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Isotherm and Kinetic investigations of toxic metal decontamination from biofluid by untreated biosorbent using a Batch design

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ABSTRACT

The biosorption potential of biosorbent (*Opuntia fragalis* leaves) for decontamination of Zn (II) ions from Human blood plasma (biofluid) was investigated. The influence of biosorbent dose, concentration of Zn (II) ions, pH and rate of biosorption was examined at constant physiological temperature (37^0C). FTIR results of the biosorbent revealed that –C-Br, -C-N, -N-O, -N-H, -C≡C- and –OH functional groups were responsible for the biosorption of Zn (II) ions from Human blood plasma. SEM micrograph revealed the active available pore sites responsible for the binding of Zn (II) ion unto *Opuntia fragalis* leaves. The optimum detoxification of Zn (II) ions was attained at biosorbent dose of 1.5 g, initial concentration of Zn (II) ion at 40 mg/L, pH at 6 and rate of biosorption of Zn (II) ions at 70 min. The experimental data were subjected to four adsorption isotherm models; Langmuir, Freundlich, Temkin and Dubinin-Radushkevich Isotherms. The adsorption process fits into Temkin isotherm with correlation coefficient R^2 value of 0.9376, the maximum monolayer coverage capacity, Qm is -1.2522 mgg^{-1}, Langmuir isotherm constant K_L is -1.029 Lmg^{-1}, separation factor R_L is -1.029 revealed a favorable biosorption process. The biosorption experimental data was modelled with Pseudo-first order, Pseudo-second order, Elovich and Intra particle diffusion kinetic models. Pseudo first order model explained the biosorption process best with R^2 = 0.9998. The interaction between Zn (II) ions and *Opuntia fragalis* leaves defined a chemisorption reaction which involved chemical bonds formation.

1. Introduction

Toxic metals are widely distributed in the ecosystem through urbanization and industrial activities. Even at low concentration heavy metals present in the environment would cause discomfort and harm to living species. The human system does not have the capacity to metabolize heavy metals because it does not degrade into harmless substance, they deposit in living bodies and get multiplied through the food chain [1]. The presence of zinc in low quantity contributes significantly to good health but will facilitate health problems when present in high concentration. Some of the health challenges that high concentration of zinc will cause include: body pain, dizziness, failed muscular coordination and chronic renal failure. In order to protect the environment and human health from toxic metals it is significant to employ biosorption and desorption techniques. Numerous methods can be employed to adsorb toxic metals from aqueous solution include biosorption [2], precipitation reaction [3], solvent extraction [4], reverse osmosis [5], ion exchange

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mechanism [6], filtration [7] and electrochemical treatment [8]. Biosorption technique is the best for the removal of heavy metals due to the availability of the biomaterials, cost effective, efficiency, ease of handling and maintenance. Currently, the application of non-conventional and low-cost materials has drawn attention worldwide instead. The removal of heavy metals from aqueous solution using natural biomass seems the best due to their vase abundance and cheap commercial value. *Opuntia fragalis* is also known as prickly pear and belongs to the family cactaceae. It is nutritionally edible, sweet, serves as beverages and also medicinal because its preparation is analgesic, anti-diabetic, anti-inflammatory, and anti-oxidant [9]. Blood plasma constitutes 60% of the total human blood volume. It is made up of liquid component of the blood and also serves as a transport media for toxic substances. It is widely composed of water making up to 90% and contains clotting factors, mineral ions, proteins, hormones, carbon dioxide and glucose. One of the basic functions of blood plasma is to transport excretory products. Therefore, when toxic metals which cannot be metabolised (non-biodegradable) are ingested into the body and transported by the blood plasma it concentrates in the system thereby posing as health challenges to living organisms [10]. The essence of the present study is to evaluate the biosorption potential of *Opuntia fragalis* leaves for decontamination of zinc ions from human blood plasma and also study its kinetic and adsorption isotherms.

2. Materials and Methods

2.1. Sample Collection

In this study biosorbent prepared from *Opuntia fragalis* leaves used for the biosorption of Zn (II) ions was collected from the botanical garden of Biological Science, Ahmadu Bello University, Zaria, Nigeria. The blood sample was sourced from the Department of Haematology, Ahmadu Bello University Teaching Hospital (ABUTH) Zaria, Nigeria and screened for heavy metal content using Atomic Absorption Spectroscopy (AAS).

2.2. Biosorbent Preparation

Opuntia fragalis leaves were repeatedly and carefully washed with a running tap water and distilled water was used to wash again to remove dirt particles, cut into small sizes and dried at 60°C for 24 hours. The dried plant was grounded, sieved and stored in a plastic container prior to experimental use.

