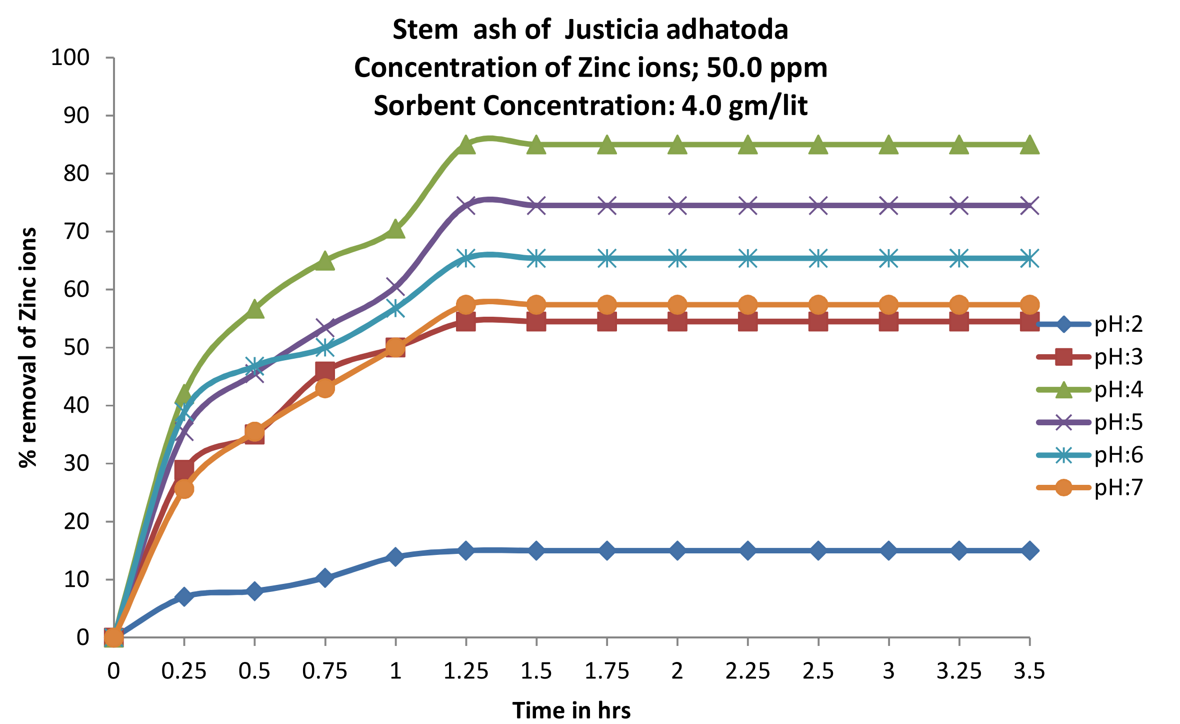
Time Vs % removal of Zinc ions

Fig. No. A: 7



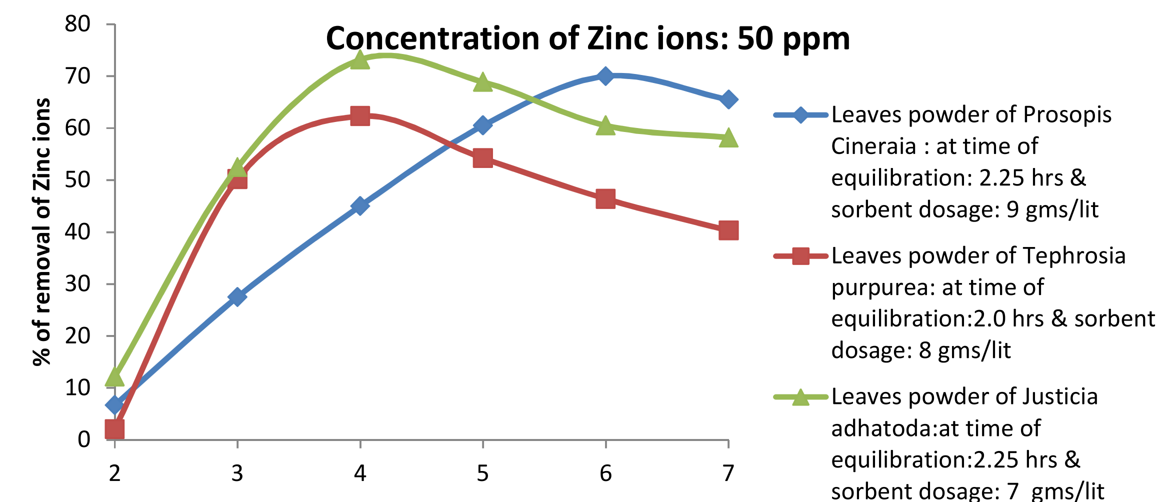
Time Vs % removal of Zinc ions

