Biosorption in Textile Effluents Using Azadirachta Indica Bark Powder with Isotherm Modelling

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Abstract*: Textile effluents are major contributors to water pollution, often containing hazardous heavy metals. Biosorption is becoming more and more popular as a low-cost, effective heavy metal removal technique. With an emphasis on isotherm modeling, this study assesses the application of powdered neem bark (Azadirachta indica) for the biosorption of heavy metals. The maximum percentage removal efficiency of Pb was attained 87.76 for the pH 7 with 2.0g AIBP of dosage content, the contact time being 240 minutes The maximum percentage removal efficiency of Ni attained was 88.64 at the pH level of 6 with dosage level of 2.0g in 240 minutes of contact time. At a pH of 7 and a dosage content of 2.0g AIBP, the highest percentage removal efficiency of Cr was achieved at 88.51 after 240 minutes of contact. With a pH of 7, a dosage of 2.0g of biosorbent, and a contact time of 240 minutes, the highest removal percentage efficiency of zinc was achieved, and it was 84.76. Every metal ion underwent spontaneous biosorption, with the order of spontaneity being Ni > Cr > Pb > Zn. Freundlich and Langmuir isotherms were applied to analyse adsorption behaviour. Effective metal removal was demonstrated by the results, and multilayer adsorption on heterogeneous surfaces was suggested by the Langmuir Isotherm model, which better fit the equilibrium data.

***Keywords*: Biosorption, Neem bark, Heavy Metals, Isotherm modelling, Langmuir Isotherm, Freundlich isotherm, Textile wastewater.**

1. Introduction

Aquatic ecosystems and human health are seriously threatened by heavy metal pollution from the textile industry. In addition, there are a lot of heavy metals in wastewater from the leather tannery, textile, pigment and dye, paint, wood processing, petroleum refining, and photographic film industries. Traditional treatment techniques, such chemical precipitation and ion exchange, are expensive and frequently ineffective at eliminating trace amounts of heavy metals [2], [10]. Biosorption, using natural materials, presents an economical and eco-friendly alternative [6], [14]. Because it contains carboxyl, hydroxyl, and phenolic groups, Azadirachta indica (neem) bark powder (AIBP) is a plentiful agricultural byproduct with intriguing metal-binding qualities [5]. Its ability to remove Pb, Ni, Cr, and Zn ions from contaminated streams has been shown in earlier research [3], [13]. The effectiveness of A. indica bark powder as a biosorbent in the adsorption of heavy metals from synthetic textile effluents and the application of Freundlich and Langmuir isotherms for isotherm modeling equilibrium are the main topics of this work [4], [7].

2. Supplies and Techniques

A. *Gathering of Samples*

For the study of this effective biosorption on textile effluent, different samples from different places were collected from Kasipalayam (11.1155ºN, 77.3850º E), V. Kallipalayam (11.068347ºN, 77.312785ºE) and, Iduvampalayam (11.0819ºN, 77.3238ºE) at Tirupur City. Samples were collected in clean, 5 Litre sterilized polyethylene Canes and stored at 4°C until analysis to preserve sample integrity.

B. *Getting the Biosorbent Ready*

The bark of Azadirachta indica, or neem, was gathered, cleaned with distilled water, and allowed to dry at room temperature. The sorbents were dried, then ground into powder and sieved through a 300 µm screen [1]. To prevent moisture damage, the powdered sorbents are kept in an airtight bottle. Toxic metals from the textile effluent were directly absorbed by the sieved powdered biosorbents in this study.

The effluent sample is taken and the biosorbent is added gradually according to the dosage of 0.5g to 2.5g and the samples is placed on the mechanical shaker for 60 minutes. The initial and the Final pH will be note down for analysing the percentage removal efficiency. Then the samples were tested on atomic adsorption spectrophotometer for analysing the heavy metal elements concentration.

C. *Equilibrium Studies*

To ascertain sorption capacity and intensity, adsorption equilibrium data were analyzed using the Langmuir and Freundlich models [4], [7]. The fundamental premise of the Langmuir adsorption process is that no more adsorption occurs after a monolayer of adsorbate forms on the adsorbent's exterior. The Langmuir isotherm was derived to describe homogeneous biosorption, in which each molecule has a sorption activation energy and a set of constant values with no additional adsorbate transmigration at the surface.

$$\left(\frac{C_e}{q_e}\right)=\left(\frac{C_e}{q_{max}}\right)+\left(\frac{1}{q_{max}K}\right)$$

where K is the Langmuir Isotherm Constant (l/mg), Ce is the Equilibrium Metal Concentration (mg/1), qe is the Amount of Metal Ion Adsorbed per Unit Mass of Adsorbent, and q max is the Maximum Monolayer Coverage and Capacity (mg/g).

