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Removal of zinc from waste waters using new biosorbents derived from *Terminalia Arjuna, Atlantia Monophylla (L) Correa and Madhuca Indica plants*

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ABSTRACT

The surface sorption nature of bio-adsorbents derived from plant materials of Terminalia arjuna, Atlantia monophylla (L) Correa and Madhuca indica plants have been probed towards the removal of Zinc ions from simulated polluted waters by varying the physicochemical parameters such as pH, sorbent concentration and time of equilibration and the extractions conditions have been optimized for the maximum removal of Zinc ions from waste waters. The extractions have been found to be pH sensitive. The optimum sorbent dosage, time of equilibration and % of removal have been found to be in the order leaves > barks > Ashes for the three plants studied. The effect of the co-ions on the % of extraction of Zinc has been studied and found that the common anions and monovalent ions are marginally interfered while cations like Cu^{2+} *and* Ni^{2+} *interfered to some extent but* Al^{3+} *interfered markedly. The developed methodologies have been successfully applied to the samples collected from real polluted lake waters and industrial effluents.*

Keywords: Adsorption, Batch studies, Zinc removal, Bio-sorbents

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INTRODUCTION

Zinc is recognized as one of the toxic pollutant and its presence in drinking waters over the permissible limits of 5 ppm is detrimental to human health [1-3]. The major source of zinc contamination are the improper disposal of sewages from industries pertaining to paint and pigments, batteries, metallurgical smelting, mining, electroplating, galvanizing, paper and pharmaceuticals besides soil erosion and over utility of zinc salts in Agriculture [4-7]. The zinc leaked into the water bodies doesn't undergo deterioration but incorporated into numerous meta-biological processes of organisms and human beings. During these biological processes, Zinc is mainly accumulated in the vital parts of human beings such as liver, pancreas, bone and kidney and thereby resulting several ailments [3, 7].

In the recent past, much research interest is being envisaged to evoke sorption potentialities of the waste materials of flora and fauna origin either in their native state or chemically modified form in controlling the hazardous polluting ions in waste waters and these methods are proving to be potential alternatives to the classical and traditional methods of pollution prevention and are stimulating continuous and expanding research in this field. In this direction, our research group has been actively working and found some interesting results which have been reported to the literature [8-14].

Some researchers investigated the control of Zinc pollution using bio-adsorbents derived from, cork powder [15,16], *Neem biomass* [17], *Moringa oleifera Lam. [horseradish tree] biomass* [18, 19], *Biomass of Agaricus Bisporus* [20], *thioglycolic modified oil-palm fiber* [21] , *Tectona grandis L.f. leaves biomass* [22], *olive oil mill solid residues(23), maize stalks (24), fungal mycelial wastes* [25], *Ulva seaweed* [26], *leaves of Araucaria cookie* [27], Duckweed [28] chemically modified distillation sludge of rose petals (Rosa centifolia) [29], Rice husk ash [30], ash derived from Oil palm [31]and Fly Ash [32-34]. Haider M. Zwain et. al. [35] reviewed the various waste material adsorbents used for the removal of Zinc from waste waters.

The present work is a comprehensive study on the sorption potentialities of bio-adsorbents derived from bio-materials pertaining to *Terminalia arjuna, Atlantia monophylla (L) Correa and Madhuca indica plants towards Zinc ions from polluted waters by optimizing the various physicochemical parameters such as pH, time of equilibration, sorbent concentration and presence of some common interfering ions using simulated waters. Thus developed methodologies have been applied to some real polluted waters.*

MATERIALS AND METHODS

(A) CHEMICALS: All chemicals used were of analytical grade.

- ***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 *Terminalia arjuna, Atlantia monophylla (L) Correa and Madhuca indica plants* have been found to have affinity towards Zinc ions.

A: Terminalia arjuna ***B: Atlantia monophylla (L) Correa*** ***C: Madhuca Indica***

Fig No. 1: Plants showing affinity towards Zinc ions

Terminalia arjuna is a tree of the genus Terminalia *and it belong to the family of Combretaceae.*

It is usually growing on river banks or near dry river beds in South and Central India. Its leaves are fed to Antheraea paphia moth which produces the tassar silk. It is reported to have traditional medicinal values in the treatment of wounds, hemorrhages and ulcers.

Atalantia monophylla (L.) Correa belongs to the family of Rutaceae and its distribution is limited to Indian Subcontinent. It has reported therapeutic values. Its leaves are applied locally on knees to relieve knee pains and the oil from the fruit is used externally for rheumatism and paralysis.

Madhuca Indica belongs to Sapotaceae family and it is a deciduous tree of 10-15 m tall and with a spreading, dense, round and shady canopy. It grows in on a wide variety of soils but prefers sandy and alluvial soils.

Sorbent Preparation: The leaves or barks 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 barks 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 sorption natures of the bio-adsorbents chosen in this study were probed with respect to the time of equilibration, pH and sorbent dosage. At a fixed sorbent concentration, the % removal of Zinc 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: 1-9; B: 1-3. To fix the minimum dosage of adsorbent needed for the maximum removal of the Zinc ions for a particular adsorbent 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: 1-3.

***(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, Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe^{2+} , Mn^{2+}, Cu^{2+}, Ni^{2+} *and* Al^{3+}. The synthetic mixtures of Zinc ions and of the foreign ions were so made that the concentration of the foreign ion was maintained at fivefold excess than the Zinc concentrations as cited in the Table: 1. 500 ml 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 and B)*** 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 Zinc concentration. % of extraction was calculated from the data obtained .***The results were presented in the Table: 1.***

(E)APPLICATIONS OF THE DEVELOPED BIO-SORBENTS:

The new methodologies developed in this work have been applied for the removal of the Zinc from real sewage/effluent samples collected from some industries and polluted lakes. For this purpose, samples were collected from the effluents of electroplating, battery, *paper* and pharmaceuticals industries in and around Hyderabad and also from Zinc polluted lakes in the Guntur District of Andhra Pradesh.