Fig. No. A: 8



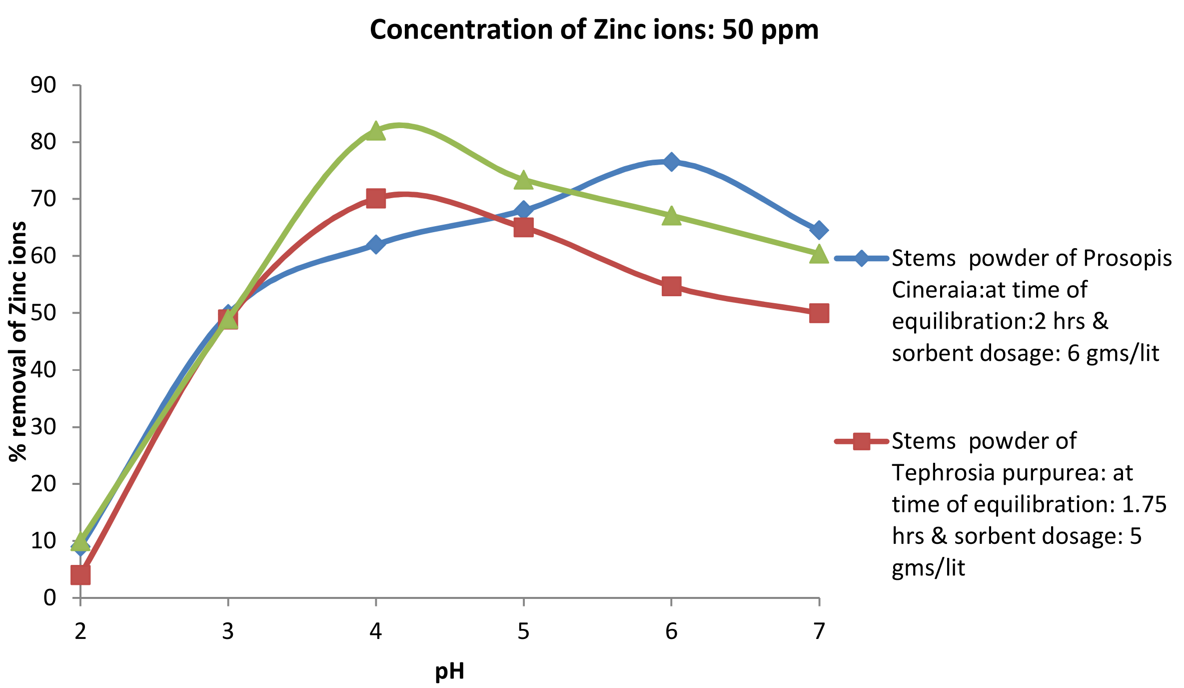
Time Vs % removal of Zinc ions

Fig. No.A: 9



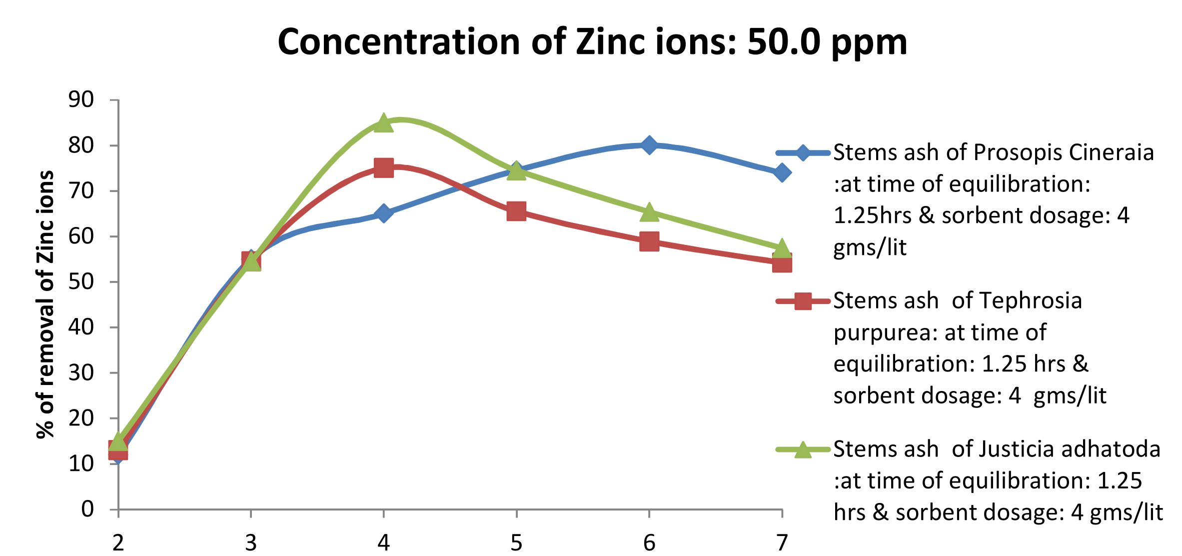