2.3. Preparation of Human Blood Plasma

The blood was drawn into tubes to full volume containing anticoagulant (~1.80 mg citrate phosphate dextrose adenine per cm^3 blood) to ensure perfect mixing of the substances. The tubes were carefully inverted ten times to ensure even mixing of blood and anticoagulant and store at ambient temperature. After, centrifugation three distinct layers were observed from the top to bottom; plasma, leucocytes and erythrocytes. The plasma was carefully aspirated at physiological temperature (37°C) and care was taken not to distort the cell layers. Inspection of plasma for turbidity was carried out and turbid sample was centrifuged again to remove remaining insoluble matters [11]. Thereafter, the human plasma was characterized for the presence of heavy metal of interest using AAS.

2.4. Characterisation of Biosorbent

2.4.1 FT-IR and SEM Analysis

The biosorbent was characterized for the presence of functional groups responsible for decontamination of Zn (II) ions from human plasma by carrying out FTIR analysis on the biosorbent before and after adsorption process. The surface chemistry of the biosorbent was analysed using Scanning Electron Microscope at Ahmadu Bello University, Zaria, Nigeria.

2.5. Batch Design: One-Factor at a Time Optimization

The percentage of Zn (II) ions decontamination was obtained using equation (1)

$$\text{Biosorption } (\%) = \frac{C_o - C_e}{C_e} \times 100 \quad (1)$$

$$q_e = \frac{(C_o - C_e)\,V}{m} \quad (2)$$

Where q_e is the amount of Zn (II) ions removed per unit mass of the biosorbent (mgg^{-1}) at equilibrium, C_i and C_e is the initial and final concentrations of the Zn (II) ions in the human blood plasma (mgL^{-1}), V is the volume of the human blood plasma (cm^3) and m is the quantity (g) of biosorbent used.

2.5.1 Optimization of biosorbent dose

The biosorbent doses were optimised by weighing accurately 0.5 g, 1 g, 1.5 g, 2 g and 2.5 g of the biosorbent. These were added to 20 cm^3 of the human plasma containing 40 mgL^{-1} of Zn (II) ions in 120 cm^3 sample bottles. The mixtures were agitated for 60 minutes at 37^0C, filtered and digested.

2.5.2 Optimization of Zn (II) ion concentration

The concentration of Zn (II) ions adsorbed by biosorbent was optimised by preparing 10 mgL^{-1}, 20 mgL^{-1}, 30 mgL^{-1}, 40 mgL^{-1} and 50 mgL^{-1}. These were added to 20 cm^3 of human blood plasma containing 1.5g of biosorbent. The mixtures were agitated for 60 minutes at 37^0C, filtered and digested.

2.5.3 Optimization of pH

Optimisation of pH was performed by weighing accurately 1.5g of biosorbent. This was added to 20cm^3 of human plasma containing 40mgL^{-1} of Zn (II) ion and the pH of the mixtures were adjusted to 2, 4, 6, 8 and 10 with HCl /NaOH. The mixtures were agitated for 60 minutes at 37^0C, filtered and digested.

2.5.4 Optimization of contact time

The rate of Zn (II) ion decontamination from human blood plasma was studied by monitoring the time of removal. Optimum biosorbent (1.5g) was added to 20 cm^3 of human plasma containing 40 mgL^{-1} of Zn (II) ion (optimum concentration) at pH 6 (optimum pH) and the compositions were agitated for 10 min at 37^0C. The experiment was repeated at varying contact time of 20, 30, 40, 50, 60, 70, 80, 90, 100, 110 and 120 minutes respectively and the compositions were filtered and digested

2.6 Spiking different concentration of Zn (II) ion solution into human blood plasma

Different concentrations of the Zn (II) ions solution were used to contaminate the human blood plasma in other to ascertain the extent at which the biosorbent could decontaminate Zn (II) ions in human blood plasma. Hence, to determine the amount of spiking solution (known concentration of Zn (II) ions) to be added to blood sample is given in equation (3).

$$\boldsymbol{V_A = \frac{C_B \times V_B}{C_A}} \qquad (3)$$

Where V_A is the volume of spiking solution to be added to the human blood plasma, C_A is the concentration of spiking stock solution prepared; C_B is the desired spike concentration to be added to the human blood plasma and V_B volume of the human blood plasma to be spiked.