Then these samples were *subjected to extraction for the Zinc ions using the bio-sorbents developed in this work at optimum conditions of extraction. The results obtained were presented in the Table 2.*

RESULTS AND DISCUSSION

The extractability of Zinc with the sorbents derived from plant materials of Terminalia arjuna, Atlantia monophylla (L) Correa and Madhuca indica plants have been studied with respect to various physicochemical parameters such as *pH, time of equilibration and sorption concentration* and the results obtained are presented in the Graph No. A: 1-9, Graph No. B: 1 -3 and Graph No. C; 1-3. The following observations are significant:

1. ***Time of equilibration***: Percent of extractability increases with time for a fixed adsorbent at a fixed pH and after certain duration, the extractability remains constant, i.e. an equilibrium state has been reached. In other words, there will not be any further adsorption after certain time of equilibration time (vide Graph Nos. A: 1-9). As for example, in the case of powders of leaves of *Terminalia arjuna, % of extraction of Zinc ions at pH :6 has been found to be 12.5% at 0.25 hrs, 15.5% at 0.5 hrs, 24.3% at 0.75 hrs, 45.6% 1.0 hrs, 56.0% at 1.25 hrs, 60.1% at 1.50 hrs, 62.5% at 1.75 hrs, 65.6 % at 2.0 hrs, 68.9% at 2.25 hrs, 69.2% at 2.5 hrs, 70.0% at 2.75 hrs and above (vide Graph No. A: 1). The trend is the same in the case of other adsorbents of the present study. The equilibrium state has been reached on and after 2.5 hrs with the 57.5% of extraction at pH: 4 with the leaves powders of Atlantia monophylla (L) Correa and 2.5 hrs with the 65.2% extraction at pH:4 with leaves powders of Madhuca indica plants.*

Similarly, with the powders of barks of Terminalia arjuna, Atlantia monophylla (L) Correa and Madhuca indica plants, the equilibrium states have been reached at 2hrs (pH:6), 2.25hrs(pH:4) and 1.75 hrs (pH: 4) respectively with varied maximum possible extractions (vide Graph No. A: 4-6). With the ashes of barks of Terminalia arjuna, Atlantia monophylla (L) Correa and Madhuca indica plants, the respective equilibration times have been found to be 1.5 hrs (at pH:6 with 76.5% extraction), 1.75 hrs(at pH:4 with 70.1% extraction) and 1.5 hrs (at pH:4 with78.9% extraction); Vide Graph No. A: 7-9.

Further, the equilibration time needed for maximum extractability of Zinc ions has been *found* to be in the order: leaves powder > barks powders > ashes of barks for all the three plants. As for example, *the optimum time has been found to be 3hrs, 2.0hrs and 1.25 hrs respectively for sorbents derived from leaves, barks and barks ashes of Terminalia arjuna; 2.5 hrs, 2.0 hrs, and 1.75 hrs for Atlantia monophylla (L) Correa and 2.0 hrs, 1.75 hrs and 1.5 hrs for Madhuca indica plants.*

2. ***Effect of pH****:* The % of extraction has been found to be affected immensely with the change in initial pH values. The pH range of 2 to 7 has been chosen for this study as alkaline pHs causes the Zinc ions to precipitate as Hydroxides. pH:6 has been found to be optimum for the maximum extraction of Zinc ions in the case all adsorbents derived from *Terminalia arjuna plant while pH:4 has been found to be optimum for the other adsorbents pertaining to Atlantia monophylla (L) Correa and Madhuca indica plants.(Vide Graph No. B: 1-3).*

For example, the maximum extractability has been found to be 0% at pH:2, 14.5% at pH:3, 40.0% at pH:4, 61.5% at pH:5, 70.0% at pH:6 and 67.5% at pH:7 in the case of leaves powders of Terminalia arjuna as adsorbent; 17.5% at pH: 2, 32.4% at pH:3, 60.0% at pH:4, 59.0% at pH:5, 57.5% at pH:6 and 50.0% at pH:7 with the powders of leaves of Atlantia monophylla (L) Correa and 20.0% at pH:2, 67.1% at pH: 3, 80.0% at pH: 4, 70.1% at pH:5, 65.2% at pH: 6 and 60.0% at pH: 7 with the powders of leaves of Madhuca Indica.

Similarly, at pH: 2, 3, 4, 5, 6, and 7, % removal of Zinc ions has been found to be 0%, 16.5%, 48.9%, 65.3%, 72.1%, 68.0% respectively with the *bark powders of Terminalia arjuna* at the optimum conditions of extraction; 19.0%, 38.9%, 65.0%, 62.0%, 59.2% and 51.0% with the *bark powders of Atlantia monophylla (L) Correa*; and 34.0%, 69.0%,78.6%. 73.4%, 68.9% and 63.0% with the *bark powders of Madhuca indica*.

With the ashes of barks of *Terminalia arjuna, Atlantia monophylla (L) Correa and Madhuca indica plants, % of extraction with varying pH values of 2, 3, 4, 5, 6, and 7 has been found to be respectively 7.8%, 37.3%, 49.6%, 65.6%, 76.5%, and 68.9% with the barks ashes of* Terminalia arjuna plants; 3.4%, 56.9%, 70.1%, 65.9%, 61.2% and 58.6% with Atlantia monophylla (L) Correa plant ; and 8.25, 52.4%, 78.9%, 68.9%, 63.45% and 58.0% with Madhuca indica.

3. ***Sorbent Concentration***: The optimum sorbent concentration required for maximum extractability of the Zinc is found in the order leaves powder < barks powders < ashes of barks for the three plants studied in this work (Vide Graph: C: 1–3). The optimum sorbent dosages have been found to be 10gm/lit, 8gms/lit and 6gm/lit respectively for leaves powder, barks powder and barks ashes of the *Terminalia arjuna plant. With the Atlantia monophylla (L) Correa plant*, the optimum sorbent dosages have been found to be 9.0 gm/lit, 6gms/lit and 5 gms/lit for leaves powder, barks powder and barks ashes respectively. With the leaves powders of *Madhuca indica* plant, the optimum dosage has been found to be 8.0gm/lit while with barks powders and their ashes, the optimum dosages have been found to be 5.0 gm/lit and 4.0 gms/lit respectively.

4. ***Interfering Ions***: *Fivefold* excess of common anions, as given in Table No.1, have *not effected the extraction of Zinc ions from waste waters. Cations like* K^+, Ca^{2+}, Mg^{2+}, Fe^{2+} & Mn^{2+} have marginal influence on the extraction of Zinc ions. But Cu^{2+} *and* Ni^{2+} *have interfered to some extent while* Al^{3+} *interfered markedly.*

DISCUSSION

The available data is inadequate to account each observation as further probe on the surface morphology is needed using such modern instruments like X-ray Photo Electron Spectroscopy (XPS), Fourier Transform Infrared spectroscopy (FTIR), Scanning Electron Microscope (SEM) and Energy Dispersive Spectrum (EDS) in addition to the classical elemental chemical analysis before and after the sorption of the zinc ions on the bio-sorbent surface. It is beyond the aims of this work. However a rough understanding of nature of sorption process may be conceived from the nature of the functional groups present the plant materials.

The surface of the sorbents derived from plant materials, has potential –OH/-COOH groups and their dissociation is pH sensitive. At high pH values, the dissociation of –OH/-COOH groups impart negative charge to the surface and thereby a thrust for cations prevails on the surface in tandem with that of classical caton-exchange process. But as the pH decreases, the –OH/-COOH groups dissociation is less favored and are even protinated, endowing positive charge to the surface which manifests in the thrust for anions at the surface at low pHs.

In the present work, the optimum pHs have been found to be 6 in the case of bio-sorbents derived from *Terminalia arjuna plant* and 4 in the case Atlantia monophylla (L) Correa and Madhuca indica plants . At these pH values, the Zinc ion exists mainly as Zn^{2+} and its maximum extraction indicates the exchange of Zn^{2+} for H^+ ions in the –OH/-COOH of the sorbents.