pH Vs % of removal of Zinc ion

Graph No. B:1



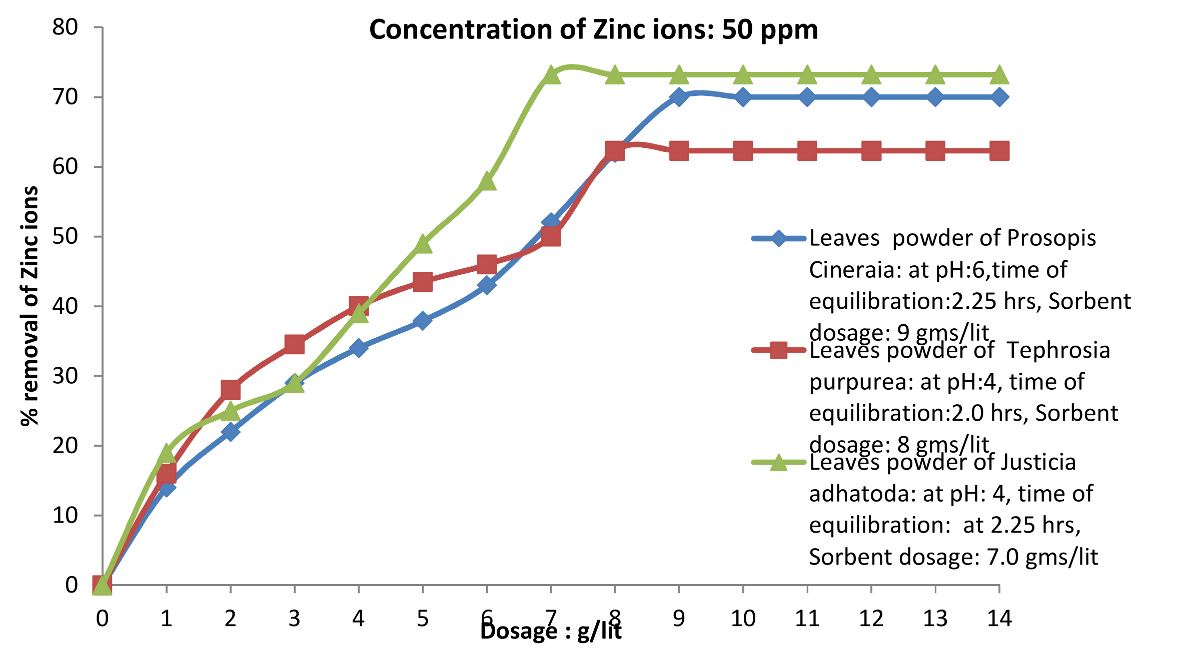
pH Vs % removal of Zinc ions

Graph No. B: 2



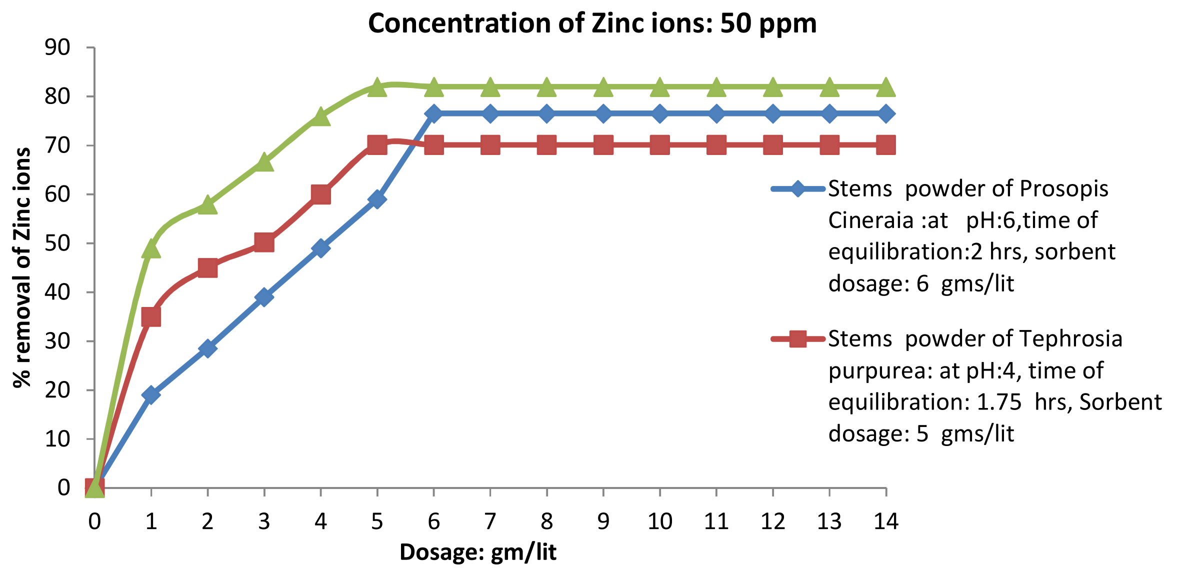
