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EFFICIENT BIOCOAGULANT *Azardicta Indica* BARK POWDER FOR ARSENIC (III) REMOVAL IN THE SOLUTION PHASE

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ABSTRACT

This study aims to remove arsenic from groundwater by employing a series of batch studies on *Azardicta Indica* bark powder that vary in terms of physic-chemical factors such as contact time, dose, pH, initial arsenic content, and temperature. The rate of arsenic absorption decreased as it moved farther inside the biosorbent particles from its initial quick pace. At a pH of 4.0-6.0 and a dosage of 1.5 gm, the impact of contact duration on arsenic biosorption was investigated for 30 minutes.As the initial arsenic concentration rises, the proportion of arsenic biosorption decreases because mass transfer between the solute and solution interface is impeded at higher concentrations. Through the assessment of the biosorbent's mass transfer coefficients, the experimental outcomes were accurately documented in terms of Freundlich and to some degree Temkin isotherms with values of R_2 0.998 and 0.956, respectively.

Keywords: Neem Bark Powder, Biosorption, Biosorbent, Isotherms, Kinetics,Thermodynamics.

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INTRODUCTION

Arsenic is considered the "King of Poisons" and is extremely dangerous for human health in many parts of the world. West Bengal, India, and Bangladesh both have contaminated regions with greater arsenic concentrations.[1] There is more than 10 µg/L of arsenic in the water. High levels of arsenic were discovered in soil samples from Kukatpally, Hyderabad, according to recent research released by scientists from the NGRI in Hyderabad.[2] Arsenic in the soil should be 0.11 mg/kg, according to US Environmental Protection Agency rules, however, the soil in Kukatpally had 0.7 mg/kg of arsenic. Arsenic metal slowly leaks into groundwater due to the region's numerous businesses. The main industries that release arsenic into the environment are agriculture and the copper, lead, and zinc sectors. The majority of the inorganic forms of arsenic found in groundwater are trivalent and pentavalent arsenate. As(III) is far more hazardous and soluble in groundwater than As(V) is. Significantly increasing the risk of cancer[3], infertility, miscarriages in women, heart issues, brain damage, and DNA damage is possible when consuming water contaminated with inorganic arsenic. Removing the hazardous inorganic arsenic from surface groundwater requires the use of purification methods, such as pre-oxidation of As(III) to As(V), to successfully eradicate arsenic.Every conventional filtering technique has pros and cons, including oxidation-precipitation, coagulation-flocculation filtration, ion exchange, reverse osmosis, nano-filtration, and biosorption.[4-6] Because of its simplicity, ability to produce little sludge and capacity for regeneration, biosorption is the most dependable and economical technique for treating groundwater when all of the aforementioned approaches' shortcomings are taken into account. The price of the biosorbent determines the entire cost of the biosorption process. NBP was selected as the biosorbent for this investigation because neem bark powder extracts arsenic more effectively.

EXPERIMENTAL

Material and Methods

Following a two-day sun drying period, distilled water was used to remove any remaining dust and dirt particles from the neem bark that had been gathered from a woodcutter in Hyderabad. The fractions were kept apart in labeled, airtight plastic containers for later usage after the bark powder was sieved using sift

to a particle size of 195 mesh.[6] By enabling the biosorbent (Neembark powder) to enter the effluent more quickly and deeply, the tiny particle size promotes biosorption.[7] Based on the number of sites on the biosorbent material, their accessibility and chemical state, and the binding strength between sites and metal, neem bark powder's characterization and effectiveness in aiding the binding mechanism onto biomass[8-11] will be discovered. Preliminary screening investigations revealed that neem bark powder removed arsenic with 93% efficiency. Neem bark powder was selected for the arsenic biosorption batch experiment based on the aforementioned factors.

General Procedure

By dissolving an adequate amount of arsenic in 1000ml of stock solution, a stock solution of As(III)(1.32g/1000ml) was prepared. The stock solution was further diluted with distilled water for the batch experiment to achieve the required arsenic concentrations, which ranged from 10µg/L to 80 µg/L, which were first created. The biomass was extracted from the sample solutions by filtration, and the concentration of arsenic was measured in the filtrate. A spectrophotometer was used to determine the amount of residual arsenic that remained after the biosorption procedure. The effects of temperature, pH, arsenic concentration, contact time, and biosorbent dosage were all considered in the experiment.

