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Biosorption Activity of *Nymphaea lotus* (Water Lily)

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ABSTRACT

Heavy metals are highly toxic to human, and can enter the food chain via contaminated food or water. Conventional methods of heavy metal removal from contaminated water and wastewater are economically non-viable, this necessitated the search for cheap and promising methods of heavy metal removal. Nymphaea lotus (Water lily) grows naturally (as weed) in water logged areas; some of these areas are usually prone to heavy metals contamination, due to anthropogenic pressure and/or run-off. This has posed serious challenge in obtaining portable water for domestic and agricultural uses. In this study, batch adsorption experiment was carried out to determine the biosorption performance of different N. lotus parts. Regression analysis revealed that, the adsorption of Cd(II) onto N. lotus seeds, leaves and roots powder fit better to Langmuir isotherm model than Freundlich isotherm model. However, the adsorption of Pb(II) onto N. lotus seeds and leaves fit better to Freundlich isotherm model, while its adsorption onto N. lotus roots powder fit better to Langmuir isotherm model. The plant roots exhibited the highest theoretical maximum adsorption capacity of 49.074 mg g^{-1} and 25.468 mg g^{-1} for Pb(II) and Cd(II) respectively. This finding suggest that, the roots powder of N. lotus can be used as a biosorbent to mop up Pb(II) and Cd(II) from polluted water.

Keywords*: Heavy metals, Biosorption, Adsorption isotherms, Water lily, Nymphaea lotus.*

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I. INTRODUCTION

Pollutants can interact naturally with the biological system, and are therefore of particular importance to wildlife and humans, even at minute concentration. Heavy metals such as cadmium and lead are persistent environmental pollutants, particularly in areas with high anthropogenic pressure (such as mining, tanning, electroplating etc). Their presence in the atmosphere, soil and water has adverse effect on agricultural products, due to their negative effect on food quality, thus, can cause serious health problems [1-3].
The existing methods of metal remediation are expensive, require expertise and are often ineffective. This has challenged Scientist, Engineers and other researchers to come up with an alternative, cheap and promising method of metal removal from polluted/ contaminated water [4]. Biosorption techniques are environmentally friendly, and are currently receiving tremendous attention as an economic alternative, for the removal of toxic metals from water and wastewater.

Nymphaea lotus (Water lily) is an herbaceous aquatic plant, it is widely distributed in streams, rivers and ponds [5, 6]. Traditionally, the plant leaves are eaten as green vegetable or grounded into powder for use as a thickening agent [7]. In addition, it is used for the treatment of dysentery, diarrhea, bowel complaints, scrofula, gonorrhea, polyuria, dropsy, kidney diseases, catarrh, bronchial troubles, tumors and as a douche for leucorrhea [8, 9]. It is also used to treat irritation of the prostate and inflamed gums. Externally, the poultice of powdered roots (in combination with flax seed) is used as remedy for painful swellings, boil, ulcers, wounds and cuts. The roots tea makes a good gargle for irritation or inflammation in the mouth and throat, eye wash, female genital douche and for treatment of tuberculosis. The lotion of the seeds and/ or leaves helps to heal sores and make skin soft [10]. A mixture of root and lemon juice is used to remove freckles and pimples [11]. Although reports on the biosorption activity of *N. lotus* are scarce, it has been reported to reduce the level of metals such as iron, zinc, copper and mercury from water [12]. Thus, may play significant role in bioremediation processes.

In this study, batch adsorption experiment was carried out to determine the biosorption performance of the leaves, roots and seeds of *N. lotus* as an alternative source of biosorbent, for removal of lead (Pb) and Cadmium (Cd) from water.

II. MATERIALS AND METHODS

2.1 Collection and Preparation of Plant Parts

Fresh leaves, seeds and roots of *N. lotus* were collected from Sabon Birni Town, Sabon Birni Local Government Area of Sokoto State, Nigeria, and authenticated at the Botany Unit of Biological Science Department, Usmanu Danfodiyo University Sokoto. The plant parts were washed, dried at room temperature and pulverized using pestle and mortar.

2.2 Batch Adsorption Experiment

Batch adsorption experiments were carried out in 250 ml Erlenmeyer flask, containing 100ml of metal solution and 0.5 g of *N. lotus* leaves powder. The pH was adjusted to 6.5 and the mixture was shaken at 120 rpm for 30 minutes. The solution was allowed to equilibrate for 1 hour, filtered using Whatman filter paper (No. 42). The filtrate was analyzed using AA240FS Atomic Absorption Spectrophotometer (Varian Medical Systems Inc., USA) to obtain the equilibrium metal concentration [13, 14]. Comparative analysis using *N. lotus* seeds and roots powder was carried out adopting the same procedure.