2.7. Digestion of Filtrate

Accurately, 3 cm^3 of the filtrate was measured into 5 Pyrex flask separately and 10 cm^3 of concentrated HNO_3 and 5 cm^3 of H_2O_2 (2:1) was added. The mixture was allowed to stand for 10 minutes and digested at 70°C for 2 hours covered with a lid until a clear digested solution was obtained and the volume of mixture reduced to semi dryness. Then, make up to 100cm^3 mark using distilled water. The concentration of Pb (II) ions in the filtrate was obtained by Atomic Adsorption spectroscopy (AAS) method (AA240FS Varian).

3. Results and Discussion

3.1. Scanning Electron Micrograph

Fig 1 and Fig 2 show the plates of SEM results of the biosorbent before and after decontamination of Zn (II) ion. Fig 1 shows numerous surface porosities of the biosorbent in its original state. Fig 2 shows the SEM micrographs of a loaded biosorbent with Zn (II) ions. It showed appreciation of the porosity of the biosorbent and qualitative assessment of their ability to adsorb Zn (II) ions. The prepared biosorbent have many pores which were clearly found on the surface was the main factor responsible for high removal of Zn (II) ions from human plasma.

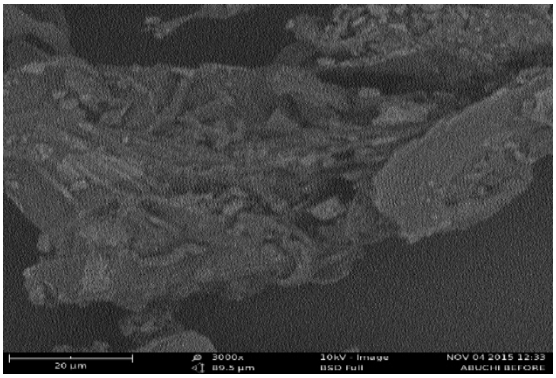

Fig 1. SEM micrograph of biosorbent before Zn (II) biosorption from human plasma.

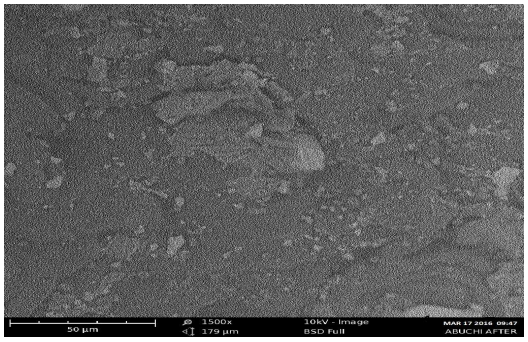

Fig 2. SEM micrograph of biosorbent after Zn (II) biosorption from human plasma.

3.2. FTIR Characterisation and Contribution of Functional Groups to Zn^{2+} Binding

The FTIR spectra of biosorbent and biosorbent loaded with Zn (II) ions are presented in Fig 3 and Fig 4 respectively. The spectra showed generally a shift in the peaks from 538.16 cm^{-1}, 644.25 cm^{-1}, 1062.81 cm^{-1}, 1332.86 cm^{-1}, 1631.83 cm^{-1} and 3306.76 cm^{-1} in biosorbent to peak, 646.17 cm^{-1}, 1066.67 cm^{-1}, 1340.57 cm^{-1}, 1637.62 cm^{-1}, 2299.07 cm^{-1} and 3408.33 cm^{-1} in biosorbent loaded with Zn (II) ion respectively. The shift in frequency showed that there was Zn (II) ion binding process taking place at the surface of biosorbent. The spectral interpretation of unloaded biosorbent and biosorbent loaded with Zn (II) ions indicated that –C-Br, -C-N, -N-O, -N-H, -C≡C- and –OH was involved in Zn (II) ion biosorption.

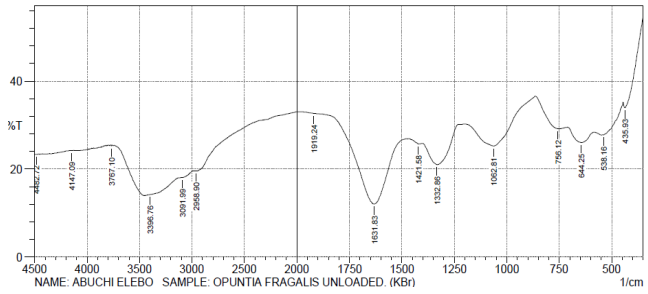

Fig 3. FTIR spectra of biosorbent before Zn^{2+} biosorption from human plasma.