Detection Method

Tannin and lignin are among the organic components found in neem bark, which is based on cellulose (Table-1). To identify the functional groups, FTIR analyses were carried out in the 4000-600 nm range. The FTIR spectra of *A. Indica* showed the presence of carboxylic acid, amine, amino, amide, and sulfate groups in addition to the functional group and surface charge[12], which catalyzed the mechanism of metal binding on Neem bark in the arsenic biosorption process.

Table-1: Properties and Functional Groups of Neem Bark Powder

S.No.	Properties	Values	Functional Groups Before Biosorption	Classification
1.	Surface Area	21.1 cm^2	C-H	Alkene
2.	Porosity	195 mesh	C=C	Alkyne
3.	Ash content	11.50%	C-O	Primary Alcohol
4.	pH	6.0	N-H	Alcohol
5.	Bulk density	0.525 mg/m^2	N-H	Amine salt
6.	Volatility	79.08%		
7.	Carbon	40%		
8.	Hydrogen	3.2%		
9.	Nitrogen	0.54%		

RESULTS AND DISCUSSION

Agitation Time

Because biosorption depends on contact time, a batch bio adsorption experiment was conducted at various intervals using 1.0 gm of neem bark powder as a biosorbent. The biosorption time is the amount of time needed for the concentration of arsenic metal to achieve equilibrium. Kinetic investigations indicate that there are two modes of biosorption: slow intracellular biosorption and fast surface biosorption.[13-15] The experiment's findings indicated that increasing the agitation period increases the elimination of arsenic's efficiency. It required 10 to 30 minutes for there to be a stronger surface binding due to the attraction of arsenic ions toward active functional groups on the adsorbent's surface, or the equilibrium shown in Fig.-1. Additionally, the research data revealed that arsenic ions were moved from the outside to the inside, slowing biosorption.[16] The ideal amount of time for communication to enable the next step was therefore thirty minutes.

Impact of Porosity and Dosage of Biosorbent

Higher doses and smaller particle sizes led to the most efficient elimination of arsenic. This was probably because there were a lot of sorption sites and a big surface area, which allowed for the most efficient removal of arsenic. Both[17,18] found a tight influence: the stronger the metal removal quality, the smaller

the particle size. Biosorbent competitively controlled biosorption potential at lower dosages.[19] Figure-2 illustrates the remarkable arsenic-eradication efficiency of neem bark powder at 1.5 gm biosorbent dosage and 195 mesh particle porosity. Up to a certain point, the amount of biosorbent utilized directly affects how much arsenic is extracted from aqueous solutions; after that, the rate decreases. Decline occurs when the dosage of the biosorbent is increased because the electrostatic contact on the binding sites between cells is broken. The effects of neem bark powder on the biosorption of heavy metals, particularly zinc, were similar.[20,21]

Impact of Porosity and Dosage of Biosorbent

One of the most important variables influencing arsenic biosorption on neem bark powder is pH. This variable generates the charge density on the biosorbent surface as well as the arsenic species.[22] In the pH range of 6.0–9.0, Fig.-3 illustrates the best arsenic biosorption, with an ideal adsorbent dose of 1.5 gm/50µg/L.The strong arsenic biosorption percentage was sixty percent at pH 6.0. After pH 9.0, biosorption could not proceed due to the precipitation of As(OH)2.[23] The impact of pH on the removal of As (III) can be inferred from the surface charge on the adsorbent content. Because of the biosorbent surface's positive charge at low pH 4.0, positively charged arsenic cations may find it more difficult to approach. This suggests that protons may compete with arsenic ions for ligands (-COOH, -NH_2), which would reduce metal-ion interaction and lower the percentage of arsenic removal.[24]Higher pH levels promote metal adsorption because of a reduction in electrostatic repulsion, which lowers the positive charge density of protons on sorption sites. Previous researchers have noted similar things.[24,25] The dissociation of various functional groups included in neem bark tan in particles may facilitate the creation of metal complexes, which in turn may be the cause of the biosorption of arsenic (III) ions on the surface of neem bark through an ion-exchange mechanism based on surface complex formation. This idea is summarized as follows:[26]