pH Vs % of removal of Zinc ions

Graph No. B:3



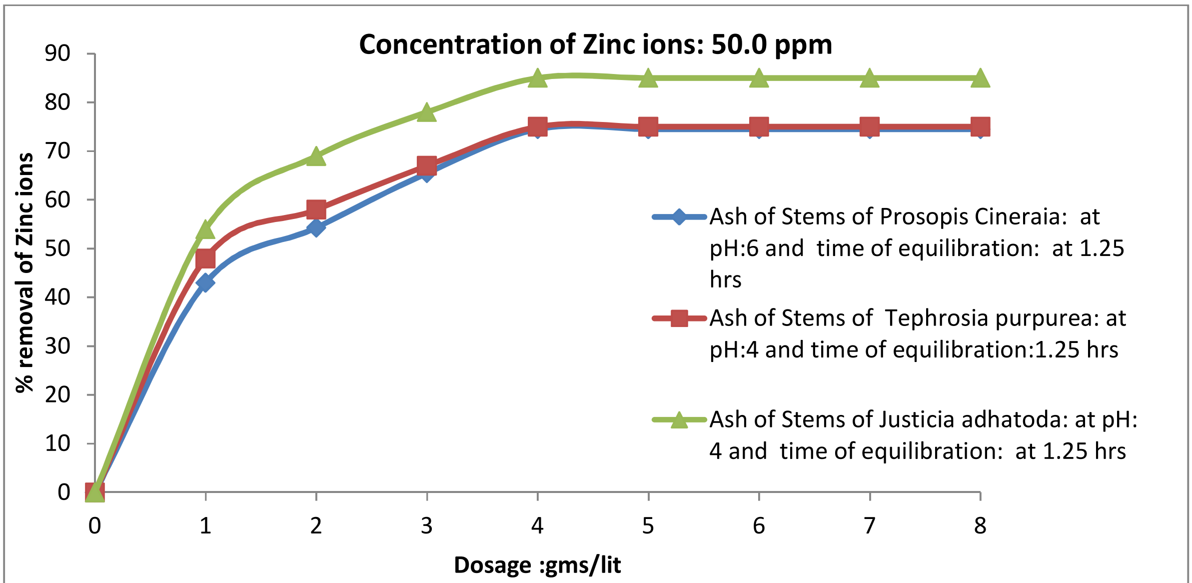
Sorbent Concentration Vs % Removal of Zinc ion