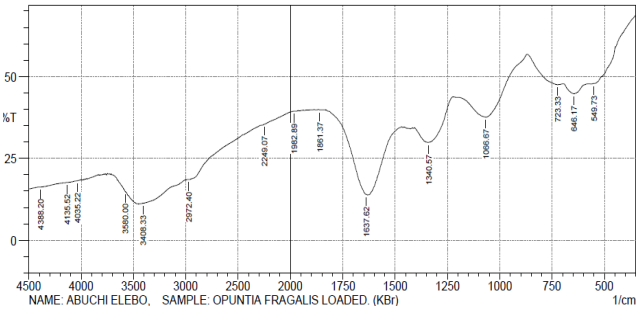

Fig 4. FTIR spectra of biosorbent after Zn^{2+} biosorption from human plasma

3.3 Effect of Biosorbent dose

Fig 5 is the plot of percentage decontamination of Zn (II) ions from human blood plasma versus biosorbent dose. The percentage decontamination of Zn (II) ion was seen to increase from 87.0425 - 90.8525% as the biosorbent dose was increased from 0.5 – 1.5 g and decreased from 90.8525 - 89.0375% with increase in biosorbent dose from 2 – 2.5 g. The increase could be as a result of the presence of available pore sites and larger surface area as the biosorbent dose increased [12,13]. while the decrease in percentage decontamination was due to the fact that the Zn (II) ions saturated the pore and leaving large amount of Zn (II) ions in the solution [14].

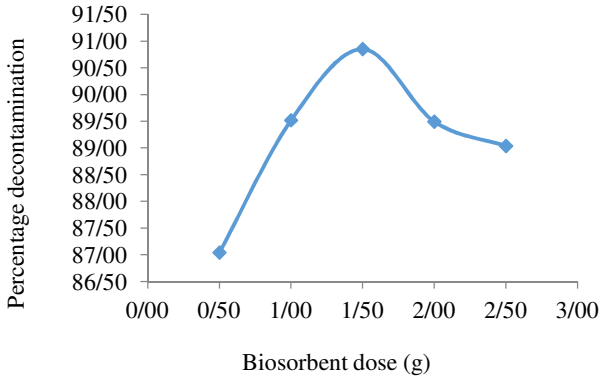

Fig 5. Percentage decontamination versus biosorbent dose.

3.4 Effect of Zn (II) ions concentration

The plot of percentage decontamination of Zn (II) ions from human plasma versus Zn (II) ion concentration is shown in Fig 6. Percentage decontamination increase was observed from 70.12 – 92.80% as Zn (II) ion concentration was increased from 10 – 30 mg/L and decrease in percentage decontamination was seen from 92.80 – 88.44% as the concentration was increased from 40 – 50 mg/L. Such increase could be attributed to fact that Zn (II) ions experienced high collision with the biosorbent surface and also due to potent available active sites regarding to optimum diffusion rate of Zn (II) ions onto biosorbent [15]. while the decrease could be as a result of Zn (II) ions could not be adsorbed any further due to saturation point of biosorbent was reached [16].

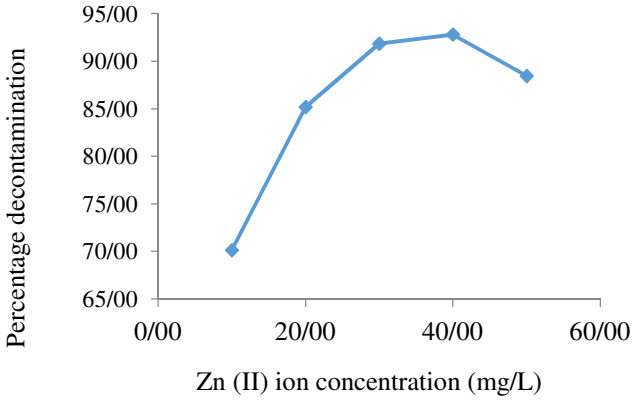

Fig 6. Percentage decontamination versus concentration of Zn (II).

3.5 Effect of pH

The plot of percentage decontamination of Zn (II) ions from human plasma versus pH is presented in Fig 7. The percentage decontamination of Zn (II) ions increased from 89.25 - 91.31% as the pH of the solution increased from 2 – 6 and slight decrease in percentage decontamination of Zn (II) ions from 90.72 – 90.28% as pH increased from 6 – 10. The increase could be as a result of declined level of Zn (II) ions and hydrogen ions competing for the vacant sites [17]. Slight decrease in percentage decontamination is as a result of soluble complexes of the Zn (II) ions was formed. Similar result was reported on the biosorption of Co (II) ions unto activated carbon by [18].