An empirical equation that has been demonstrated to be adequate for low concentrations is the Freundlich isotherm. The intercept and slope of linear regression can be used to calculate the empirical constants K_F and 1/n by a plot of Logqe with respect to LogCe. Surface heterogeneity or adsorption intensity is measured by the slope, which ranges from 0 to 1. As its value approaches zero, it becomes increasingly heterogeneous.

$$\text{Log}q_e = \log K + \left(\frac{1}{n}\right) \log C_e$$

Where, K_F is the Adsorption equilibrium constant, Ln is the Heterogeneity factor, which is related to the capacity and intensity of the adsorption and Ce is the Equilibrium concentration (l/mg) correspondingly.

3. Outcomes and Conversation

A. The Impact of pH

The impact of pH (1–10), contact period (60–300 minutes), biosorbent dose (0.5–2.5 mg/L), and metal concentration (10–100 mg/L) on biosorption efficiency was examined in experiments [9]. The Atomic Absorption Spectrophotometer (AAS) was used to measure the amounts of metal ions [11]. It was observed that no adsorption occurred between pH 1 and pH 5, and the maximum percentage removal effectiveness of 80.21 was reached at the pH 7 dose level of 2.0g for the Pb adsorption process.

The percentage removal of Ni was obtained maximum and it was 82.21 at pH 6 2.0 of dosage. At the same dosage, the Cr was maximum as 78.18 at pH 6. Similarly, Zn was attained maximum and it was 76.12 at pH 7 and 2.0g of dosage respectively (Fig, 1) These interpretations of gradually rise in percent adsorption for the anionic dyes onto neem bark were like that studied [23]. Both the degree of ionization of dye molecules and the surface characteristics of the adsorbent change when the pH of the medium changes from acidic to alkaline, which in turn affects the pace at which dyes biosorbent. On the other hand, the presence of large ion concentrations on the adsorbents in the basic medium at pH 8–10 effectively interacts with the dye molecules, resulting in a decreased percentage of both dyes adhering to the adsorbent surface.

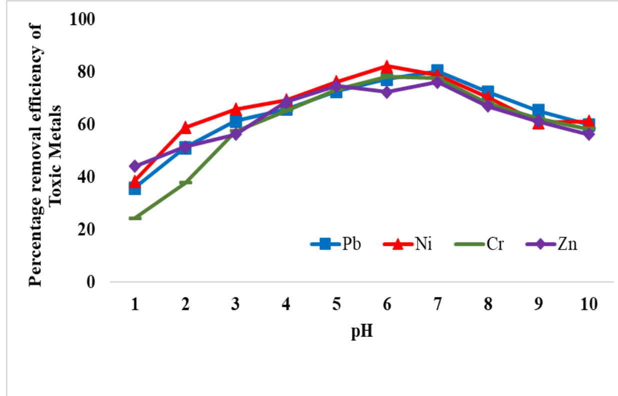

Fig. 1. Visual display of ph against percentage removal efficiency of toxic metals using AIBP

B. Adsorbent Dosage's Effect

Fig. 2 illustrates the impact of varying the adsorbent dosage from 0.5 to 2.5g on the effluent. It is evident that the percentage of metal removal rises as the dosage of the biosorbents increases. The highest percentage removal efficiency was achieved by the adsorption of metals onto Pb, which was 80.21 at pH 7 with a dose quantity of 2.0g. At pH 6, a maximum % elimination of Ni of 82.21 was achieved with a 2.0g dose. At the dose content of biosorbent as AIBP, Cr and Zn also reached their maximums, measuring 80.21 at pH 6 1.5g and 76.12 at pH 7 2.0g, respectively. The biosorbent and adsorption process of Pb was reached for the maximum % removal efficiency as with the dosage content of 2.0g, and the adsorbent changed for Cr. The maximum percentage removal efficiency of Cr was achieved with the dosage content of AIBP 2.0g as biosorbent. As the dosage of adsorbent increases, the number of active sites available for adsorption also increases, thus increasing the percent removal for the dyes. The highest dosage of 2.0g resulted in the removal of the maximum efficiency of ions due to the increased availability of convertible locations, whereas the initial stages of dosage content in 0.5g had begun its removal effectiveness.