Metal uptake was calculated from equation 1.

$$\text{Metal uptake 'q' (mg/g)} = \frac{V\,(C_i - C_e)}{S} \quad \ldots\ldots (1)$$

Where: C_i and C_e = Initial and Equilibrium Metal Concentration (mg/L); V= Volume of Solution (L); S= Weight of Biosorbent (g).

Adsorption Isotherm plot was obtained from a plot of metal uptake against equilibrium metal concentration.

2.3 Data Analysis

DATAFIT Software, Version 9.0 (Oakdale, United States) was employed for all curves fitting of batch adsorption data. The evaluation of fitting parameters was done using nonlinear regression analysis.

III. RESULTS AND DISCUSSION

Figure 1 and Figure 2 shows the curve fittings of Cd(II) and Pb(II) equilibrium adsorption data to Langmuir and Freundlich isotherm models. Table 1 and Table 2 shows the isotherm fitting parameters and corresponding error functions of Cd(II) and Pb(II) to Langmuir and Freundlich isotherm models, as obtained by non linear regression analysis using DATAFIT Software (Oakdale, United States).

The Langmuir isotherm model assumes a monolayer adsorption of a sorbent onto an adsorbent surface, containing a finites number of identical sites, with no interaction between the adsorbed molecules. The absorption intensity is give as "b", while the theoretical maximum adsorption is given as "$q_{\max}$". On the hand, Freundlich isotherm model is an indicator of energetically heterogeneous multilayer surface. The distribution coefficient "k_F" is related to the adsorption capacity, while the exponent "$1/n_F$" is related to surface heterogeneity and adsorption intensity; the high the "n_F" value, the more favourable the adsorption [13, 14].

Regression coefficient (R^2) values revealed that, the adsorption of Cd(II) onto *N. lotus* seeds, leaves and roots powder fit better to Langmuir isotherm model than the Freundlich isotherm model. The adsorption of Pb(II) onto *N. lotus* roots powder fit better Langmuir isotherm model, while its adsorption onto leaves and seeds powder of *N. lotus* fits better to Freundlich isotherm model.

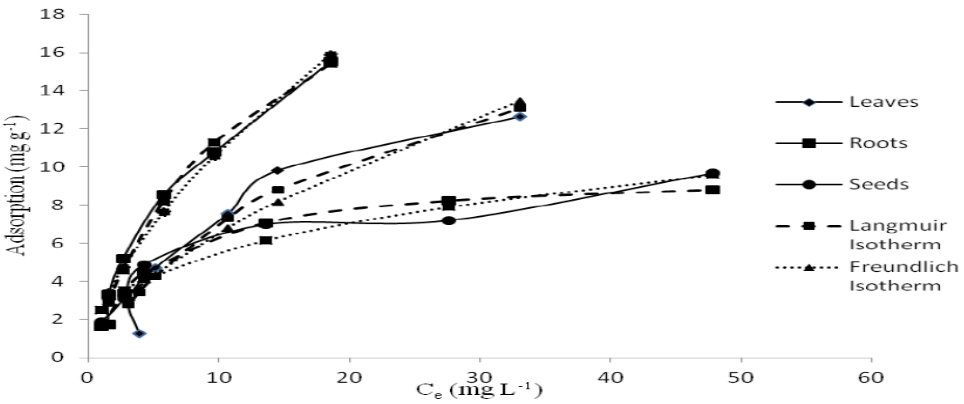

Figure 1: Curve fitting of equilibrium adsorption data for Cd(II) onto roots, seeds and leaves of *N. lotus* (Water lily) with Langmuir and Freundlich isotherm models.