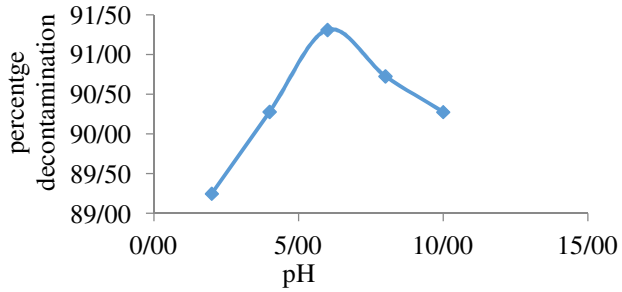

Fig 7. Percentage decontamination versus pH

3.6 Effect of contact time

Fig 8 is the plot of percentage decontamination versus time. The percentage decontamination of Zn (II) ion from human plasma increased slowly from 80.89 – 91.46% as rate of biosorption was increased from 10 – 70 minutes (optimum contact time: 70 minutes). Further increase in contact time to 120 min initiated no significant decontamination of Zn (II) ions by biosorbent as equilibrium was attained. This could be as a result of limited available binding sites and the Zn (II) ions could not bind to the remaining available sites [19, 20].

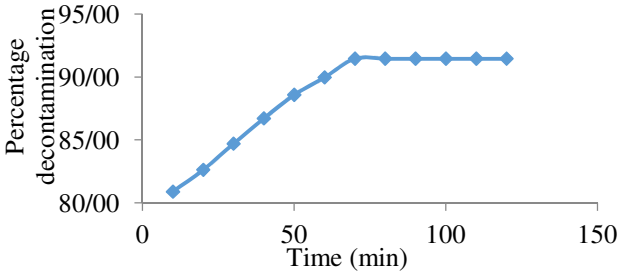

Fig 8. Percentage decontamination versus contact time

4. Adsorption Isotherm Studies

In this study the experimental data obtained from decontamination of Zn (II) ions from human plasma using a biosorbent was subjected to Langmuir, Freundlich and Temkin Isotherms.

4.1 Langmuir isotherm

Langmuir isotherm explains that adsorbed molecules have no interaction in the vacant sites and the rate of adsorption is not dependent on the amount of adsorbate adsorbed. Monolayer is reached when the occupied sites become saturated [21]. Langmuir equation is presented in equation (4).

$$\frac{C_e}{q_e} = \frac{1}{K_L Q^o} + \frac{C_e}{Q^0} \qquad (4)$$

where qe and Q^0 are the equilibrium and quantity of adsorbate adsorbed by the biosorbent (mol g^{-1}) respectively. C_e is the Zn (II) ion concentration at equilibrium in the solution (mol l^{-1}) and K_L is the Langmuir constant (mol^{-1}) related to the free energy of biosorption.

The Hall separation factor, R_L is used to express the suitability of the biosorption of adsorbate to biosorbent [22] and R_L is presented in equation (5).

$$R_L = \frac{1}{1+K_L C_o} \qquad (5)$$

Where C_o is the final concentration of adsorbate in the solution (mg L^{-1}). The plot of $\frac{C_e}{Q^0}$ versus C_e for Zn (II) ion decontamination onto biosorbent is presented in Fig 9. Table 2 shows correlation parameters of the Langmuir Isotherms. When 0< RL<1 is favourable, R_L>1 is unfavourable, R_L=1 is linear and R_L= 0 irreversible [23]. From the result obtained the correlation coefficient (R^2) is 0.01 indicated that decontamination of Zn (II) ions from human blood plasma did not fit into Langmuir isotherm and the dimensionless factor (R_L) value of -1.029 suggests that decontamination of Zn (II) ion biosorbent was favourable.

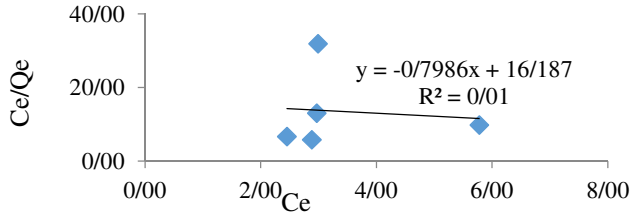

Fig 9. Langmuir Isotherm of Zn (II) ion decontamination

4.2 Freundlich isotherm

The Freundlich isotherm deals with the adsorption of adsorbate onto adsorbent on a heterogeneous surface. The Freundlich model is presented in equation (6).

$$Inq_e = InK_f + \left(\frac{1}{n}\right) InC_e \quad (6)$$

where, qe (mgg^{-1}) is the quantity of molecules adsorbed per unit biosorbent, K_f (Lmg^{-1}) is the Freundlich constant measuring quantity of adsorption, Ce (mgL^{-1}) is the final concentration, n is constant related to the intensity of adsorption. Fig 10 shows the plot of Inq_e versus InC_e for Zn (II) ions decontamination from human blood plasma. The correlation coefficient R^2 = 0.1617 indicated that the experimental data did not fit into Freundlich model and n value 1.1171 is higher than 1.0 indicated that Zn (II) ions decontamination process was favorably [24] as shown in T able 2.