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

At low pH values, the exchange is not favored as the equilibration shift towards the left hand side resulting desorption of Zinc ions. But at high pH values, the zinc ions converts to negatively charge zincate ion which has less affinity towards the negatively charged surface of adsorbents at high pH values. Hence, at optimum pH only the adsorption is more.

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.

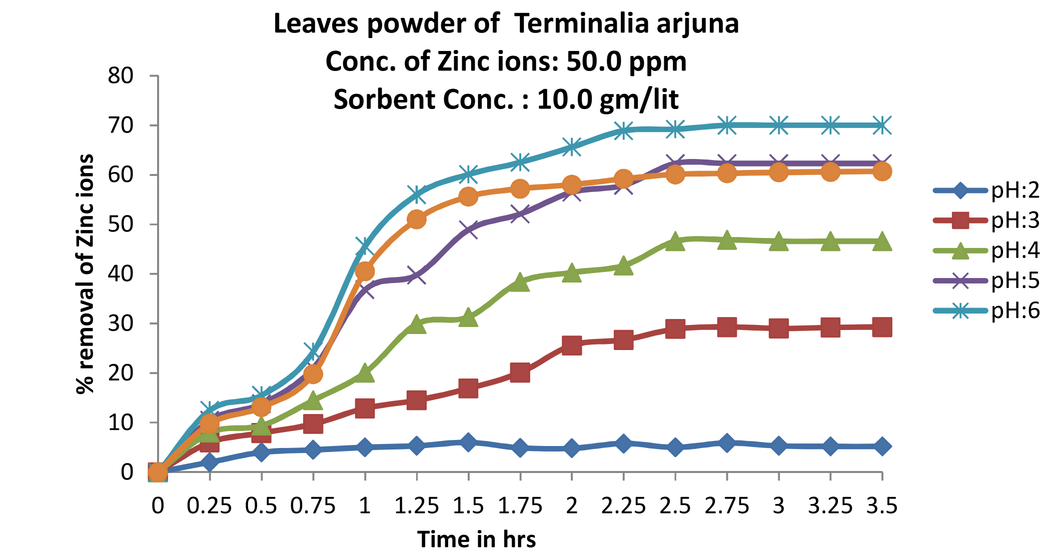
The observations made with respect to the interfering ions are as per the expected lines. Anions being negatively charged have no affinity towards the adsorbents at the pH conditions: 4 or 6 favorable to cation exchange. Monovalent cations and divalent cations like Ca^{2+}, Mg^{2+}, Fe^{2+} & Mn^{2+} having less cation exchanging ability than Zn^{2+} ions, show marginal interference at the optimum conditions of extraction as cited in the Table 1. Trivalent cation, Al^{3+} having more cation-exchange ability than divalent Zn^{2+}, has interfered.

4: APPLICATIONS

The procedures developed in this work using new bio-sorbents was applied to the real samples of collected from polluted natural lakes and effluents of industries and the obtained results were presented in the Table 2.

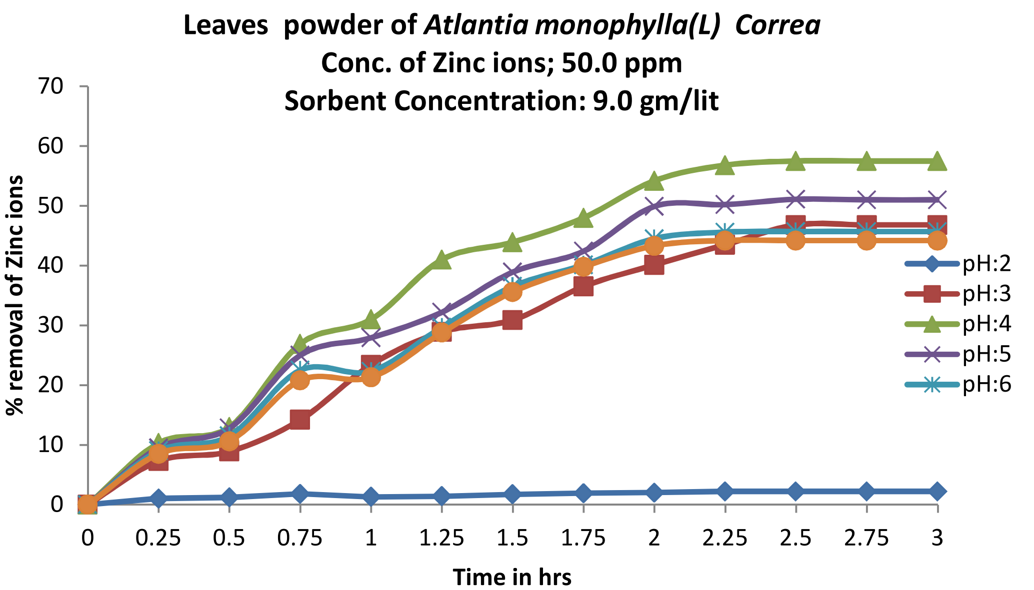
With the bio-sorbents derived from *Terminalia arjuna plant, the % removal of Zinc was found to ranging from* 67.5 to 69.0% with its leaves powders, 69.9% to 71.5% with its barks powder and 72.5 to 74.6% with the ashes of barks. By using the bio-sorbents pertaining to the *Atlantia monophylla (L) Correa plant, Zinc was removed to an extent of*

53.5% to 56.0% with leaves powder, 62.9% to 64.5% with barks powder and 67.0 % to 69.5% with ashes of barks. Bio-sorbents of of *Madhuca indica plant, were found to remove considerable amounts of Zinc:* 62.0% to 63.8% with leaves powder, 73.0% to 75.0% with bark powders and 75.5% to 77.0% with the ashes of Barks at optimum conditions of extraction as cited in the Table 2.