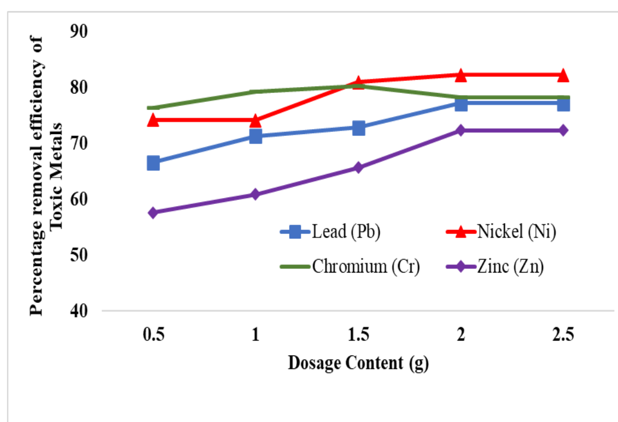

Fig. 2. Visual display of dosage content against percentage removal efficiency of toxic metals using AIBP at pH 6

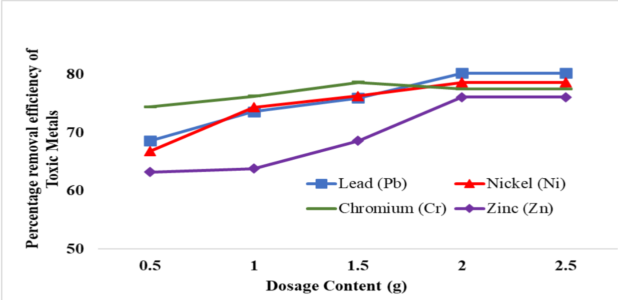

Fig. 3. Visual display of dosage content against percentage removal efficiency of toxic metals using AIBP at pH 7

C. *Impact of Contact Duration*

The percentage removal of the different heavy metals by the AIBP as a biosorbent was displayed in Figures 4 and 5. There was an increase in the percentage of metal ions removed from the textile wastewater contact time for each of the metal ions present. The chemical attraction of the adsorbents for harmful ions might be used to explain the higher removal effectiveness with an increase in contact time. The percentage of adsorption generally rose until t was reached, as can be plainly seen. At pH 7, the Cr and Pb metals achieved the highest percentage removal efficiency of 88.51 and 87.76 in 240 minutes, respectively, at a dose level of 2.0g (Fig. 5). At pH 6 and 240 minutes of contact time, the greatest percentage removal efficiency of Ni was 88.64 (Fig. 4); at pH 7, the maximum percentage removal efficiency of Zn was 84.76 (Fig. 5). After that, as it gets closer to equilibrium conditions, the process becomes relatively constant until equilibrium is reached at a specific moment.

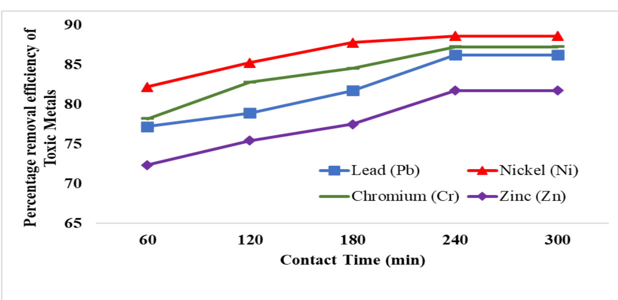

Fig. 4. Visual display of contact time against percentage removal efficiency of toxic metals using AIBP at pH 6 (2.0g)

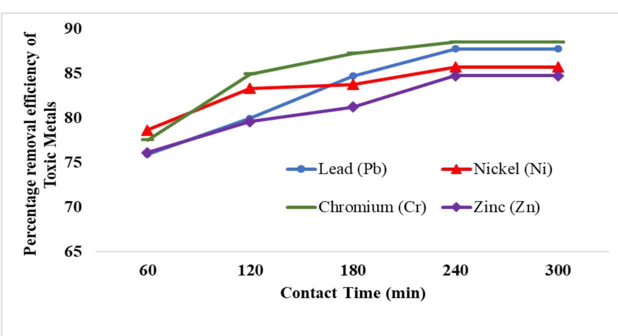

Fig. 5. Visual display of contact time against percentage removal efficiency of toxic metals using AIBP at pH 7 (2.0g)