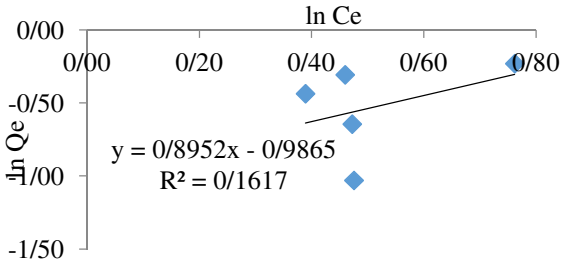

Fig 10. Freundlich Isotherm of Zn (II) ion decontamination

4.3 Temkin isotherm

Temkin isotherm expresses that the free energy of adsorption depends on the surface coverage of the interaction of biosorbent and adsorbates [25]. The equation is presented in equation (7)

$$q_e = BInA + BInC_e \quad (7)$$

where $\frac{RT}{bT}$ = B, T (^{0}K) is the temperature, R is the ideal gas constant (8.314Jmol-1K^{-1}), A (L/g) is the binding energy, *B* (J/mol) is a constant related to heat of sorption and b_T is the Temkin isotherm constant. The plot of qe versus lnCe for the biosorption is presented in Fig 11. From the result presented in Table 2, the correlation coefficient R^2 is 0.9376, the value of A is 13.086 Lg^{-1} and B_T = 8672.99 $Jmol^{-1}$ implies high heat of biosorption between Zinc (II) ions biosorbent and decontamination process fits into Temkin isotherm.

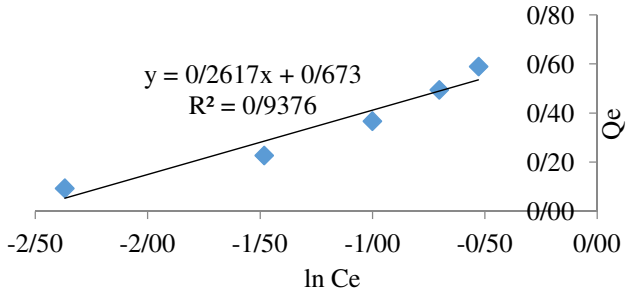

Fig 11. Temkin Isotherm of Zn (II) ion decontamination

4.4 Dubinin-Radushkevich (D-R) Isotherm

It explained that the pores of the biosorbent have a characteristic relationship with the biosorption curve [26]. The linearized form is presented in equation (8).

$$lnq_e = lnQ_D - B_D \in^2 \quad (8)$$

Where Q_D is the theoretical maximum adsorption capacity (mol/g), B_D is the D-R model constant (mol^2/kJ^2), ε is the Polanyi potential and is equal to equation (9).

$$\in = RTln\left(1 + \frac{1}{C_e}\right) \quad (9)$$

where R, T and Ce represent the gas constant (8.314 J/mol K), absolute temperature (K) and final adsorbate concentration (mg/L), respectively. The mean energy of adsorption, E (kJ/mol), is calculated by using equation (10).

$$E = \frac{1}{\sqrt{2B_D}} \quad (10)$$

The D-R parameters and mean free energy for adsorption are shown in Table 1. Dubinin-Radushkevich (DRK) isotherm model is temperature dependent that makes it unique amongst all isotherms with the same curves having suitable data known as characteristic curve [27]. The plot of lnq_e vs $\in^2$ s presented in Fig 12. From the results Q_D was determined to 0.507 mg/g, the E = 7.0711×10^2 KJ/mol indicates a physiosorption process [28] and the R^2 = 0.0927 indicates poor correlation of the data.

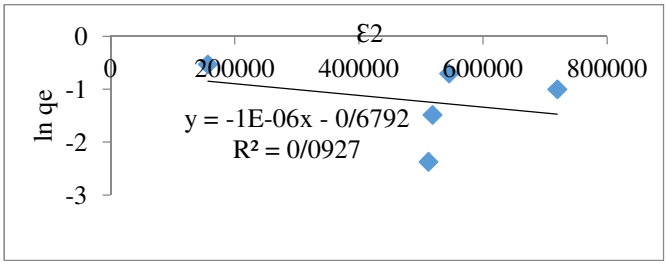

Fig 12. Dubinin-Radushkevich (D-R) Isotherm of Zn (II) ion decontamination

5. Adsorption kinetics

In order to get a well fitted kinetics model of Zn (II) ions decontamination from human blood plasma, experimental data was fitted into Pseudo-first-order, Pseudo-second-order, Elovich and Intra particle kinetic models.