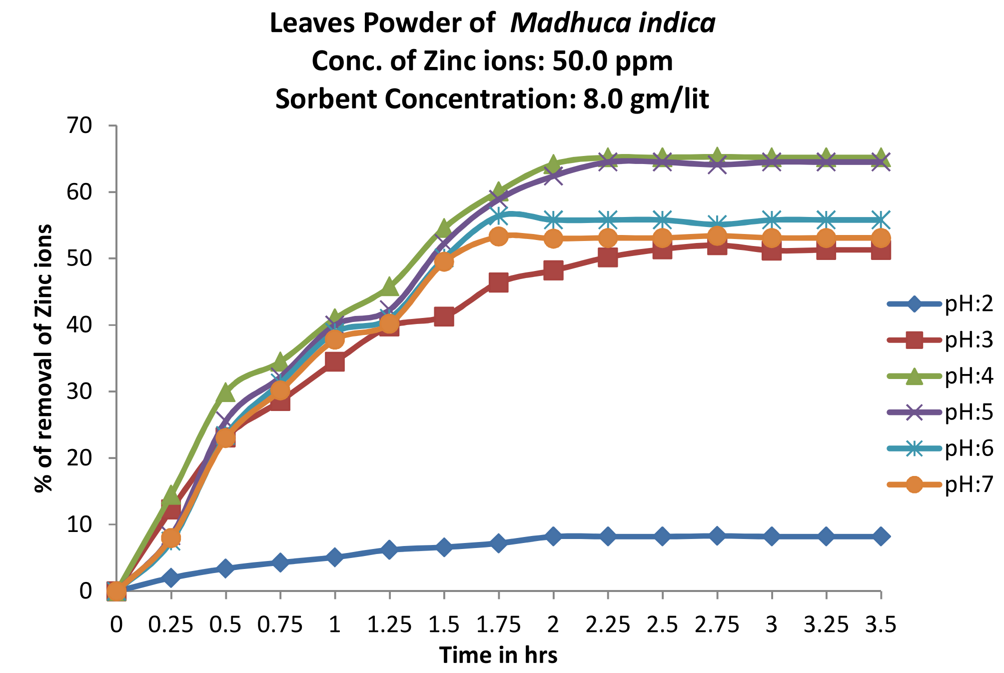
Time Vs % or removal of Zinc ions

Graph No.A: 1



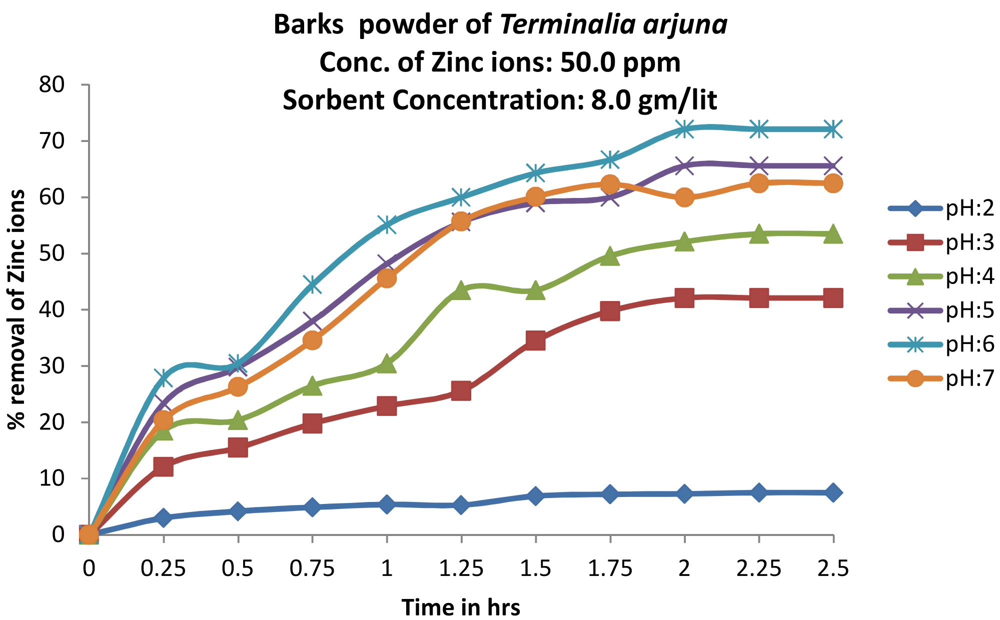
Time Vs % of removal of Zinc ions

Graph No. A:2



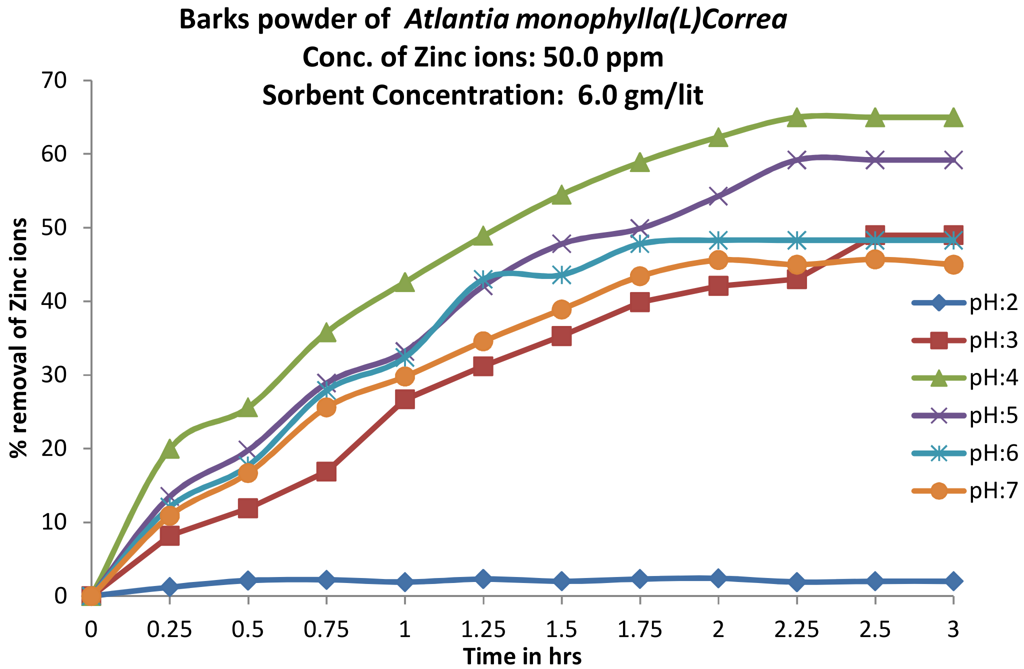
Time Vs % of removal of Zinc ions

Graph No. A: 3



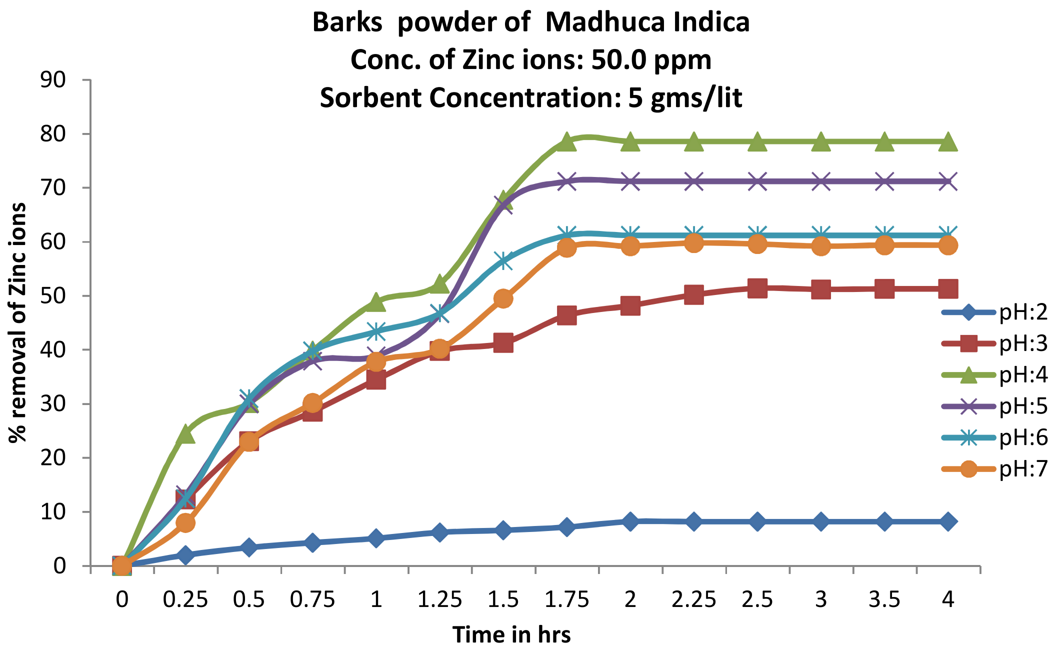
Time Vs % of removal of Zinc ions

Graph No. A:4



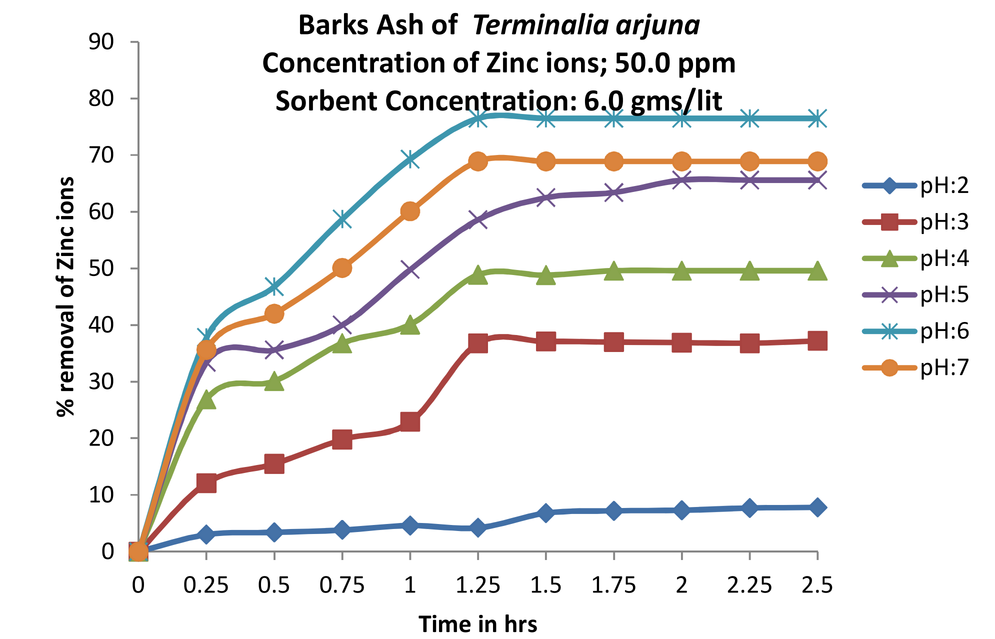
Time Vs % of removal of Zinc ions

Graph No. A:5



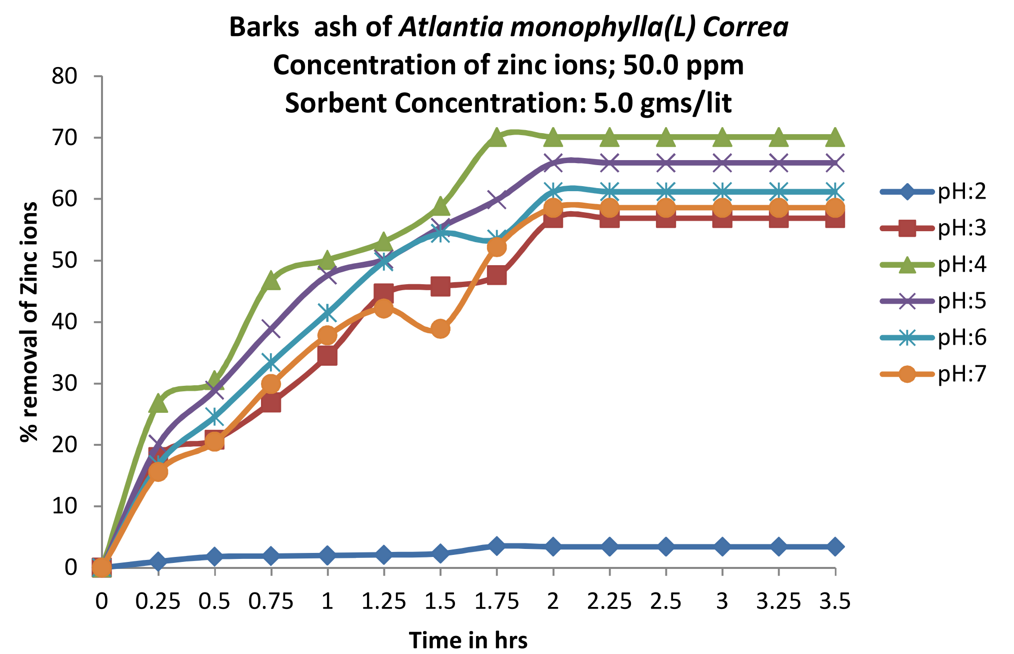
Time Vs % Removal of Zinc ions

Graph No. A: 6



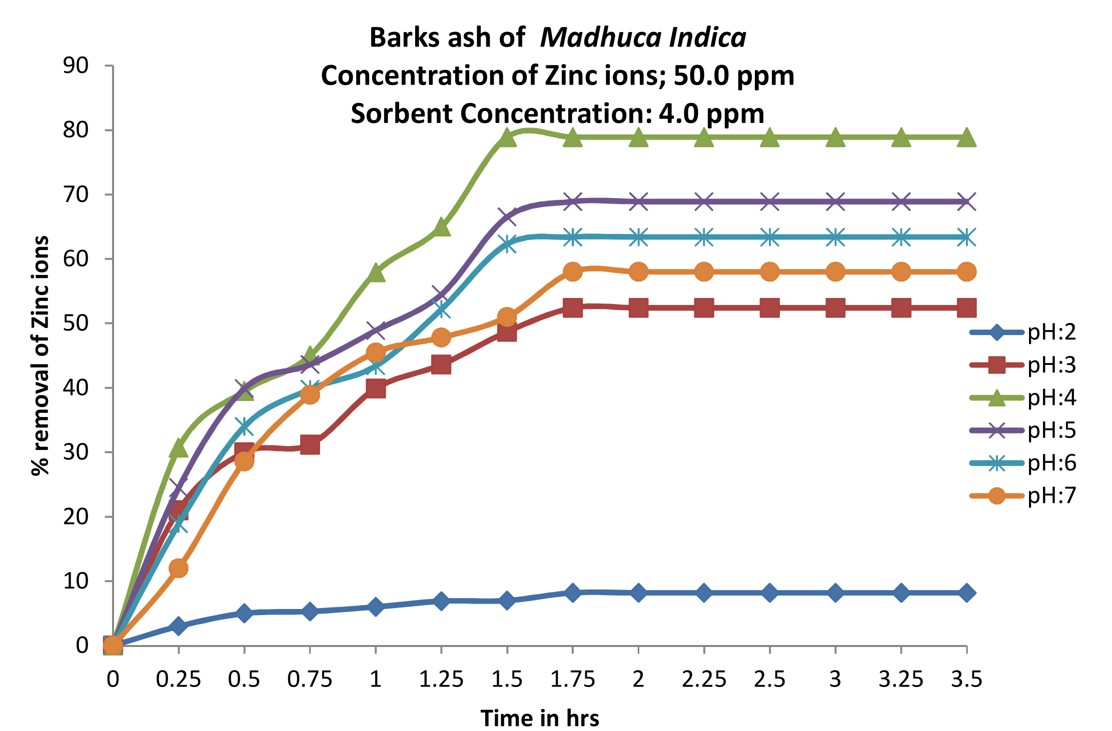
Time Vs % removal of Zinc ions

Fig. No. A: 7



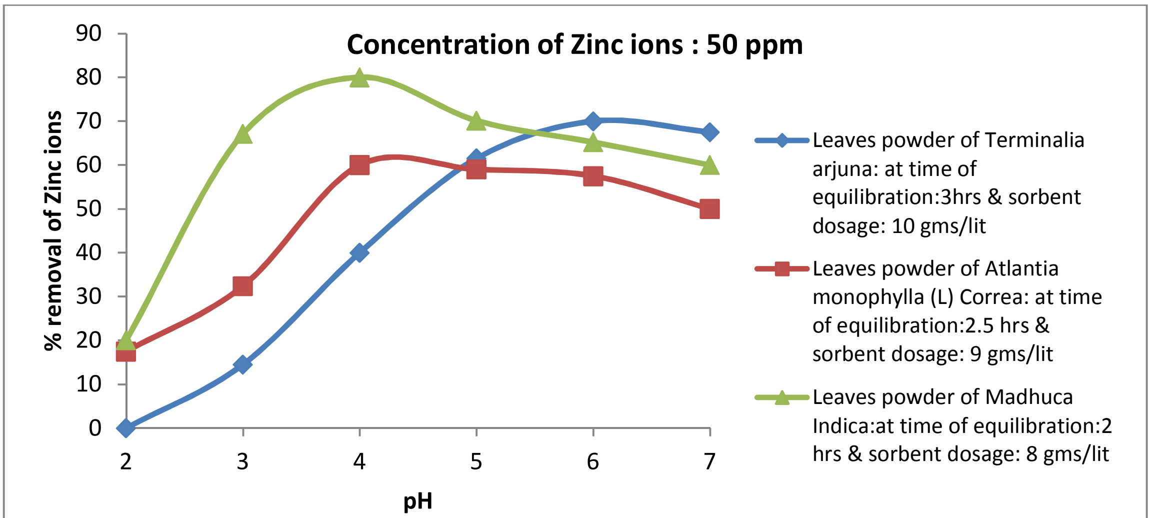
Time Vs % removal of Zinc ions

Fig. No. A: 8



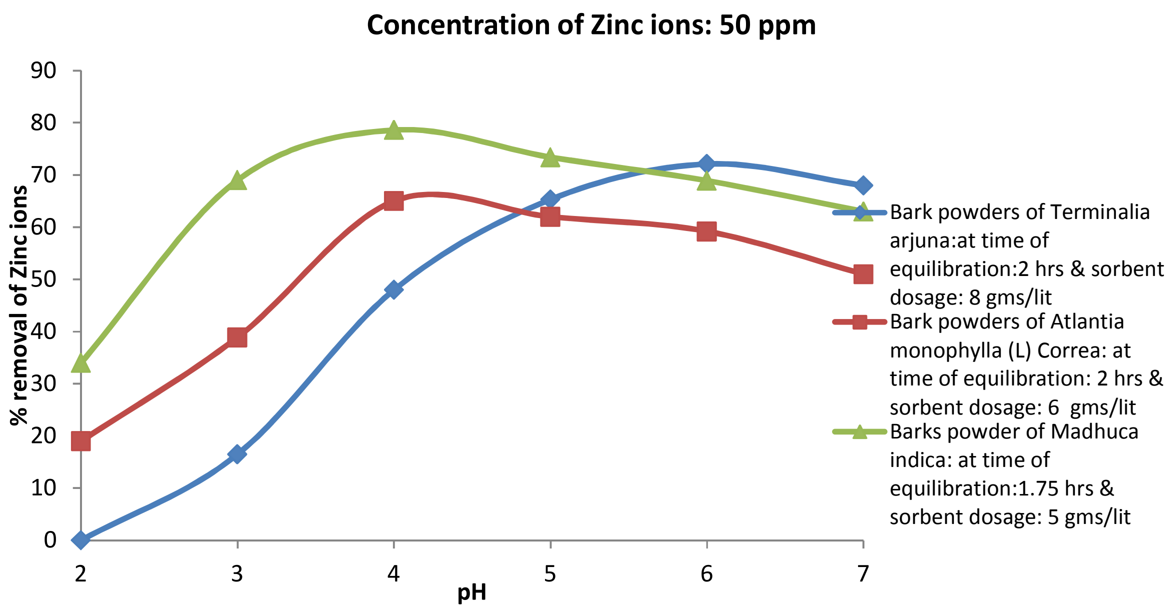
Time Vs % removal of Zinc ions

Fig. No.A: 9



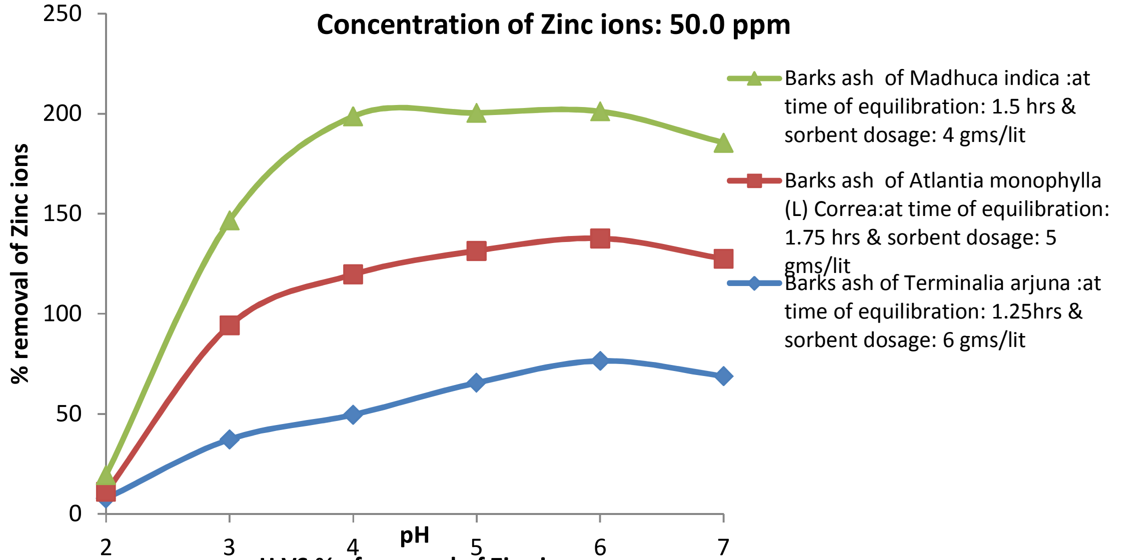
pH Vs % removal of Zinc ion

Graph No. B:1



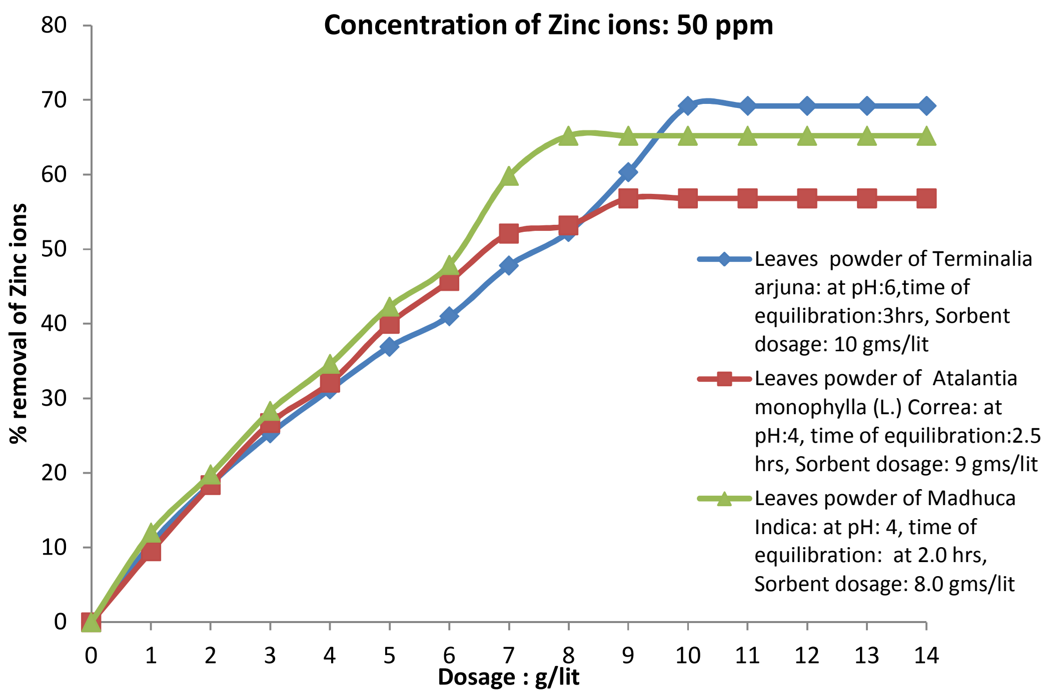
pH Vs % removal of Zinc ions

Graph No. B: 2



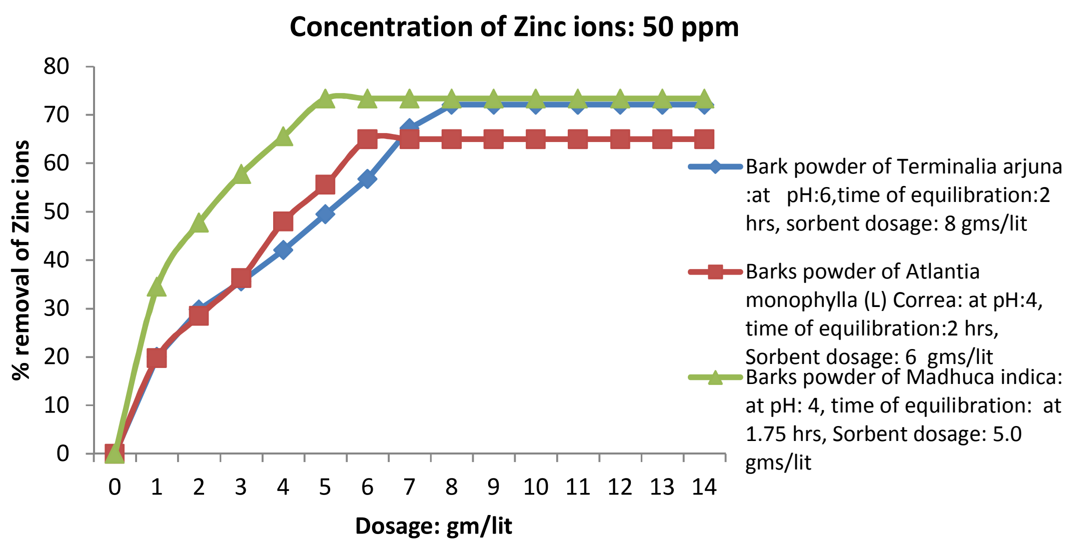
pH VS % of removal of Zinc ions

Graph No. B:3



Sorbent Concentration Vs % Removal of Zinc ion

