

ADSORPTION BEHAVIOR OF CADMIUM AND NICKEL FROM AQUEOUS
SOLUTION BY *SARACA INDICA* LEAF POWDER

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Summary

The development of economic and efficient processes for the removal of toxic metals from water bodies has become a priority task for environmentalists. Biosorption processes are tangible alternatives to traditional methodologies, particularly if low metal concentration, large volume and cost are considered. The present communication reports the unexploited sorption properties of the *Saraca indica* leaf powder (SILP) for the removal of Cd(II) and Ni(II) from aqueous media. Sorption studies using standard practices were carried out in batch experiments as a function of biomass dosage, metal concentration, contact time, particle size and pH. Sorption studies result into the standardization of optimum conditions for the removal of Cd(II) – 92.60% and Ni(II) – 46.20% as follows: biomass dosage (4.0 g), metal concentration (Cd(II) 10 $\mu\text{g}/\text{cm}^3$, Ni(II) 10 $\mu\text{g}/\text{cm}^3$) and volume of the test solution (200 cm^3) at pH 6.5 for Cd(II) and Ni(II). The present study explores for the first time, the efficacy of *Saraca indica* leaf powder as a novel and environment friendly possibility to remediate heavy metal contaminated water in a cost efficient manner.

INTRODUCTION

A relatively homeostatic environment is essential for the survival of an organism in a given ecosystem. Though in nature trace amounts of heavy metals are essential, they become toxic when their concentration exceeds certain level. The rapid industrialization has resulted in accelerating the flux of heavy metals into aquatic environment. The metal ions may enter the food chain and get biomagnified through bioaccumulation, thereby increasing the magnitude of the problem. In view of their high toxicity, environment mobility, non-biodegradability and stability, their removal becomes an absolute necessity. Among various toxic metals, a significant quantity of cadmium and nickel is of profound concern as toxic waste and contaminant of surface water. Environmental Protection Agency “Top 20 Hazardous substance Priority list” has ranked cadmium being seventh and nickel as thirteenth owing to their high toxicity at relatively low doses. The maximum levels permitted in wastewater are 0.01 mg/dm^3 for cadmium [14] and 0.1 mg/dm^3 for nickel [6]. The toxicity and

deleterious effects of cadmium and nickel have been very well documented [1, 13]. Methods, such as, precipitation, oxidation/reduction, ion exchange, filtration and evaporation used for this purpose, are extremely expensive, sometimes inefficient and they also generate toxic sludge. With the increase in environmental awareness and government policies, there has been a push towards development of new environment friendly ways to clean metal contamination of water [6]. Biosorption of heavy metals is thus one of the most promising and tangible alternatives to traditional methodologies that has attracted an increased scientific attention. Biosorption processes comprise a mechanism to purify metal contaminated water followed by the desorption process for the recovery of the sorbed metals simultaneously regenerating the exhausted plant biomass. A variety of low cost plant materials such as petiolar sheath palm [7], cocoa shells [10], silverleaf nightshade [3] and grape stalks [8] for cadmium and nickel removal have been reported.

Saraca indica Linn. (Ashok), an evergreen tree, abundantly available throughout the Asian continent, possesses multidimensional curative properties and carries great significance since the past ages. Its diverse applications involve its use in fractures of bones, beautifying complexion, as an astringent and in various gynecological problems [9]. Though the plant possesses great medicinal properties against an array of disorders and ailments, its efficacy for heavy metal removal has not been explored so far. The present communication is aimed to focus the potential of *Saraca indica* leaf biomass, as a bioremedial approach for cleansing the water effluents containing cadmium and nickel.

EXPERIMENTAL

Biosorbent Preparation

Green healthy leaves of *Saraca indica* Linn. were collected in May 2004. The leaves were washed repeatedly with water to remove dust and soluble impurities, dried at 65°C for 24 hours, crushed and finally sieved through (105 µm, 210 µm and 420 µm) mesh copper sieves. *Saraca indica* leaf powder (SILP) was used as biosorbents. No other chemical or physical treatments were used prior to adsorption experiments.