$$As^{n+}+m[RO7(OH)11]\leftrightarrow As[RO7(OH)9(O^{-})2]_m^{n-m}+mH^{+}$$

Where -RO7(OH)11=acidic portion of the bark surface, Asn+=arsenic ion with n+ charge, R denotes the matrix portion of the biosorbent and mH+=number of protons generated.
A higher pH can promote improved metal ion biosorption because of the condensation reaction that occurs between the sorbent bearing the –OH groups and the hydrolysis product of sorbate ions.[26,27] Consequently, it can infer that anion-mediated arsenic biosorption on neem bark powder is most likely the cause of complexation, and the combined defect of site binding biosorption is involved in the exchangeprocess. As(III) chemical species (oxyanions) and the amount of hydroxyl groups on the surface of neem bark powder may decrease when pH rises.

The Impact of As(III) Concentration

As arsenic concentrations climb from 10µg/L to 80µg/L, 90% arsenic removal is achieved at 41.2µg/L at the ideal circumstances of 1.5 g of biosorbent and 6.0pH, as illustrated in Fig.-4. The coherence of biosorption (surface saturation) is dependent on the initial concentration of arsenic ions. Arsenic ions are rapidly absorbed by biosorption sites at low concentrations, however, at high concentrations, intraparticle diffusion causes low-level diffusion of arsenic metal ions to the surface of the biosorbent.[28] Adsorption of the arsenic metal ions was easier at initial (lower) concentrations because the impedance of mass transfer between the solid and solution was controlled.[29] Arsenic elimination would not be significantly impacted by an increase in arsenic content since the sorptive sites cannot handle the excess. Arsenic ion concentration. Similar outcomes were obtained by copper biosorption on Cinnamomum camphor leaf powder.[30] Lignin cellulose plant fibers, which have a lot of nitrogenous, hydroxyl, and carboxylic groups, may bind metal ions in neem bark when in an aqueous solution.

Temperature-Dependent Profile of Biosorption

Neem bark powder and different quantities of arsenic solution were used in the Arsenic biosorption procedure, which was conducted at different temperatures. In this investigation, as temperatures and concentrations rose, so did the degree of biosorption.

Due to the increased sorption sites at high temperatures, which facilitate the efficient uptake of arsenic metal ions with greater interface interactions between arsenic ions and different functional groups present in neem bark powder via bioaccumulation, as shown in Fig.-5, temperature had a greater effect on the percentage removal.

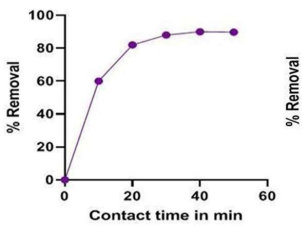

Figure 1: Rate of agitation time for the Arsenic Ren

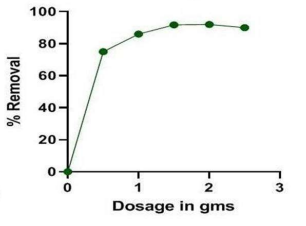

Figure 2: Effect of Dosage on the Arsenic Removal

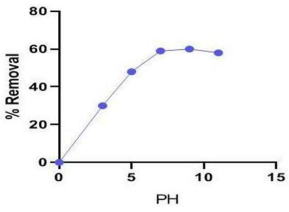

Figure 3: The Influence of initial pH

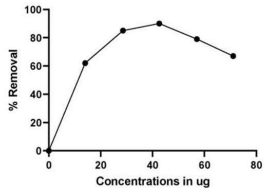

Figure 4: The Effect of Concentration

Langmuir, Freundlich, and Temkin Biosorption Isotherms

It was common practice to investigate the relationship between sorbed and aqueous concentrations at equilibrium in the temperature range of 0ºC to 80ºC using the Langmuir, Freundlich, and Temkin biosorption isotherm models. Biosorption isotherms provide the solute concentration for the solution at equilibrium Ce as well as the mass of the solute absorbed per unit mass of biosorbent qe. R_2 values were computed to determine which biosorption isotherm model fit the data the best.

