



Original Article

USE OF SPINES OF *Bombax buonopozense* AND LEAVES OF *Polyalthia longifolia* AS ABSORBENTS AND ANTIMICROBIAL AGENTS FOR WATER TREATMENT

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Submitted: October, 2016; Accepted: November, 2016; Published: December, 2016

ABSTRACT

The reduction of microbial load in water and adsorption of lead (II) and iron (II) ions onto carbonized and activated carbons from aqueous solution using spines of *Bombax buonopozense* and leaves of *Polyalthia longifolia* were investigated. The carbonized and activated adsorbents were studied by varying the contact time, pH, initial metal concentration and the adsorbent dose. The sorption data were computed using Langmuir and Freundlich isotherms. Results proved that the rate of adsorption was better described by the Langmuir model. The maximum adsorption capacities ranged from 1.95 to 2.35 mg/g for carbonized *Bombax buonopozense* (CB), activated *Bombax buonopozense* (AB), carbonized *Polyalthia longifolia* (CP) and activated *Polyalthia longifolia* (AP). Adsorption kinetic data obtained for the metal ions sorption were described using pseudo-first order and pseudo-second-order equation. It was found that the kinetic data followed the pseudo-second-order kinetic. The adsorbents act as antimicrobial agents against the microorganisms in water thereby decreasing the number of bacteria and fungi. Therefore, applications of these adsorbents are recommended for eco-friendly and nontoxic water treatment processes since they could also act as environmentally friendly antimicrobial agents for purification of contaminated water that will be eventually used for drinking and other purposes.

Keywords: Carbonized, activated, *Bombax buonopozense*, *Polyalthia longifolia*, antimicrobial agent, contaminated

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INTRODUCTION

Waste biomass is known to be an effective and efficient sequester of heavy metals. Studies have revealed that the most commonly applied materials are biosorbents (Ho and Ofomaja, 2006). These materials have shown the ability to remove metal ions from aqueous solutions which performed favourably when compared to conventional water purification methods such as precipitation, ion exchange, solvent extraction and liquid membrane for the removal of potentially toxic metal ions from industrial wastewater. This is because these processes have the limitations of technical and economic viability (Sciban *et al.*, 2007)

The sorption of heavy metals into these biomaterials is attributed to their constituents, which are mainly proteins, carbohydrates and phenolic compounds since they contain functional groups such as carboxylates, hydroxyls and amines that are attached to the metal ions (Choi and Yun, 2006). Studies have shown that lignin has the potential of acting as an adsorption material due to its high adsorption efficiency (Hengky *et al.*, 2009). Lignin adsorption capacity can be enhanced by chemical activation methods such as the addition of functional groups or cross-linking (Parajuli *et al.*, 2005). The structural components of biological materials contain various functional groups which interact with metal ions. These biosorbents, containing lignin, possess metal-sequestering property and can be used to decrease the concentration of potentially toxic metal ions in aqueous solutions (Araújo *et al.*, 2007). It can effectively remove metal ions from dilute complex solutions with high efficiency. Therefore it is an ideal or potential

adsorbent for the treatment of high volume and low concentration complex wastewaters (Wang and Chen, 2006).

Adsorption using activated carbon is considered to be one of the most efficient methods for the removal of colours, odours, organic and inorganic pollutants from wastewater. Activated carbon has been used as an adsorbent for removal of toxic metal pollutants from wastewater and has proved to be effective (Goyal *et al.*, 2008). This is because of its good adsorption capacity which depends on its porosity and large surface area (Kang *et al.*, 2008). It can also be produced from cheap and readily available raw materials (Okpareke *et al.*, 2009). Surface chemistry has played a major role in the adsorption of heavy metals in aqueous solution onto activated carbons. Chemical oxidation incorporates both oxygen and nitrogen functional groups found on the surface of the activated carbon, enhance the adsorption of aqueous metal cations and modify the selectivity of the activated carbon for these metal cations (Jia *et al.*, 2002).

The equilibrium relationships, generally known as adsorption isotherms, describe how pollutants interact with the adsorbent material, and thus are essential for optimization of the adsorption mechanistic pathways, effective design of the adsorption systems, expression of the surface properties and capacities of adsorbents (El-Khaiary, 2008). The method of adsorption using commercial activated carbon is costly especially for developing countries. Thus, the use of adsorbent materials is desirable considering the difficulties faced during commercial activated carbon regeneration and the disposal problems posed by regeneration solutions. In an attempt to address the cost problems

associated with commercial adsorbents; the use of abundant, locally available adsorbents derived from agricultural wastes is proposed in this study. In present study, the reduction of microbial load in water and sequestering of Pb(II) and Fe(II) ions in wastewater using leaves of *Polyalthia longifolia* and spines of *Bombax buonopozense* were carried out.