Biosorption and Analytical Procedures

Sorption studies were carried out in a batch process in triplicates as a function of biomass dosage (2.0, 4.0 and 6.0 g), contact time (10, 20, 30, 40 and 50 min.) metal concentration (1, 5, 10 and 20 µg/cm³), particle size (105 µm, 210 µm and 420 µm) and pH of the test solution ranging from 4.5 to 8.5. Cadmium and nickel solutions were prepared by dissolving the desired quantity of cadmium nitrate (AR) and nickel sulphate (AR) in deionized water. After pH adjustments, a known quantity of dried biosorbent was added and finally metal bearing suspensions were magnetically stirred until equilibrium conditions were reached. The residual biomass sorbed with metal ion was filtered using Whatman 42 filter paper. Filtrates were collected and metal concentrations were determined using acetylene air flame Atomic Absorption Spectrometer (Perkin Elmer-3100) with single element hollow cathode lamp computed using the equation:

$$\% \text{ sorption} = C_0 - C_e / C_0 \times 100, \quad (1)$$

where: C_0 and C_e are the initial and final concentration of metal ions in the solution.

Fourier Transform Infrared Analysis

To analyze the main functional groups that might be involved in metal sorption, FTIR analysis in solid phase was performed using a Fourier Transform Infrared Spectrometer (FTIR-8400, Shimadzu). Spectra of the sorbent before and after cadmium and nickel sorption were recorded.

Scanning Electron Microscopy

Surface morphology was studied with Scanning Electron Microscope (Steroscan 360, Cambridge Instruments, UK). The Scanning Electron Micrograph (SEM) of untreated (native) and metal treated *Saraca indica* leaf powder (exhausted) at bar length equivalent to 50 μm, working voltage 20 KV with 600 X magnification were recorded and are presented as Fig. 1 (a, b and c).

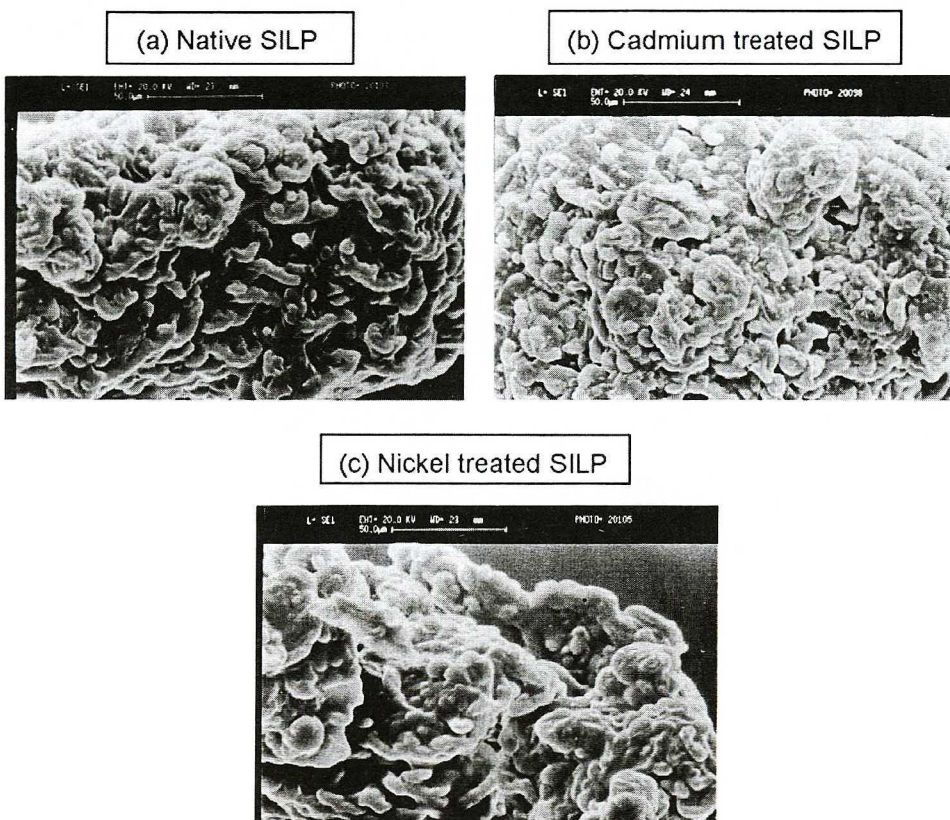


Fig. 1a, b and c Scanning Electron Micrograph of native and exhausted Cd and Ni treated SILP

Adsorption Isotherms

In order to describe the adsorption of cadmium and nickel by *Saraca indica* leaf powder, the data were analyzed using a Freundlich isotherm:

$$q = K_f C_e^{1/n} \tag{2}$$

and data are fitted to the logarithmic form of the equation:

$$\log q = \log K_f + 1/n \log C_e \quad (3)$$

where q is the uptake of metal per unit weight of biosorbent, C_e the equilibrium (residual) concentration of metal ion in solution, K_f and n are the characteristic constants.