Langmuir Model

An isothermal survey was conducted using a varied initial concentration, optimum biomass of 1.5 gm, and pH of 6.0 in order to collect data from biosorption tests. The Langmuir model did not linearize to the extent that would have indicated that, despite higher R_2 values as shown in Table-2, the biomass of neem bark was not able to adsorb arsenic ions. Langmuir concluded that the trials' apparent standardized, monolayer adsorption was not the case, and he was unable to provide a plausible explanation for the arsenic biosorption with neem bark powder.

Freundlich Isotherm

The plot of Freundlich (Fig.-6) log qe vs log Ce and its linear equation was modified to the arsenic biosorption in order to identify the interaction of metal ions with biomass.[31] This adaptation accounts for the high magnitude of k_f, 1/n, and R_2 values in Table-3, demonstrating the strong biosorption capability of neem bark powder. The heterogeneity of the sorbent surface aligned with the Freundlich model. These results showed that this model is appropriate for the biosorption of arsenic on powdered neem bark.

Temkin Model

The interaction of As(III) on the surface of neem bark powder is shown in linear form (Fig.-7) with equal adsorption energies, and the R_2 values in Table-4 are above 0.92. The paper states that all of the molecules in the layer experienced a linear rise in heat of adsorption. This model can also explain arsenic metal biosorption because of its good match. These three models suggest that the biosorption energy of metal binding sites is dependent on the occupied sites nearby. Consequently, it seemed that neem bark powder's biosorption of As(III) ions involved a multilayer, interactive, or multiple-site form binding process.[32]

Kinetic Sorption

Kinetic sorption investigates the reciprocal activity between the biosorbent and adsorbate using kinetic models. The mass transfer as well as the physical and chemical characteristics of the sorbent determine the biosorption process. The expected values derived from the models' and experimental data's conformance were indicated by correlation coefficients (R_2). The pseudo-second-order kinetic equation of As^{+3}connecting qe and k_2 allows for the prediction of the time-dependent accumulation's progress using kinetic parameters.

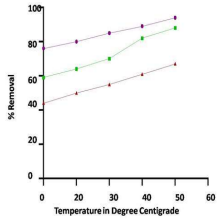

Figure 5: The Effect of Temperature on Removal

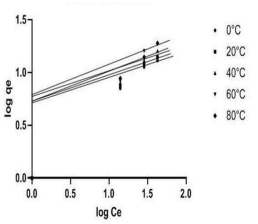

Figure 6: Linear plot of Freundlich for Arsenic biosorption

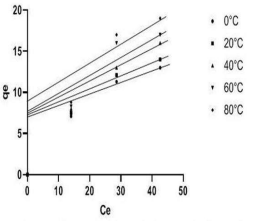

Figure 7: Linear plot of Temkin for Arsenic biosorption

Table-2: Biosorption Isotherm Constant and Statistical Comparison Values of Arsenic Biosorption by Neem Bark Powder

S.No.	Parameters	Langmuir Adsorption Isotherm				
		Temperature ^{0}C				
		0	20	40	60	80
1.	R^2	0.997	0.995	0.989	0.885	0.862
	ASS	0.527	0.525	0.483	0.460	0.419
	Q_0	-0.0070	-0.0073	-0.0070	-0.006	-0.006
	b_L	0.595	0.628	0.662	0.707	0.727
	Freundlich Adsorption Isotherm					
2.	ASS	0.001	0.000	0.000	0.000	0.000
	Log k_f	0.530	0.600	0.615	0.634	0.697
	l/n	0.075	0.017	0.048	0.016	0.016
	b_T	0.222	0.225	0.185	0.351	0.154
	Temkin Adsorption Isotherm					
3.	R^2	0.869	0.989	0.987	0.986	0.981
	ASS	0.067	0.005	0.006	0.006	0.009
	a_T	0.158	0.240	0.282	0.305	0.330
	b_T	0.959	1.436	0.486	0.568	0.678