MATERIALS AND METHODS

Biosorbents Collection and Preparations

The low-cost adsorbents used in this study were derived from spines of *Bombax buonopozense* and leaves of *Polyalthia longifolia*. The samples were obtained from farms in Bosso Local Government Area, Niger State, Nigeria, where they are generated as primary agricultural wastes. These were extensively washed to remove dirt and other particulate matter that might interact with the sorbed metal ions and then cut into chips. The samples were washed with distilled water, sun-dried and ground, and then sieved to a particle size of 200. The sample materials after sieving were divided into two parts: The first portion was placed in a crucible and positioned at the centre of a muffle furnace for 15 min at 500°C and the activated carbon produced was cooled in a desiccator. The second was carbonized as mentioned above and then washed with benzoic acid.

Adsorbent

The adsorbent materials, carbonized *Bombax buonopozense* (CB); activated *Bombax buonopozense* (AB); carbonized *Polyalthia longifolia* (CP) and activated *Polyalthia longifolia* (AP) were prepared as described above.

Preparation of Metal Ion Concentrations

All Chemicals used were of high purity, commercially available Analar grade. The analytical grades of $\text{Pb}(\text{NO}_3)_2$ and $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ were purchased from Aldrich chemicals. Stock solutions of 1000 mg dm^{-3} concentrations of Pb and Fe were prepared by dissolving appropriate amounts of $\text{Pb}(\text{NO}_3)_2$ and $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ respectively in distilled water. Standard solutions by serial dilution of the required concentrations were prepared by successive dilution of the stock solutions.

Culturing Most Probable Number (MPN) of Coliform

Double strength and single strength media were prepared. Aliquots of 10 cm^3 each of the double strength medium was pipetted into 3 test tubes per sample and 10 cm^3 each of the single strength media was pipetted into 6 test tubes. These were then autoclaved at 121°C for 15 min and allowed to cool at room temperature. Aliquots of 10 cm^3 of each sample was added to each test tube of double strength. Aliquots of 1.0 cm^3 was added to each of the single strength media. Aliquots of 0.1 cm^3 was equally added to the remaining tubes of single strength per sample. All inoculation was done aseptically and the test tubes were incubated at 37°C for hours.

Estimation of Microbial Load

Diluents were prepared (normal saline) and dispensed into the test tubes (9 cm^3 each for the 9 test tubes per sample). They were corked and sterilized by autoclaving at 121°C for 15 mins. The tubes were allowed to cool to room temperature. Nutrient agar (NA) and potato dextrose agars (PDA) were prepared and autoclaved. Aliquots of 1 cm^3 of the sample was introduced into the first test tube and shaken to ensure proper mixing which was labeled 10^{-1} .

Further serial dilution was made by transferring 1 cm³ from the 10⁻¹ tube to other test tubes (10⁻² – 10⁻⁹). Aliquots of 1 cm³ out of 10⁻⁶ was taken and dispensed into a petri dish and another was again dispensed into the second petri dish i.e for bacteria and fungi. Molten nutrient agar (about 20 cm³) was poured into the petridish containing 1cm³ and potato

dextrose agar was again poured into the second petridish containing the second 1cm³ of the sample and rocked on the bench and allowed to gel. Similar procedure was done for the other samples. The nutrient agar plates were taken and incubated at 37°C for 24 hours while P.D.A plates were incubated at 25°C±2 for 3-5 days.

$$\text{Number of CFU/cm}^3 = \frac{\text{Colonies counted}}{\text{Volume of plate (cm}^3\text{)} \times \text{Total dilution used}} \quad (1)$$

Batch Adsorption Studies

Effects of four parameters were considered on the adsorption of metal ions from solutions and these were contact time, metal ion concentration, pH and dosage. All experiments were carried out with constant shaking at 160 rpm for uniform distribution of the adsorbent.

The solutions were filtered and the filtrates were analyzed by flame atomic absorption spectroscopy (AAS) for residual metal concentrations. Removal efficiency and adsorption capacity were calculated by using the relationships:

$$\text{Adsorption (\%)} = \frac{(C_i - C_e)}{C_i} \times 100 \quad (2)$$

$$q_e = \frac{C_i - C_e}{M} \times V \quad (3)$$

Where C_i is initial concentration of metal ions in the solution (mgdm⁻³), C_e is the equilibrium concentration or initial concentration of metal ions in the solution (mgdm⁻³), V is the initial volume of metal ion solution used (dm³) and M is the mass of adsorbent (g).