5.1 Pseudo first order kinetic model

The linearized form of Pseudo first order kinetic model was suggested by [29] as presented in equation (11).

$$log\ (q_e - q_t) = log\ q_e - \frac{k_1}{2.303} t \qquad (11)$$

where qe (mmol g^{-1}) and qt ($mmolg^{-1}$) are the amount of Zn (II) ions adsorbed at equilibrium and at time (t) respectively, K_1 (min^{-1}) is the first order rate constant of adsorption. Fig 13 is the plot of t versus log (qe-qt) for Zn (II) ion decontamination from human blood plasma by biosorbent. From the result presented in Table 1, the rate constants (K_1) is 0.04122, correlation coefficient R^2 is 0.576 and qe = 0.011066 indicate that large amount of Zn (II) ions was decontaminated per unit biomass [30].

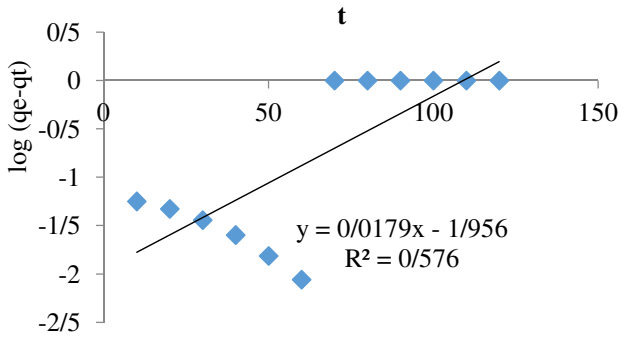

Fig 13. Pseudo first order kinetics of Zn (II) ion decontamination

5.2 Pseudo second-order kinetic model

The pseudo second-order kinetic model is presented in equation (12).

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{t}{q_e} \qquad (12)$$

where K_2 is the pseudo second order rate constant ($gmg^{-1}.min$), q_e (mgg^{-1}) is the amount of Zn (II) ions adsorbed per unit mass of adsorbent and q_t is the amount of Zn (II) ions adsorbed per unit mass of adsorbent at time (t). Fig 14 is the plot of $\frac{t}{qt}$ versus t for Zn (II) ion decontamination from human plasma. From the result presented in Table 1, the rate constants K_2 is 0.8066, correlation coefficient R^2 values is 0.9998, qe = 0.4995 which implies that the biosorption of Zn (II) ions followed the pseudo second order kinetic model which indicate a chemical biosorption process between Zn (II) ions and biosorbent [31].

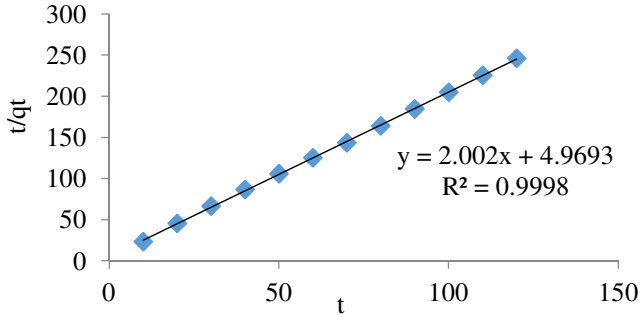

Fig 14. Pseudo second order kinetics of Zn (II) ion decontamination

5.3 Elovich model

The Elovich model is presented in equation (13).

$$q_t = \frac{1}{\beta} \ln(\alpha\beta) + \frac{1}{\beta} \ln(t) \qquad (13)$$

Where α is the initial adsorption rate ($mgg^{-1}.min$), β is desorption constant during any experiment. Fig 15 is the plot of qe versus ln (t) for Zn (II) ion decontamination from human blood plasma. The correlation coefficient R^2 is 0.9491 indicated that decontamination of Zn (II) ions process fits into Elovich model as shown in Table 1 which implies chemisorption.