Graph No. C:1



Concentration of Adsorbent Vs % removal

Graph No. C: 2



Concentration of Adsorbent Vs % removal of Zinc ions
Graph No. C:3

Table :1: Effect of interfering Ions on the Extractability of Zinc ions with different Bio-sorbents

S.No	Adsorbent and its concentration	Maximum Extractability at optimum conditions	*% Extractability of Zinc in presence of fivefold excess of (500 ppm) interfering ions at optimum conditions: Conc of Zinc: 50 ppm*												
			SO_4^{2-}	PO_4^{3-}	Cl^-	CO_3^{2-}	F^-	K^+	Ca^{2+}	Mg^{2+}	Fe^{2+}	Mn^{2+}	Cu^{2+}	Ni^{2+}	Al^{3+}
1	Leaves powder of ***Prosopis Cineraia***	70.0%; pH: 6 Agitation time: 2.25 hrs; sorbent conc.: 9.0 g/l	67.5	68.5	69.0	68.5	67.9	68.9	66.5	66.0	68.0	67.0	61.0	63.0	60.0
2	Stems powder of ***Prosopis Cineraia***	76.5%; pH:6 Agitation time: 2.0 hrs; sorbent conc.: 6.0 g/l	73.0	74.0	73.5	71.5	72.5	72.0	71.5	70.5	73.5	73.5	65.0	65.5	63.5
3	Stems ash of ***Prosopis Cineraia***	80.0%; pH:6 Agitation time: 1.25 hrs; Sorbent conc.:4.0 g/l	77.5	78.5	76.5	77.5	75.0	74.0	73.0	74.5	76.5	74.0	68.5	69.0	64.0
4	Leaves powder of ***Tephrosia purpurea***	62.3%;pH:4 ; Agitation time:2.25 hrs; Sorbent conc.: 8.0 g/l	60.0	61.0	59.5	60.0	59.0	58.5	58.0	56.0	58.5	58.5	52.5	53.5	50.0
5	Stems powder of ***Tephrosia purpurea***	70.2%; pH:4 Agitation time: 2.0 hrs; Sorbent conc.:5.0 g/l	66.8	67.6	68.0	69.0	66.5	68.0	67.5	68.0	66.5	67.5	61.0	60.5	59.0
6	Stems ash of ***Tephrosia purpurea***	75.0%; pH:4 ; Agitation time: 1.25 hrs; Sorbent Conc..: 4.0 g/l	73.0	74.0	71.0	72.5	73.0	71.5	73.5	72.5	73.5	71.5	63.5	62.5	60.0
7	Leaves powder of ***Justicia adhatoda***	73.2%; pH: 4 Agitation time: 2.0hrs; Sorbent Conc.: 7.0 g/l	71.5	70.5	70.0	72.0	72.5	71.0	70.5	69.5	68.9	68.5	61.0	60.0	59.0
8	Stems powder of ***Justicia adhatoda***	82.0%; pH:4 Agitation time: 1.75 hrs; Sorbent Conc.: 5.0 g/l	80.0	81.0	80.5	79.9	79.6	78.9	78.5	77.5	76.5	75.5	69.5	68.5	64.0
9	Stems ash of ***Justicia adhatoda***	85.0%; pH:4 Agitation time: 1.25 hrs; Sorbent Conc.: 4.0 g/l	84.0	83.5	82.5	83.0	82.0	79.5	78.5	80.0	81.5	82.5	70.0	65.0	62.3