D. *Isotherm of Adsorption*

To ascertain sorption capacity and intensity, adsorption equilibrium data were analyzed using the Langmuir and Freundlich models [4], [7]. Table 1 and Figures 5 to 6 display the regression equation of AIBP using regression analysis to determine the parameters of the Freundlich and Langmuir isotherms. The dimensionless separation parameter (R_L), which indicates the shape of the isotherm and forecasts whether an adsorption system is favorable, can be used to illustrate the key feature of the Langmuir isotherm. Although a higher R^2 value suggests that the Langmuir isotherm is the most favorable, these results suggested that the equilibrium adsorption data of hazardous metals were well matched to the isotherms, Table. 1, Fig. 6, Fig.7. The best Sorption Capacity and Isotherm Fit were Langmuir isotherm provided the best fit, indicating monolayer adsorption. [7], [8]. The Freundlich model indicated favourable sorption consistent with heterogeneity of the binding sites [15].

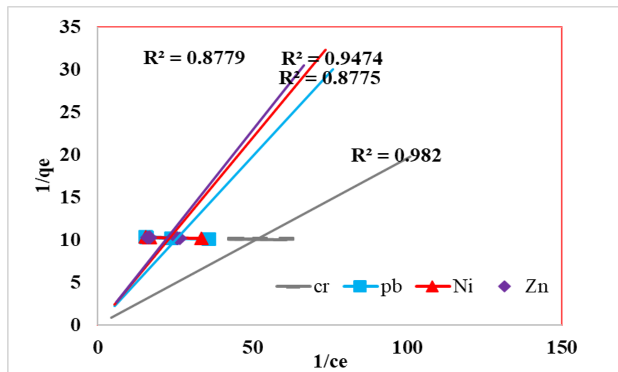

Fig. 6. Toxic metal analysing using langmuir isotherm plot

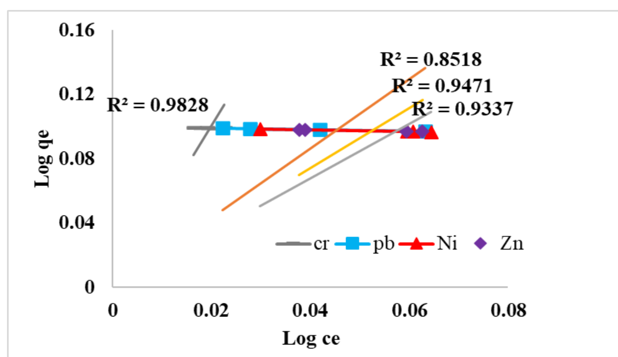

Fig. 7. Toxic metal analysing using freundlich isotherm

Table.1
Aspects of the isotherm model for AIBP

Isotherm parameters	Metal Elements			
	Pb	Ni	Cr	Zn
Langmuir Isotherm				
R^2	0.9932	0.9921	0.9956	0.9947
R_L	0.0423	0.0371	0.0316	0.0338
q_{max} (mg/g)	25.64	18.49	20.83	22.15
b(l/mg)	0.185	0.265	0.301	0.287
Freundlich Isotherm				
R^2	0.9823	0.9807	0.9875	0.9851
n	2.49	2.72	2.65	2.58
K_F (mg/g)	4.01	2.89	3.12	3.45

4. Final Results

The findings of the AIBP study can be applied to the removal of heavy metals from dye effluent as an inexpensive adsorbent substitute. It is very effective and has a large adsorption capability. The equipoise time is almost 240 minutes as 88.64 at pH 6 in the dosage content of 2.0g, and the percentage elimination of Ni increased as the contact time increased. Because Azadirachta indica bark is readily available and reasonably priced locally, it can be used in somewhat larger quantities to achieve total heavy metal elimination. Therefore, it can be said that Azadirachta Indica Bark is a viable biomass alternative for Ni ion removal because it is abundant, inexpensive, and effective, and it can be sourced locally. The adsorption capacity of Azadirachta. indica bark powder compared favourably with other low-cost biosorbents like sawdust, coir pith, and rice husk [2], [9]. For the removal of heavy metals from textile effluents, powdered bark from Azadirachta indica is an efficient and reasonably priced biosorbent. Its potential in wastewater treatment is suggested by its favorable isotherm properties and strong adsorption capacity. Regeneration efficiency and column studies should be the main topics of future research [6], [14]. As a result, environmental pollution can be decreased by removing heavy metals from wastewater. The Langmuir isotherms provide the best fit to the obtained results.

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