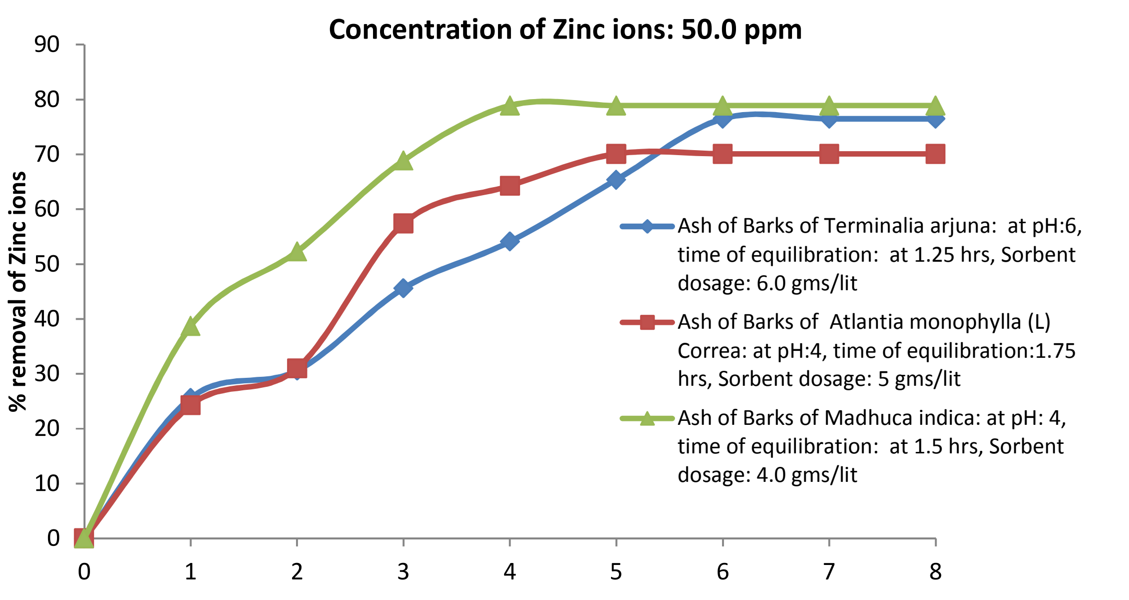
Graph No. C:1



Dosage: gm/lit

Concentration of Adsorbent Vs % removal

Graph No. C: 2



Concentration of Adsorbent Vs % removal of Zinc ions

Graph No. C: 3

Table No. 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 *Terminalia arjuna*	70.0%; pH: 6, Agitation time: 3 hrs; sorbent conc.: 10.0 g/l	68.5	67.5	68.8	69. 0	67.5	69.0	67.5	67.0	68.7	67.9	62.5	63.3	60.9
2	Barks powder of *Terminalia arjuna*	72.1%; pH:6, Agitation time: 2.0 hrs; sorbent conc.: 8.0 g/l	69.0	68.0	67.6	69.0	68.5	70.2	67.3	68.2	69.2	67.6	64.5	65.3	61.0
3	Barks ash of *Terminalia arjuna*	76.5%; pH:6, Agitation time: 1.25 hrs; Sorbent conc.:6.0 g/l	73.2	74.1	72.0	74.5	75.0	74.2	73.5	72.9	73.4	72.0	70.2.0	71.0	65.0
4	Leaves powder of *Atlantia monophylla (L) Correa*	57.5%;pH:4; Agitation time:2.5 hrs; Sorbent conc.: 9.0 g/l	56.0	55.8	56.3	56.2	57.0	57.0	55.0	55.8	56.7	56.0	53.5	54.5	50.1
5	Barks powder of *Atlantia monophylla (L) Correa*	65.0%; pH:4, Agitation time: 2.25 hrs; Sorbent conc.:6.0 g/l	64.6	63.8	63.5	62.6	64.8	64.5	63.6	64.0	64.0	63.5	62.0	62.5	60.0