Adsorption Isotherms

Adsorption isotherms were used to describe the equilibrium adsorptive behaviours and to investigate the

adsorption mechanism. Langmuir and Freundlich isotherm equations were investigated to fit the experimental data:

$$\text{Langmuir: } \frac{C_e}{q_e} = \frac{1}{Q_o K_L} + \frac{1}{Q_o} C_e \quad (4)$$

$$\text{Freundlich: } \ln q_e = \ln K_F + \frac{1}{n} \ln C_e \tag{5}$$

Where C_e is the equilibrium concentration (mgdm^{-3}), q_e is the amount adsorbed at equilibrium time (mg/g), Q_o and K_L are Langmuir constants related to adsorption capacity (mg/g) and energy of adsorption (L/mg) respectively. K_F and n are Freundlich constants. K_F is the capacity of the adsorbent and n indicates the favorability of adsorption.

Adsorption Kinetics

Two adsorption kinetic models namely, the pseudo-first and pseudo second-order

were applied for the adsorption of the adsorbents

$$\text{Pseudo – first order: } \ln(q_e - q_t) = \ln q_e - k_1 t \tag{6}$$

$$\text{Pseudo – second order: } \frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{t}{q_e} \tag{7}$$

Where q_e and q_t are the amounts adsorbed at equilibrium and at time t , and k_1 is the pseudo-first order rate constant (min^{-1}). K_2 is the second-order reaction rate equilibrium constant (g/mgmin).

RESULTS

Figure 1 gave the effect of contact time on the adsorption of Fe(II) ions by the

adsorbents. The carbonized *Bombax buonopozense* gave the highest percentage adsorption removal while the least adsorption capacity was for the carbonized *Polyalthia longifolia*.

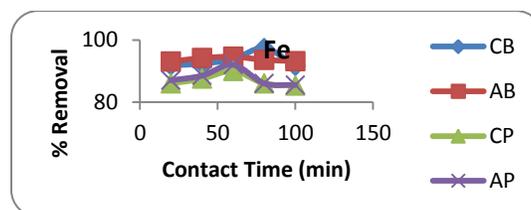


Fig. 1. Effect of contact time on Fe(II) biosorption

Figure 2 represented the effect of contact time on the adsorption of Pb(II) ions on the adsorbents. The activated *Bombax buonopozense* gave the highest

adsorption capacity while the carbonized *Polyalthia longifolia* gave the least adsorption.

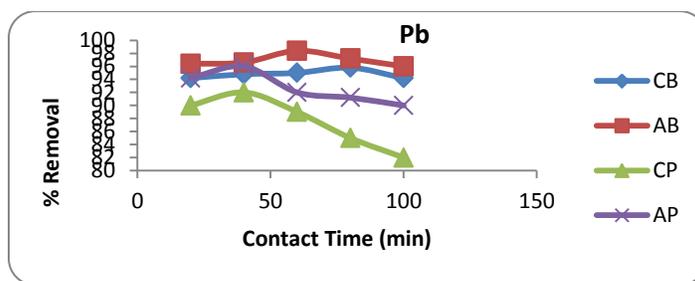


Fig. 2. Effect of contact time on Pb(II) biosorption

Figure 3 gave the effect of pH on the biosorbent activities of the adsorbents on Fe(II) ions. The carbonized *Bombax buonopozense* gave the highest

percentage removal while the least was obtained for the activated *Polyalthia longifolia*

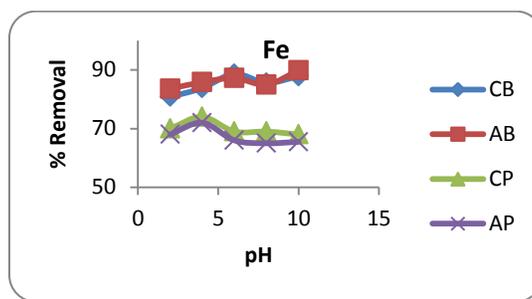


Fig. 3. Effect of pH on Fe(II) biosorption

Figure 4 indicated the effect of pH on the adsorption of Pb(II) ions by the adsorbents. The activated *Bombax buonopozense* carbon gave the highest

percentage adsorption while the least capacity was obtained for the carbonized *Polyalthia longifolia*

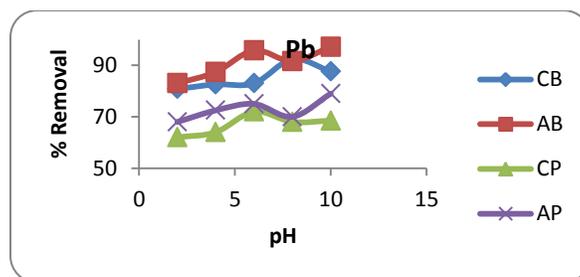


Fig. 4. Effect of pH on Pb(II) biosorption

Figure 5 showed the effect of initial concentration on the adsorptive capacities of the biosorbents on Fe(II)

ions. All the four biosorbets showed decrease in the adsorption capacity for these ions at a fixed dosage of 0.5 g.