Table-3: Kinetic Parameters for Biosorption of Arsenic by Neem Bark Powder

S.No.	Parameters	Arsenic Concentration (10 µg/L)	Arsenic Concentration (20 µg/L)	Arsenic Concentration (30 µg/L	Arsenic Concentration (40 µg/L)	Arsenic concentration (50 µg/L)
	Pseudo first order kinetic model					
1.	R^2	0.931	0.902	0.885	0.838	0.887
	ASS	0.007	0.013	0.017	0.028	0.016
	K_1	0.011	0.009	0.007	0.004	0.004
	Pseudo second order kinetic model					
2.	R^2	0.954	0.955	0.959	0.990	0.950
	ASS	0.004	0.004	0.003	0.000	0.004
	K_2	0.320	0.372	0.461	0.415	1.100
	Elovich model					
3.	R^2	0.986	0.921	0.985	0.986	0.942
	ASS	0.006	0.009	0.000	0.000	0.005
	α	-10.28	-9.553	-8.625	-5.329	-6.620
	β	21.17	19.24	16.95	11.58	12.12

	Intraparticle diffusion model					
4.	R^2	0.980	0.953	0.979	0.936	0.929
	ASS	0.001	0.004	0.001	0.007	0.008
	k_{id}	-1.841	-1.696	-1.510	-0.922	-1.165
	I	16.37	14.70	12.74	8.925	8.927

Table-4:Thermodynamic Parameters of Arsenic Biosorption by Neem Bark Powder

S.No.	Temperature	ΔG (KJ/mol)	ΔS (KJ/mol)	ΔH (KJ/mol)
1.	273	-54.47	17.14	- 0.054
2.	293	-56.02		
3.	313	-52.04		
4.	333	-52.60		
5.	353	-46.95		

Equation of Pseudo-First-Order Kinetics

In their wide use of the metal ion adsorption method, Lagergren and Sven produced good findings in their metal adsorption investigations. Ho, Y.S. (1995). Since the equation for the Lagergren plot of log (qe-qt) vs t (Fig.-8) did not provide the linear shape displayed in Fig.-8, it was not possible to quantify the amount of arsenic biosorbent attainment. The R_2 and k_1 values derived from the plot are quite small in Table-4. The fact that the computed value of qe differs from the experimental value of qe suggests that this model was unable to determine qe.

Equation of Pseudo-Second Order Kinetics

Several authors have also suggested that, under certain conditions, second-order kinetics may provide insight into the relationship between biosorbate and biosorbent.[33-36] The study found that the greatest match for the data from this examination was achieved by applying a pseudo-second-order kinetic equation. As (III) biosorption activation energy can be measured by evaluating rate constants at all concentrations, and the experimental data fit well to the pseudo-second-order kinetic with strong correlation coefficients (R_2 0.954-0.990) from Table-5 and linear map (Fig.-9). Since there was no consideration of the external mass transfer obstruction, the computed qe value is consistent with one experiment. It can be inferred from these results that the biosorption of arsenic and other heavy metals followed a pseudo-second-order kinetic.

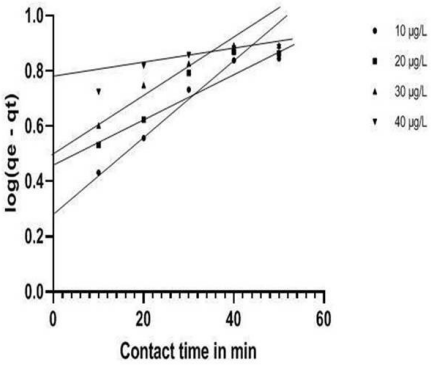

Figure 8: Lagergren plot of Arsenic biosorption

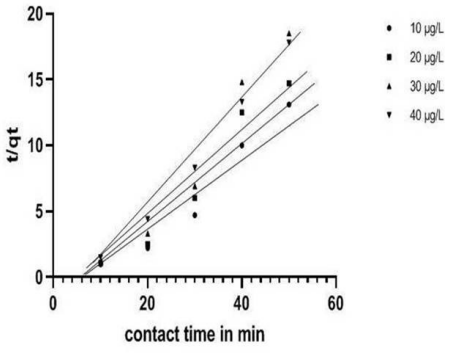

Figure 9: Pseudo second order kinetic biosorption

Table-5: Equilibrium Parameter RL Values at Different Concentrations and Temperature