The biosorption capacity (K_f) and the biosorption intensity ($1/n$) were estimated from the intercept and slope of the Freundlich isotherm.

The Langmuir equation has the general form of:

$$C_e/q_e = (1/Q_0 b) + (C_e/Q_0) \quad (4)$$

where: C_e is the equilibrium concentration, q_e is the amount adsorbed of cadmium and nickel at equilibrium and Q_0 and b are the Langmuir constant related to adsorption capacity and energy of adsorption respectively.

The linear plot of C_e/q_e versus C_e shows that the adsorption is in agreement with Langmuir model. Q_0 and b were determined from the slope and intercept of the Langmuir isotherm.

Desorption of metals from loaded biomass

Desorption studies (batch process) were conducted to recover the metal ions from cadmium and nickel loaded biomass as a function of eluant concentration (0.01–0.2 M) of two different acids (hydrochloric and nitric acid). Metal loaded biosorbent obtained from our sorption experiments was transferred to Erlenmeyer flask and shaken with 50 cm³ of each acid for 40 minutes. The filtrate was analyzed for desorbed cadmium and nickel.

Statistical Analysis

Batch experiments were conducted in triplicates ($N = 3$) and the data represent the mean value. Correlation coefficients and standard deviations were calculated using SPSS PC⁺ statistical package [12]. For the determination of inter group mean values differences, each parameter was subjected to Student's t test for significance level ($p < 0.05$).

RESULTS AND DISCUSSION

Table 1 and 2 represent soluble Cd(II) and Ni(II) concentration after biosorption at optimum time (30 minutes) on unmodified *Saraca indica* leaf powder (SILP) as a function of metal concentration, biomass dosage and volume of the test solution at pH 6.5. In each case the data were evaluated at significance level ($p < 0.05$).

Effect of biomass dosage

Biomass dosage used for the present investigation varied from 2.0 to 6.0 g. Percent sorption of cadmium and nickel increased with the increase of biomass dosage from 2.0 to 4.0 g. However, no significant increase in sorption was observed on further raising the biomass dosage from 4.0 g onwards. This might be due to attainment of equilibrium between adsorbate and adsorbent at the existing operating conditions rendering adsorbent incapable of further adsorption.

Table 1. Soluble Cd(II) ion concentration after maximum biosorption at optimum time (30 minutes) on unmodified *Saraca indica* leaf powder (SILP) as a function of metal concentration, biomass dosage and volume of the test solution at pH 6.5

Initial concentration $\mu\text{g}/\text{cm}^3$ (μM)	Soluble Cd(II) ion concentration		
	Biomass 2.0 g	Biomass 4.0 g	Biomass 6.0 g
Volume of the test solution (100 cm^3)			
1 (0.88) ^a	$0.54 \pm 0.03^{+\Phi x}$	$0.43 \pm 0.02^{+\Phi x}$	$0.42 \pm 0.02^{+\Phi\Phi x}$
5 (4.43)	$2.41 \pm 0.13^{+\Phi x}$	$1.39 \pm 0.20^{+\Phi x}$	$1.38 \pm 0.07^{+\Phi\Phi x}$
10 (8.87)	$4.82 \pm 0.26^{+\Phi x}$	$2.28 \pm 0.50^{+\Phi x}$	$2.27 \pm 0.12^{+\Phi\Phi x}$
20 (17.74)	$9.62 \pm 0.51^{++\Phi x}$	$4.48 \pm 0.88^{++\Phi x}$	$4.47 \pm 0.88^{++\Phi\Phi x}$
Correlation coefficient (r)	0.97	0.98	0.98
Volume of the test solution (200 cm^3)			
1 (0.88) ^a	$0.81 \pm 0.04^{+\Phi x}$	$0.53 \pm 0.02^{+\Phi x}$	$0.53 \pm 0.03^{+\Phi\Phi x}$
5 (4.43)	$3.08 \pm 0.17^{+\Phi x}$	$1.57 \pm 0.08^{+\Phi x}$	$1.56 \pm 0.08^{+\Phi\Phi x}$
10 (8.87)	$4.41 \pm 0.25^{+\Phi x}$	$1.31 \pm 0.07^{+\Phi x}$	$1.29 \pm 0.07^{+\Phi\Phi x}$
20 (17.74)	$8.78 \pm 0.46^{++\Phi x}$	$2.55 \pm 0.13^{++\Phi x}$	$2.51 \pm 0.13^{++\Phi\Phi x}$
Correlation coefficient (r)	0.96	0.98	0.97
Volume of the test solution (400 cm^3)			
1 (0.88) ^a	$1.63 \pm 0.09^{+\Phi xx}$	$1.06 \pm 0.06^{+\Phi xx}$	$1.04 \pm 0.06^{+\Phi\Phi xx}$
5 (4.43)	$6.14 \pm 0.34^{+\Phi xx}$	$3.12 \pm 0.17^{+\Phi xx}$	$3.08 \pm 0.16^{+\Phi\Phi xx}$
10 (8.87)	$8.80 \pm 0.48^{+\Phi xx}$	$2.59 \pm 0.14^{+\Phi xx}$	$2.51 \pm 0.14^{+\Phi\Phi xx}$
20 (17.74)	$17.49 \pm 0.92^{++\Phi xx}$	$4.96 \pm 0.26^{++\Phi xx}$	$4.79 \pm 0.23^{++\Phi\Phi xx}$
Correlat ion coefficient (r)	0.96	0.97	0.99