Table 2: % of Extractability of Zinc from real samples collected from natural lakes and different industrial effluents using the Bio-sorbents developed in this work

Sl. No.	BIO-SORBENTS	% of Extractability of Methylene Blue				
		NATURAL LAKES		INDUSTIRAL EFFLUENTS		
		Sample 1: (contains 76.5 ppm of Zinc)	Sample 2: (contains 40.2 ppm of Zinc)	Sample 3: (contains 110.0 ppm of Zinc)	Sample 4: (contains 125.0 ppm of Zinc)	Sample 5: (contains 108.0 ppm of Zinc)
1	Leaves powder of ***Prosopis Cineraia*** :at pH:6; Equilibration time: 2.25 hrs and sorbent conc.: 9.0 g/l	68.0%	67.0%	66.0%	65.5%	67.5%
2	Stems powder of ***Prosopis Cineraia*** : at pH:6; Equilibration time: 2.0 hrs and sorbent conc.: 6.0 g/l	**70.0 %**	69.5%	71.1%	70.5%	68.9%
3	Stems ash of ***Prosopis Cineraia*** :at pH:6; Equilibration time: 1.25 hrs and sorbent conc.: 4.0 gms/l	75.5 %	76.0%	74.0%	73.5%	74.5%
4	Leaves powder of ***Tephrosia purpurea*** :at pH:4; Equilibration time: 2.25 hrs and sorbent conc.: 9.0 gm/lit	60.5%	61.0%	59.7%	60.0%	59.0%
5	Stems powder of ***Tephrosia purpurea*** :at pH:4; Equilibration time: 2.0 hrs and sorbent conc.: 5.0 g/l	69.0%	68.5%	67.8%	68.0%	**67.0%**
6	Stems ash of ***Tephrosia purpurea***: at pH:4; Equilibration time:1.25 hr and sorbent conc.: 4.0 g/l	73.00%	72.1%	70.0.%	71.0%	70.5%
7	Leaves powder of ***Justicia adhatoda plant*** :at pH:4; Equilibration time:2.0 hr and sorbent conc.: 8.0 g/l	72.0%	68.5%	67.0%	70.0 %	71.0%
8	Stems powder of ***Justicia adhatoda plant*** :at pH:4; equilibration time: 1.75 hrs and sorbent conc.: 5.0 g/l	77.0%	78.5%	76.5%	70.0%	71.2%
9	Stems ash of ***Justicia adhatoda plant*** at pH:4; equilibration time: 1.25 hrs and sorbent concentration: 4.0 g/l	80.0%	82.5%	79.0%	78.0%	76.5%

With the data available in this work, it is not possible to propose theoretical basis for each observation as further study of morphology of the sorbents before and after sorption of the adsorbate on the adsorbent, is needed using such modern instruments like XPS, FTIR, SEM and EDS besides the information obtained from the classical methods of analysis, which is beyond the scope of this work. However, a rough understanding may be conceived based on the nature of the functional groups present the plant materials.

The plant materials have potential –OH/-COOH groups and are exchanged with Zn^{2+} as per the equations:

$$\text{Adsorbent surface-COOH} + Zn^{2+} \rightleftharpoons \text{Adsorbent Surface -COO})_2Zn + 2\,H^{+}$$

$$\text{Adsorbent surface-OH} + Zn^{2+} \rightleftharpoons \text{Adsorbent Surface-O})_2Zn + 2\,H^{+}$$

These exchanges are pH dependent and the exchange of Zn^{2+} to the sorbent is less favored with the decrease of pH. However, in basic solutions, Zinc exists as Zincate, an anion, which has less affinity towards the negatively charged surface of the adsorbent. Hence, the optimum pH is found to be '6' for sorbent based on the Prosopis Cineraia plant and '4' for the sorbents pertaining to Tephrosia purpurea and Justicia adhatoda plants.