S.No.	Temperature (°C)	Concentration of Arsenic (µg/L) and R_L values		
		10µg/L	30µg/L	50µg/L
01.	0	0.1007	0.033	0.200
02.	20	0.1007	0.033	0.200
03.	40	0.1007	0.033	0.200
04.	60	0.1006	0.033	0.200
05.	80	0.1006	0.033	0.200

Elovich Model

The initial adsorption rate in the Elovich equation and the adsorption constant of the model are connected to the adsorption energy.[37]The energetic heterogeneity of the adsorption sites is a crucial component of this model that was considered for the investigation.[38]This is how the Elovich equation works:

$$(dq_t/dt) = \alpha\exp(-\beta q)_t$$

Researchers are encouraged by the Elovich equation to explore the kinetics of pollutant adsorption in natural biosorbents and to comprehend the optimum behavior of data. Understanding reaction mechanisms like solute transport in solution or interphase and surface activation and deactivation is further aided by this equation. It also considers abnormalities in the data that other sophisticated equations have missed.[39] The linearized graphic seen in Fig.-10 was not generated by the Elovich equation. Hence, this model could not be used to demonstrate.

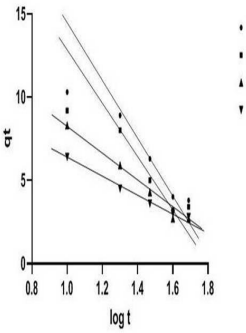

Figure 10: Elovich model for the Arsenic biosorption

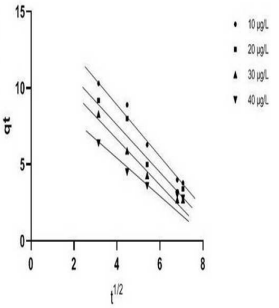

Figure 11: Weber-Morris plot onto study of Arsenic biosorption

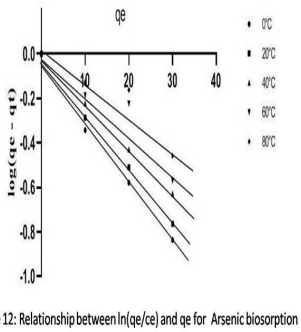

Figure 12: Relationship between ln(qe/ce) and qe for Arsenic biosorption

The Weber–Morris Model

Plotting qt vs $t^{1/2}$ yields the rate-limiting step; lines must cross the origin. This model is associated with the diffusion mechanism.[40] The constant k values (slope) derived from the plot with high values[41]determine the great adsorption speed. However, the rate of arsenic biosorption was sluggish due to the low k values in the sample.In the sample, lines did not pass through the origin (Fig.-11), suggesting that biosorption was not the stage that limited the rate and was not controlled by intra-particle diffusion.

Thermodynamic Parameters

Using Gibb's energy (ΔGo, k J mol-1), enthalpy (ΔHo, k J mol-1), and entropy (ΔSo, k J mol-1) changes at temperatures of 273,293,313,333, and 353 K, the thermodynamic behavior of arsenic biosorption onto neem bark powder was investigated.[42]With rising temperatures[43](-54.47to-46.95kJmol^{-1}), the negative and tiny l values of Gibbs free energy for arsenic metal showed that the adsorption process was thermodynamically feasible and impromptu. The biosorption mechanism in this investigation was exothermic, as evidenced by the negative value of ΔHo (-0.054kJ mol^{-1}). This suggests that chemical sorption occurred during the biosorption process. The positive value of entropy ΔSo (17.14 k J mol^{-1}) during arsenic biosorption onto neem bark powder, as depicted in Fig.-12, suggested an increase in randomness at the solid/solution interface.[44]

Equilibrium

The equilibrium parameter, also referred to as the dimensionless constant se parathion factor, is dimensionless. The vital role of Langmuir's isotherms is known as RL.RL can be expressed as follows:[45]

$$R_L = [1/(1+bC_0)]$$

Where Co is bis Langmuir's constant and the starting concentration of the arsenic metal ion As(III) (mg. L^{-1}). The RL shows whether the isotherm is unfavorable (RL > 1), linear (RL = 1), or permanent (RL = 0). The equilibrium parameter for arsenic biosorption at various temperatures and concentrations was reported to be the favorable biosorption process onto neem bark powder.[45, 46]