6	Barks ash of *Atlantia monophylla (L) Correa*	70.1%; pH:4 ; Agitation time: 1.75 hrs; Sorbent Conc..: 5.0 g/l	68.5	68.3	69.0	68.5	68.0	68.6	67.2	68.0	68.5	67.9	65.5	64.5	63.0
7	Leaves powder of *Madhuca indica plant*	65.2%; pH: 4, Agitation time: 2.25 hrs; Sorbent Conc.: 8.0 g/l	64.5	63.4	64.6	64.	63.5	64.5	63.5	64.0	64.5	64.8	62.9	62.0	60.0
8	Barks powder of *Madhuca indica plant*	76.8%; pH:4, Agitation time: 1.75 hrs; Sorbent Conc.: 5.0 g/l	76.0	75.5	74.5	73.8	75.8	76.0	75.5	76.2	75.9	74.5	70..3	71.0	68.9
9	Barks ash of *Madhuca indica plant*	78.9%; pH:4, Agitation time: 1.5 hrs; Sorbent Conc.: 4.0 g/l	77.8	78.0	77.0	76.9	76.0	76.8	75.5	74.5	73.5	75.6	72.5	73.0	70.0

Table No. 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 *Terminalia arjuna* :at pH:6; Equilibration time: 3 hrs and sorbent conc.: 10.0 g/l	69.0%	68.5%	67.4%	67.5%	68.5%
2	Barks powder of *Terminalia arjuna* : at pH:6; Equilibration time: 2.0 hrs and sorbent conc.: 8.0 g/l	**70.5 %**	71.5%	70.1%	69.9%	70.0%
3	Barks ash of *Terminalia arjuna* :at pH:6; Equilibration time: 1.25 hrs and sorbent conc.: 6.0 gms/l	74.5 %	73.0%	73.5%	74.6%	72.5%