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 with respect to the interfering ions are as per the expected lines. Anions having negative charge have no affinity towards the adsorbents as their surface is charged negatively at pH: 4 (for Tephrosia purpureaand Justicia adhatoda plant materials) or 6 (for Prosopis Cineraia plant material). Monovalent cations and divalent cations like Ca^{2+}, Mg^{2+}, Fe^{2+} & Mn^{2+} having less cation exchanging ability than Zn^{2+} ions, show marginal interference at the optimum conditions of extraction as cited in the Table 1 while Trivalent cation, Al^{3+} and other divalent ions like Cu^{2+} and Ni^{2+} possessing more cation-exchange ability than divalent Zn^{2+}, have interfered.

4: APPLICATIONS

The methods developed in this work have been applied to the samples of water collected from polluted Lake and effluents of industries and the results observed have been presented in Table 2.

% removal of Zinc has been found to be in the range of 65.5% to 68.0% for leaves powders, 68.9% to 71.1% for stems powder and 73.5 to 76.0% for ashes of stems of *Prosopis Cineraia plant (vide Table 2: Sl No. 1-3)*; *59.0*% to 61.0% for leaves powders, 67.0% to 69.0% with stems powder and 70.5 % to 73.0% with ashes of stems of *Tephrosia purpurea plant (vide Table 2: Sl No. 4-6);* 67.0% to 72.0% with leaves powder, 70.0% to 78.5% with stems powder and 76.5% to 82.5% with the ashes of stems of *Justicia adhatoda plant (vide Table No. 2: Sl No. 7-9)*

CONCLUSION

Plant materials of *Prosopis Cineraia*, *Tephrosia purpurea and Justicia adhatoda plants* have been probed for their extraction ability towards Zinc ions from simulated polluted waters by changing gradually the various physicochemical parameters such as pH, sorbent concentration and time of equilibration.

The adsorbents have shown pH dependent sorption ability. The optimum pH has been found to be '6' for the adsorbents based on *Prosopis Cineraia and '4' for the adsorbents based on Tephrosia purpurea and Justicia adhatodaplants.*

The sorbent concentration and time of equilibration have been found to be in the order: *leaves > barks > Ashes for a particular plant. So also is the % of extraction: for a particular plant, the % removal of Zinc ions is more for ashes, followed by stems powder and leave powder.*

With plant materials of *Prosopis Cineraia as adsorbents, at optimum pH: 6, the maximum extraction has been found to 70.0%* for *leaves powder* with agitation time of 2.25 hrs and at sorbent dosage of 9.0 g/l; *76.5% for stems powder* with agitation time of 2.0 hrs and at sorbent dosage of 6.0 g/l; and *80.0% for ashes of stems* with agitation time of 1.25 hrs and at the sorbent conc.: 4.0 g/l

At the optimum pH: 4, the maximum extraction is found to be: 62.3% with *leaves powder* of *Tephrosia purpurea* at optimum agitation time: 2.25 hrs and at optimum sorbent conc.: 8.0 g/l; *70.2%* with *the powders of stems* at optimum agitation time: 2.0 hrs and at sorbent conc.:5.0 g/l; *75.0%* for *ashes of stems* at optimum agitation time: 1.25 hrs and at sorbent conc. of 4.0 g/l.

With the plant materials of Justicia adhatoda as adsorbents, the maximum extraction is found to be 73.2% for *leaves powder* at optimum conditions of extraction: pH: 4, agitation time: 2.0 hrs and sorbent dosage: 7.0 g/lit; *82.0%* for *stems powder* at pH: 4, agitation time: 1.75 hrs and sorbent conc.: 5.0 g/l; and *85.0%* for *ashes of stems* at pH: 4, agitation time: 1.25 hrs and sorbent conc. 4.0 g/l.
% removal has been marginally affected by anions commonly found in waters such as. Sulphate, Fluoride, Chloride, Nitrate, Phosphate and Carbonate. Monovalent cations and divalent cations such as Ca^{2+}, Mg^{2+}, Fe^{2+} and Mn^{2+} have not shown interference with the extraction of Zinc but cations like Cu^{2+} and Ni^{2+} and trivalent Al^{3+} interfered.

The procedures developed have been successfully applied to remove Zinc ions from the samples collected from industrial effluents and polluted lakes as given in Table: 2.

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