^a – numbers in parenthesis represent soluble metal concentrations in μM ,

\pm – standard deviations,

Mean value difference initial Cd(II) loaded versus soluble Cd(II) (μM) as a function of metal concentration: * – significant ($p < 0.05$), ** – insignificant ($p > 0.05$).

Biomass dosage: Φ – significant ($p < 0.05$), $\Phi\Phi$ – insignificant ($p > 0.05$).

Volume of the test solution: * – significant ($p < 0.05$), ** – insignificant ($p > 0.05$).

Effect of volume

Percentage sorption of the cadmium and nickel on the target biomass was recorded under similar conditions in a different set of volumes (100 to 400 cm^3) of the test solution. Maximum sorption was found in the volume 200 cm^3 of the test solution. It is inferred that at

Table 2. Soluble Ni(II) ion concentration after maximum biosorption at optimum time (30 minutes) on unmodified *Saraca indica* leaf powder (SILP) as a function of metal concentration, biomass dosage and volume of the test solution at pH 6.5

Initial concentration $\mu\text{g}/\text{cm}^3$ (μM)	Soluble Ni(II) ion concentration		
	Biomass 2.0 g	Biomass 4.0 g	Biomass 6.0 g
Volume of the test solution (100 cm^3)			
1 (1.70) ^a	$1.44 \pm 0.07^{+\Phi x}$	$01.36 \pm 0.07^{+\Phi x}$	$01.36 \pm 0.07^{+\Phi\Phi x}$
5 (8.53)	$6.45 \pm 0.35^{+\Phi x}$	$06.36 \pm 0.35^{+\Phi x}$	$06.34 \pm 0.32^{+\Phi\Phi x}$
10 (17.06)	$12.87 \pm 0.65^{+\Phi x}$	$11.22 \pm 0.58^{+\Phi x}$	$11.20 \pm 0.59^{+\Phi\Phi x}$
20 (34.12)	$25.69 \pm 1.33^{++\Phi x}$	$22.42 \pm 1.21^{++\Phi x}$	$22.37 \pm 1.27^{++\Phi\Phi x}$
Correlation coefficient (r)	0.99	0.98	0.98
Volume of the test solution (200 cm^3)			
1 (1.70) ^a	$2.68 \pm 0.15^{+\Phi x}$	$2.45 \pm 0.13^{+\Phi x}$	$01.83 \pm 0.10^{+\Phi\Phi x}$
5 (8.53)	$12.25 \pm 0.63^{+\Phi x}$	$11.22 \pm 0.60^{+\Phi x}$	$05.86 \pm 0.33^{+\Phi\Phi x}$
10 (17.06)	$20.68 \pm 1.13^{+\Phi x}$	$18.36 \pm 0.95^{+\Phi x}$	$07.55 \pm 0.40^{+\Phi\Phi x}$
20 (34.12)	$41.26 \pm 2.26^{++\Phi x}$	$17.06 \pm 1.90^{++\Phi x}$	$17.01 \pm 0.88^{++\Phi\Phi x}$
Correlation coefficient (r)	0.97	0.98	0.96
Volume of the test solution (400 cm^3)			
1 (1.70) ^a	$5.39 \pm 0.28^{+\Phi xx}$	$4.91 \pm 0.26^{+\Phi xx}$	$4.88 \pm 0.26^{+\Phi\Phi xx}$
5 (8.53)	$24.46 \pm 1.24^{+\Phi xx}$	$22.40 \pm 1.18^{+\Phi xx}$	$22.37 \pm 1.20^{+\Phi\Phi xx}$
10 (17.06)	$41.26 \pm 2.10^{+\Phi xx}$	$36.64 \pm 1.83^{+\Phi xx}$	$36.59 \pm 1.82^{+\Phi\Phi xx}$
20 (34.12)	$82.41 \pm 4.12^{++\Phi xx}$	$72.98 \pm 3.72^{++\Phi xx}$	$72.81 \pm 3.85^{++\Phi\Phi xx}$
Correlation coefficient (r)	0.98	0.98	0.97