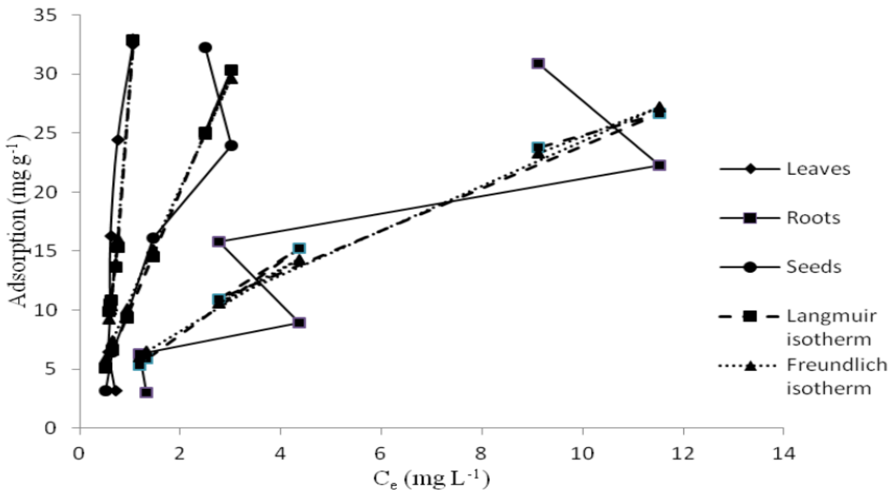

Figure 2: Curve fitting of equilibrium adsorption data for Pb(II) onto roots, seeds and leaves of *N. lotus* (Water lily) with Langmuir and Freundlich isotherm models.

Table 1: Langmuir Isotherm Parameters for Adsorption of Pb(II) and Cd(II) onto the Seeds, Roots and Leaves Powder of *N. lotus* (Water lily).

Samples	Parameters (units)	Pb(II)	Cd(II)
Roots	q_{max} (mg g^{-1})	49.074	25.468
	b	0.103	8.228
	RSS	142.825	2.128
	SE	5.976	0.729
	R^2	0.746	0.984
Leaves	q_{max} (mg g^{-1})	-17.667	21.023
	b	-0.610	4.971
	RSS	235.502	6.126
	SE	7.673	1.238
	R^2	0.631	0.934
Seeds	q_{max} (mg g^{-1})	-3077.40	9.754
	b	-3.233	0.193
	RSS	99.164	2.159
	SE	4.979	0.745
	R^2	0.840	0.949

Key: q_{max} = Theoretical maximum adsorption capacity

b	= Langmuir constant related to adsorption-desorption energy
RSS	= Residual sum of squares
SE	= Standard error
R^2	= Coefficient of regression

Table 2: Freundlich Isotherm Parameters for Adsorption of Pb(II) and Cd(II) onto *N. lotus* (Water lily) Seeds, Roots and Leaves Powder.

Samples	Parameters (units)	Pb(II)	Cd(II)
Roots	k_F (L g^{-1})	5.404	2.542
	$1/n_F$	0.661	0.628
	RSS	150.675	3.769
	SE	0.138	0.971
	R^2	0.732	0.972
Leaves	k_F (L g^{-1})	28.765	1.603
	$1/n_F$	2.141	0.608
	RSS	230.306	9.969
	SE	7.589	1.579
	R^2	0.639	0.892
Seeds	k_F (L g^{-1})	10.780	3.790
	$1/n_F$	0.915	1.021
	RSS	95.609	9.845
	SE	4.889	1.569
	R^2	0.846	0.765

Key:	k_F	= Freundlich constant indicating adsorption capacity
	n_F	= Freundlich constant adsorption intensity
	RSS	= Residual sum of squares
	SE	= Standard error
	R^2	= Coefficient of regression

The roots powder of *N. lotus* has the highest theoretical maximum adsorption capacity (q_{max}) of 49.074 mg g^{-1} and 25.468 mg g^{-1} for Pb(II) and Cd(II) respectively. However, the index of affinity (b) was higher for Cd(II) (8.228) when compared to Pb(II) (0.103). This is an indication that, Cd(II) may be more tightly adsorbed than Pb(II) onto the roots powder of *N. lotus*, despite the higher "q_{max}" for Pb(II).

The Freundlich constant of adsorption capacity (k_F) was higher for Pb(II) when compared to Cd(II) for all the plant samples. In contrast, Freundlich constant of adsorption intensity (n_F) was higher for Cd(II), this further confirms the better adsorption intensity of *N. lotus* roots for Cd(II) as compared to Pb(II).

IV. CONCLUSION

Regression analysis revealed that, the adsorption of Cd(II) onto *N. lotus* seeds, leaves and roots powder occurs via a monolayer adsorption process. Also, the adsorption of Pb(II) onto *N. lotus* roots powder occurs via a monolayer adsorption process, while its adsorption onto *N. lotus* leaves and seeds powder proceeds via a heterogeneous multilayer process. In comparison to other *N. lotus* parts, the roots powder exhibited the highest theoretical maximum adsorption capacity (q_{max}) for both Cd(II) and Pb(II). Though, a higher "q_{max}" was obtained for Pb(II), the intensities of absorption (i.e. b and n_F) were higher for Cd(II). Based on these findings, it is logical to suggests that, *N. lotus* roots powder can serve as a good biosorbent for the removal of Cd(II) and Pb(II) from water and wastewater, if properly exploited by communities facing water contamination by these metals.

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