4	Leaves powder of *Atlantia monophylla (L) Correa* :at pH:4; Equilibration time: 2.5 hrs and sorbent conc.: 9.0 g/l	56.0%	55.5%	54.7%	53.8%	53.5%
5	Barks powder of *Atlantia monophylla (L) Correa* :at pH:4; Equilibration time: 2.25 hrs and sorbent conc.: 6.0 g/l	64.0%	63.5%	63.8%	64.5%	**62.9%**
6	Barks ash of *Atlantia monophylla (L) Correa* : at pH:4; Equilibration time:1.75 hr and sorbent conc.: 5.0 g/l	68.0%	69.5%	68.9.%	67.0%	67.9%
7	Leaves powder of *Madhuca indica plant* :at pH:4; Equilibration time:2.25 hr and sorbent conc.: 8.0 g/l	63.0%	62.5%	62.0%	63.5%	63.8%
8	Barks powder of *Madhuca indica plant* :at pH:4; equilibration time: 0.75 hrs and sorbent conc.: 5.0 g/l	75.0%	74.5%	73.7%	73.0%	74.2%
9	Barks ash of *Madhuca indica plant* at pH:4; equilibration time: 1.5 hrs and sorbent concentration: 4.0 g/l	77.0%	76.5%	75.5%	76.0%	75.5%

CONCLUSION

Bio-adsorbents derived from plant materials of *Terminalia arjuna, Atlantia monophylla (L) Correa and Madhuca indica plants* have been investigated and optimized for their sorption abilities towards Zinc ions by varying the physicochemical parameters such as pH, sorbent concentration and time of equilibration for the maximum removal of *Zinc ions from waste waters using simulated waters.*

The extractions are found to be pH sensitive and the optimum pH has been found to be 6 for the adsorbents belonging to *Terminalia arjuna while it is 4 with the adsorbents belonging to Atlantia monophylla (L) Correa and Madhuca indica plants.*

The optimum sorbent dosage, time of equilibration and % of removal have been found to be in the order leaves > barks > Ashes for the three plants studied.

Commonly found anions in waters have marginally interfered with the % of extraction of Zinc even when they are present in five fold excess concentrations. Monovalent Cations like K^+ and divalent Cations such as Ca^{2+}, Mg^{2+}, Fe^{2+} and Mn^{2+} $^+$ have shown less interference while Cu^{2+} and Ni^{2+} interfered to some extent but Al^{3+} interfered markedly.

The procedures developed have been found to successful in removing the Zinc ions from the samples collected from industrial effluents and polluted lakes as given in Table No: 2.

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