^a – numbers in parenthesis represent soluble metal concentrations in μM ,

\pm – standard deviations,

Mean value difference initial Cd(II) loaded versus soluble Cd(II) (μM) as a function of metal concentration: + – significant ($p < 0.05$), ++ – insignificant ($p > 0.05$).

Biomass dosage: Φ – significant ($p < 0.05$), $\Phi\Phi$ – insignificant ($p > 0.05$).

Volume of the test solution: * – significant ($p < 0.05$), ** – insignificant ($p > 0.05$).

this volume, the ratio of sorption surface of the seed powder to total metal ions availability is optimum exhibiting maximum percentage removal for cadmium and nickel ions.

Effect of particle size

Sorption behavior of cadmium and nickel on *Saraca indica* leaf powder (SILP) was studied at three different ranges of particle size (105 to 420 μm) of seed powder. Results show

that a decrease in particle size has a favorable effect on metal sorption. It may be ascribed to the fact that an increase in the surface area of the biomass occurs with a decrease of its particle size providing therefore more reactive sites to the biomass for the sorption of metal ion (Fig. 2).

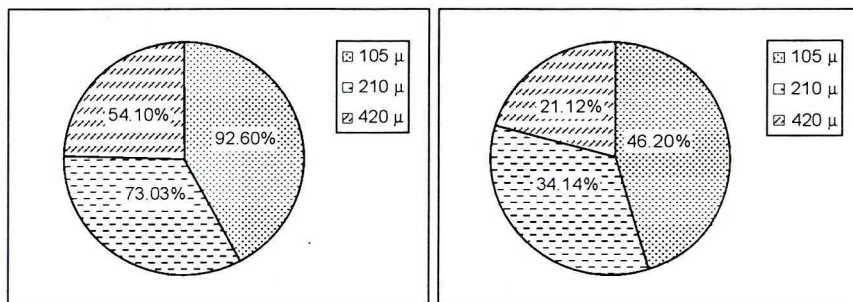


Fig. 2. Effect of particle size on sorption behavior of Cd(II) and Ni(II) ion on *Saraca indica* leaf powder

Effect of sorption time

The effect of the contact time on biosorption of cadmium and nickel on *Saraca indica* leaf powder (SILP) was observed for 10 to 50 minutes. The percent sorption of metal ion gradually increases with time within 10 to 20 minutes, with maximum sorption occurring at 30 minutes and then remains fairly uniform thereafter. The rapid metal removal has a significant practical importance, as this will facilitate and ensure efficiency and economy.

Effect of metal concentration

The sorption behavior of cadmium and nickel was carried out over a wide range of concentration ranging from 1 to 20 $\mu\text{g}/\text{cm}^3$. In general, sorption of cadmium and nickel on *Saraca indica* leaf powder (SILP) increased with increasing concentration of the metal ion finally reaching the optimum level (92.60%) for cadmium and (46.20%) for nickel at 10 $\mu\text{g}/\text{cm}^3$ respectively. Later, an increase in initial concentration decreased the percentage binding. These observations can be explained by the fact that at low concentrations, the ratio of sorptive surface area to the metal ions available is high and thus, there is a greater chance for metal removal. When metal ion concentrations are increased, binding sites become more quickly saturated as the amount of biomass concentration remained constant.