Neem Bark Powder SEM Analysis Following Biosorption

An effective tool for examining morphology, texture, pore volume, pore diameter, particle size, and form is the scanning electron microscope (SEM). Neem bark has been shown in earlier studies to be an amorphous substance with a rough texture and surface. SEM tests were performed at different magnifications and widths (500 k, 50 k, 2.0 k, and 1.0 k) to investigate the morphological and behavioral changes of neem bark following biosorption.[47] Figure-13 displays the SEM pictures.

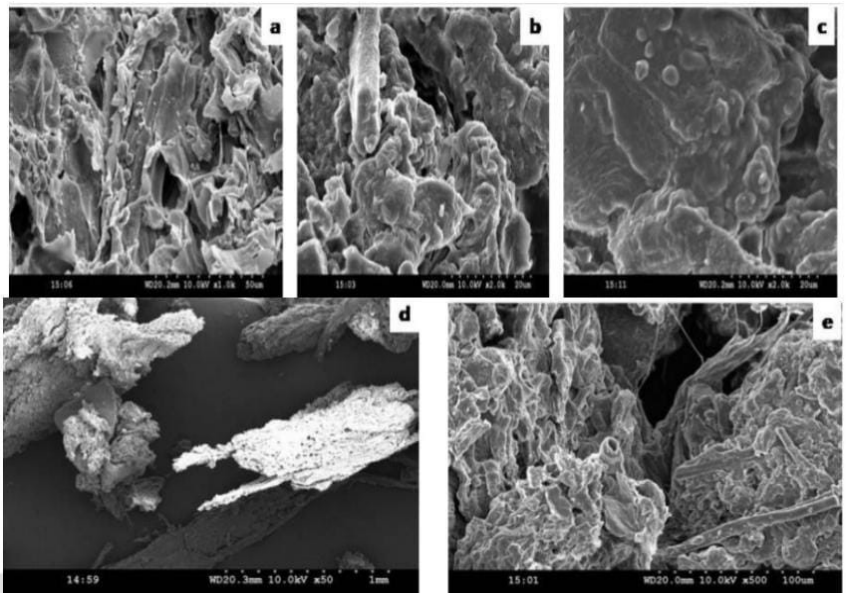

Fig.-13: Scanning Electron Microscopy (SEM) Images after Biosorption

(a),(b)Multi-structured particle aggregation, cavities, aberrations, andk ink scan all be seen on the surface of neem bark. The small molds indicate the biosorption of arsenic ions by the surfaces of neem bark, suggesting the presence of porosity.(c)The rear two distinct phases of arsenic and neem bark are visible. At 2.0 k, there is a decrease in surface heterogeneity with two different images of different widths.Thebiosorptionofarsenicbyploy-molecular/poly-electrolyteandthe behavior of neem bark as a strong biosorbent is confirmed by the surface coverage with particles adhering to the surface. (d)The molecules and the aggregation of arsenic particles at certain parts of the surface determined the biosorbent-biosorbate relationship. (e) The surface appears to be rough because of the cavities and tubular/long rod-shaped particles that are aggregated into normal shapes/mosses.

FTIR Spectra Before and After Adsorption

In Fig.-14, the FTIR spectrum of the biomaterial derived from neem bark displays a broad band between 3550 cm^{-1} and 3250 cm^{-1}, indicating the existence of –NH and –OH vibration strains. The amine groups' C-N stretches peak at 1180 cm^{-1}, whereas the primary and secondary amines' N-H stretches peak at 1690 and 1590 cm^{-1}, respectively. A wavelength of 1300cm^{-1}–1400cm^{-1} indicates the presence of aliphatic carbons, CH2 coupled to double bonds, aromatic compounds, and carbonyls, according to research studies.[48-51] The shift in the peak of the arsenic-loaded biomaterial to 3700 cm^{-1} - 3900 cm^{-1}, or 3907.8 cm^{-1}, 3884 cm^{-1} to 3858.4 cm^{-1}, 3705.5 cm^{-1}, suggests that the -NH and -OH groups are present during the biosorption process. The vibrations/peaks in the 1500–1600 cm^{-1} range show the involvement of the carboxyl group's C–OH, alkyl carbonate groups, and primary secondary amines' –NH stretching. Divergent peak located in the biomaterial's fingerprint regionNeembark's biosorption behavior is improved by the behavior that is seen. Chelation with various functional groups explains neem bark's biosorbent behavior.