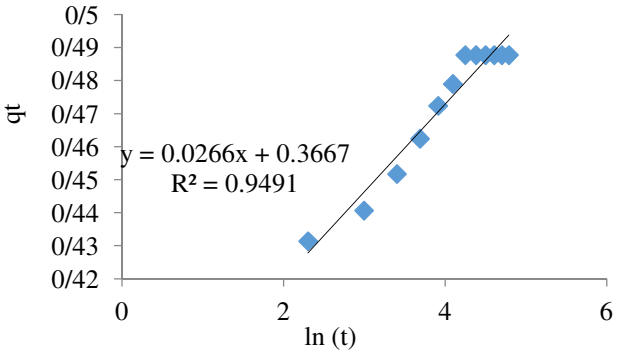

Fig 15. Elovich model of Zn (II) ion decontamination

5.4 Intra-particle diffusion

Several processes are involved in transferring of the liquid phase to the adsorbent surface area. However,

one or more processes might control the overall adsorption processes like diffusion occurring externally, diffusion in pore, diffusion in surface and adsorption on the surface area or the involvement of more than one step. The intra particle diffusion regulates the batch process for the contact time and adsorption parameters. Weber and Morris equation gave a detailed explanation on plausible resistance of intra particle diffusion affecting adsorption. Intra particle diffusion equation is presented in equation (14).

$$q_t = K_{id}\, t^{1/2} + I \qquad (14)$$

However, as the intercept increases the boundary layer effect also increases. The difference in initial and final steps of adsorption in the rate of mass transfer could be as a result the straight line deviating from the origin which indicates that the rate controlling step is not the pore diffusion [32]. Also, the rate limiting step is not the intra particle diffusion because $I \neq 0$. R^2 value of 0.9078 which indicates good correlation between the plot of qt and $t^{1/2}$ as presented in Fig 16.

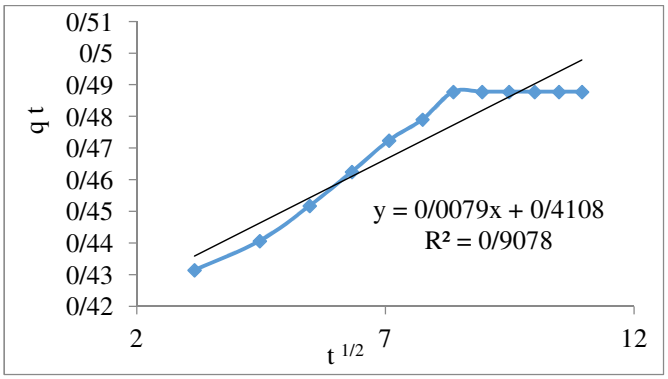

Fig 16. Intra particle diffusion model of Zn (II) ion decontamination

Table 1. Correlation parameters for Pseudo first order, Pseudo second order, Elovich and Intra-particle diffusion models for Zn (II) ions adsorption from human plasma at 37^0C.

Pseudo first-order			Pseudo second-order			Elovich model			Intra-particle diffusion model		
R^2	q_e	K_1	R^2	q_e	K_2	R^2	α	β	R^2	$K_{i.d}$	I
0.5760	0.011066	0.04122	0.9998	0.4995	0.8066	0.9491	1.450	37.594	0.9078	0.0079	0.4108

Table 2: Correlation Parameters for Langmuir, Freundlich, Temkin and Dubinin-Radushkevich Isotherms of Zn (II) ions Decontamination from Human Blood Plasma by Biosorbent at 37°C.

Langmuir Isotherm				Freundlich Isotherm			Temkin Isotherm			Dubinin-Radushkevich (D-R) Isotherm			
Q_o (mg/g)	K_L (L/m)	R_L	R^2	n	K_f (mg/g)	R^2	A_T (L/m)	b_T	R^2	R^2	B_D	Q_D	E
-1.2522	-1.029	-1.029	0.010	1.1171	0.10325	0.1617	13.086	8672.99	0.9376	0.0927	0.000001	0.507	707.11

7. Conclusion

The study demonstrated that biosorbent sourced from the leaves of *Opuntia fragalis* have the potential to decontaminate Zn (II) ions from human plasma. The experimental data showed that as the concentration of Zn (II) ions, biosorbent dose, pH and rate of biosorption of Zn (II) ions was increased the percentage of decontamination also increased at physiological temperature (37^0C). The adsorption process fitted well into Temkins adsorption isotherm and kinetic data showed best correlation with Pseudo second-order kinetic model confirming the plausibility of Zn (II) ions decontamination from

human plasma. The physical characterization of the biosorbent was expressly analyzed using SEM and FTIR spectroscopy. It showed that the surface chemistry of the biosorbent exhibited available pores which participated in decontamination of Zn (II) ions from human plasma and the presence of some keen functional groups in the biosorbent were also responsible for decontamination process.

Recommendations

1. The experiment should be extended to the effect of particle sizes on the biosorption of heavy metals from human plasma.
2. Other Kinetic and Isotherm models should be employed.
3. Activated carbon form of the biosorbent should be utilized.
4. Desorption studies should be carried out.
5. Thermodynamic studies should be carried out for a comprehensive understanding of the biosorption process.

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