pH profile and metal binding

The percentage sorption of cadmium and nickel on *Saraca indica* leaf powder (SILP) increases as the pH of the solution increased from 4.5 to 8.5 (Fig. 3). The pH profile for the cadmium and nickel sorption on leaf powder shows that metal sorption is a function of pH, exhibiting maximum sorption at pH 6.5. There was no significant difference in sorption behavior with further increase in pH up to 7.5. Investigation on pH variation beyond 7.5 yielded an apparent increase in sorption up to pH 8.5, which might be due to the precipitation of cadmium and nickel which starts at pH 7.5 [7]. Metal precipitation interferes with and is undistinguishable from sorption phenomenon at pH 7.5 [2]. In fact, biosorption of cadmium and nickel occurs in the pH range from 4.5 to 7.5 only.

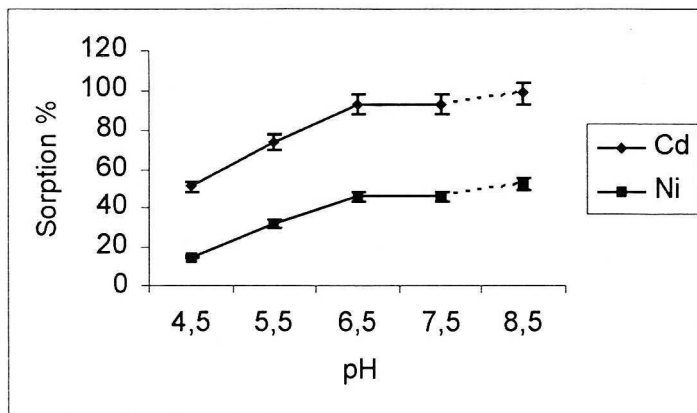


Fig. 3. Effect of pH on sorption behavior of Cd(II) and Ni(II) ion on *Saraca indica* leaf powder

The work has embodied the potential that exists in *Saraca indica* leaf powder (SILP) as biosorbent for removal of toxic metals from water bodies. It thus becomes imperative to understand the mechanistic aspects of interactions of leaf constituents with metal ions highlighting the nature of chemical species playing the pivotal role in biosorption obtained in present experiments. The interaction of the chemical constituents of *Saraca indica* leaf powder with metals and resulting products are not known. Further more, the chemical constituents and structure of its various parts are not also thoroughly studied. Based on our experimental findings and pertinent information available on the relevant topic, we synthesize an appropriate mechanism for metal binding to the leaf powder. The aerial part of the plant *Saraca indica* possesses various organic chemical moieties prominently large proportions of low molecular weight amino acids [11]. Amino acids have been found to constitute a physiologically active group of binding agents working even at low concentration, which due to ability to interact with metal ions are likely to be active sites for the sorption of metal ions [4]. Our experimental findings show that as the pH of the solution increases from 4.5 to 7.5, cadmium and nickel reflect increased binding behavior to the biomass with optimum binding at pH 6.5. This provides an insight into the mechanism of the metal binding involved with the *Saraca indica* leaf powder. The majority of naturally occurring amino acids have isoelectric point between pH 4.0 to 8.0 [5]. In this range of pH, over 90% of the amino acid molecules are in an ionized state. Biosorption of target metals may be ascribed to the availability of carboxyl ligands of amino acids for interaction with metal ions at pH 4.5 to 6.5. SILP-Metal ion binding thus appears to be an ion exchange process involving electrostatic attraction between negatively charged groups of amino acids and metallic cations.

Biomass characterization

Cadmium and nickel interactions with target leaf biomass (SILP) can be further highlighted on the basis of IR spectrum. The IR spectrum of the solid phase of untreated (native) and metal treated (exhausted) samples reflects the complex nature of the biomass. In the case of nickel, NH_3^+ stretching band shifts from 2428.52 and 2722.50 cm^{-1} to 2648.70 and 3091.51 cm^{-1} . The characteristic peak shifting of carboxylate ion from 1350.86 and 1552.14 cm^{-1} to 1539.17 and 1706.39 cm^{-1} confirms an ionic interaction between carboxylic groups of amino acids with the cationic metal species. A well pronounced shift of NH_3^+ is