XRD Study of Powdered Neem Bark

Figure-15 shows that the XRD diffraction revealed no clearly defined peaks in any region, which is typical of biosorbent materials and indicates amorphous behavior. This behavior has been noted in research on the elimination of chromium and is shown both before and after arsenic ions are absorbed by the surface of neem bark.[52-54] As a result, we can conclude that neem tree bark is an effective biocoagulant for the adsorption of arsenic in solid waste.

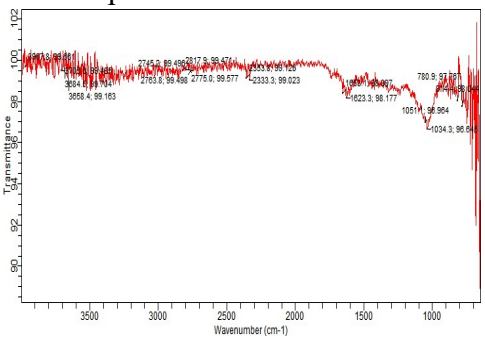

Fig.-14: FTIR image of Neem Bark Powder after Biosorption

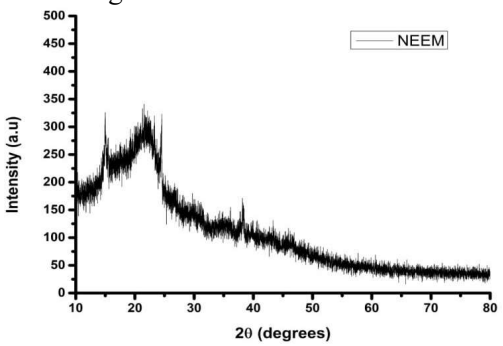

Fig.-15: XRD Image of Neem Bark Powder after Biosorption

CONCLUSION

Batch biosorption experiments were carried out in this study to discard As(III) from aqueous solutions using neem bark as a low-cost, readily available natural biosorbent. Biosorption properties were investigated at various pH levels, initial metal ion concentrations, contact time, and biosorbent dosage levels. The following is a summary of the findings:

- Since the number of adsorption sites increases as the mass of the adsorbent increases, metal ion adsorption increases. Maximum absorption for As (III) for biosorbent was obtained at an adsorbent dose of 1.5g, which may be considered the optimum biosorbent dosage level under the conditions.
- The pH experiments revealed that rivalry of H+ ions with metal ions at low pH values, maximal adsorption at pH 4–6, and precipitation of hydroxyl species onto the adsorbents at higher pH values are the governing factors affecting the biosorption characteristics of allbiosorbents(pH7-11).
- As evidenced by correlation coefficient values, the experimental data were best represented by a pseudo-second-order model(R2). On neem bark, As(III) biosorption follows the Freundlich adsorption isotherm model.
- Thermodynamic parameter studies revealed that As(III)biosorption occurs naturally. With increasing temperatures, the Gibbs free energy (Go)values for As(III) in neem bark powder increase from-54.47to-46.95KJmol^{-1}.
- Biosorption was found to be exothermic with an enthalpy of -0.054 k Jmol-1 and an improvement in randomness at the solute-solution interface with an entropy of 17.14kJmol^{-1}.
- The functional groups C–O,C-H, and C–N are responsible for metal binding, according to

Fourier Transform In infraredspectrophotometer (FT-IR) studies. Hence, *AZARDICTA INDICA*bark can be used as an important natural biosorbent for the economical treatment of wastewater containing As(III).

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CONFLICT OF INTERESTS

The authors have no conflicts to declare.

AUTHOR CONTRIBUTIONS

All the authors contributed significantly to this manuscript, participated in reviewing/editing, and approved the final draft for publication. The research profile of the authors can be verified from their ORCID IDs, given below:

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