observed from 2428.52 and 2722.50 cm^{-1} to 2654.86 and 2824.90 cm^{-1} in the case of cadmium treated biomass. Furthermore, the characteristic peak shifting of carboxylate ion from 1450.86 and 1652.14 cm^{-1} to 1459.43 and 1553.45 cm^{-1} corroborates the electrostatic attraction between carboxylic ion and positively charged metal species. Fig. 1a represents the Scanning Electron Micrograph of untreated *Saraca indica* leaf powder. Morphology seems to be of large spherical clusters having a pore size: 0.13 μm ; pore area: 6.32 μm^2 . Fig. 1b and c) represents dense agglomerated, etched dendrite type morphology having pore size – 0.02 μm , pore area – 0.72 μm^2 of cadmium and pore size – 0.04 μm , pore area – 0.53 μm^2 of nickel which is in a sharp contrast to spherical type clusters appeared in untreated *Saraca indica* leaf powder. The observed aggregation and reduction of pore size and pore area in exhausted biomass of *Saraca indica* leaf powder indicates the liquid phase concentration of removed metal ions.

Sorption capacity using isotherms

Study of the isotherm indicates the adsorption capacity of leaf powder for the removal of target metal ions from the solution under standardized conditions. The adsorption isotherm accurately describes the biosorption experimental data of cadmium and nickel ions. The magnitude of Freundlich (K_f and n) and Langmuir (Q_0 and b) shows high adsorption capacity and ease of separation of heavy metal ion from wastewater (Table 3).

Table 3. Effect of regeneration on the sorption and desorption of cadmium and nickel (10 mg/dm^3) by *Saraca indica* leaf powder

No. of cycles	Amount of metals after adsorption (mg/dm^3)	Adsorption %	Recovery %
Cd(II)			
1	0.70	93.0	98.0
2	0.73	92.7	99.0
3	0.81	91.9	98.0
4	1.20	88.0	92.0
Ni(II)			
1	5.39	46.14	95.0
2	5.30	47.01	96.0
3	5.31	46.88	96.0
4	6.98	30.19	81.0

Desorption and regeneration studies

A more logical approach to the treatment of metal-contaminated waters is to combine metal removal for clean-up purposes with metal recovery. With this aim in view, the desorption of both the metal ions from exhausted leaf powder has also been attempted. In general, an extent of metal desorption increases with the increase in the strength of acids ranging from 0.01 to 0.1 M. The maximum metal desorption – 88% Cd(II) and 90% Ni(II) – was observed from hydrochloric acid (0.1 M). However, comparatively a better metal desorption – 98% Cd(II) and 96% Ni(II) – could be achieved with nitric acid (0.1 M) as eluant. In order to make the proposed process of adsorption and desorption of metal ions more economical, it was found necessary to regenerate the exhausted biosorbent. Sorption and desorption of cadmium and nickel on *Saraca indica* leaf powder after each regeneration cycle using nitric acid (0.1 M) is depicted in Table 4. It is interesting to note that sorption remains maximum – 91.9% Cd(II) and 46.88% Ni(II) – up to the 3rd regeneration cycle and then goes down – 88% Cd(II) and 30.19% Ni(II) – in the 4th cycle. The recovery of metal species also remains maximum – 98% Cd(II) and 96% Ni(II) – up to the 3rd cycle and then decreases. This behavior indicates that the biosorbent can be used successfully three times after regeneration for metal decontamination of water.

Table 4. Langmuir and Freundlich isotherm constants for sorption of cadmium and nickel on *Saraca indica* leaf powder

Concentration (ppm)	Langmuir constants		Freundlich constants		Correlation coefficients
	Q_0	b	K_f	n	
Cd(II)					
1	2.16	0.27	3.04	0.98	0.99
5	3.01	0.32	0.10	1.0	1.0
10	3.09	0.38	0.13	1.2	0.98
20	2.99	0.28	0.11	0.99	0.99
Ni(II)					
1	2.69	0.08	0.22	0.23	1.0
5	3.32	0.14	0.32	0.24	1.0
10	4.32	0.19	0.92	0.33	0.99
20	3.81	0.11	0.30	0.89	1.0

CONCLUSION

The present process is deemed to be a bioremedial approach to be used as domestic, ecofriendly, low cost or pretreatment step for large volume of industrial waste for metals abatement from water bodies. The suitability of proposed adsorption process is indicated by Freundlich and Langmuir significant isotherm constants. Amino acid-metal interactions appear to be responsible for metal binding. The exhausted biomass can be successfully regenerated for three times. The findings open up new ways in the decontamination of

metals using *Saraca indica* leaf powder and have enough potential in the modern technology of water treatment as biosorbent.

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