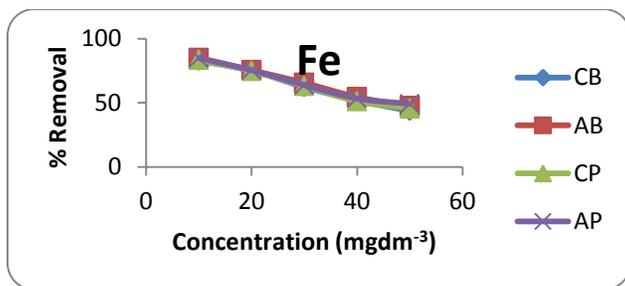


Fig. 5. Effect of initial concentration in Fe(II) biosorption

Figure 6 gave the effect of concentration on the adsorption of Pb(II) ions by the adsorbents. At lower concentrations, the

adsorptive capacities of the sorbents steadily decreased but slightly rose at 40 mgdm⁻³ and decreased again.

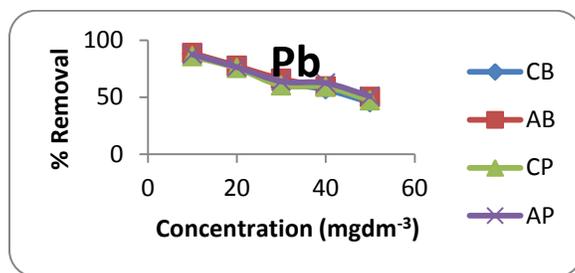


Fig. 6. Effect of initial concentration in Pb(II) biosorption

Figure 7 showed the effect of dosage on the adsorption of Fe(II) ions by the adsorbents. The adsorptive capacities of

the sorbents steadily increased with dosage.

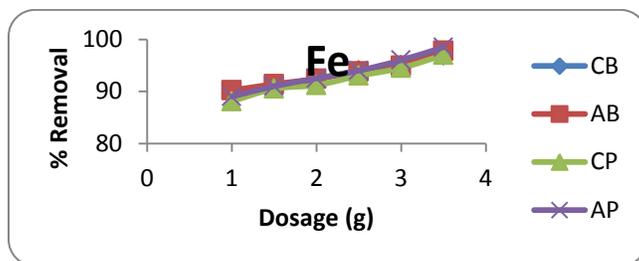


Fig. 7. Effect of dosage on Fe(II) biosorption

Figure 8 gave the effect of dosage on the adsorption of Pb(II) ions by the biosorbents. The activated *Bombax buonopozense* carbon gave the highest percentage adsorption removal while carbonized *Polyalthia longifolia* gave the least. However, all the biosorbents showed steady increase in their adsorptive capacities with dosage.

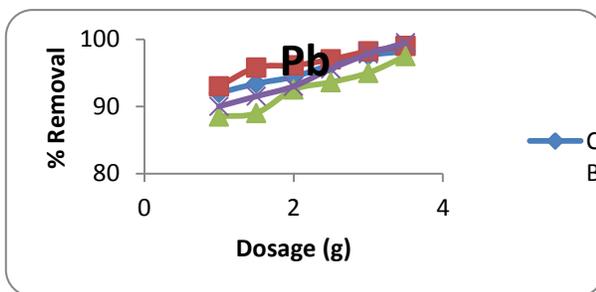


Fig. 8. Effect of dosage on Pb(II) biosorption

Table 1 gave the adsorption isotherms for Fe(II) and Pb(II) ions by the adsorbents.

The Langmuir isotherm fitted better than the Freundlich's.

Table 1: Adsorption isotherm parameters for Fe (II) and Pb(II) removal by spines of *Bombax buonopozense* and *Polyalthia longifolia* leaves

Isotherm	Parameter	Fe				Pb			
		CB	AB	CP	AP	CB	AB	CP	AP
Freundlich	(mgg^{-1})	0.61	0.63	0.61	0.62	0.68	0.71	0.64	0.69
	N	2.89	2.88	2.88	2.73	2.95	2.94	2.82	2.67
Langmuir		0.936	0.954	0.976	0.976	0.986	0.987	0.962	0.885
	(mgg^{-1})	1.95	2.13	2.02	2.21	2.21	2.25	2.16	2.35
	(L/mg)	0.30	0.28	0.28	0.24	0.28	0.31	0.27	0.26
		0.999	0.998	0.997	0.991	0.990	0.994	0.981	0.981

Figure 9 gave the plot of separation factors against the initial concentrations of Fe(II) ions at 40 cm³ volume of the adsorbate, 0.5 g of adsorbent and pH 6.9.

While activated *Polyalthia longifolia* carbon had the highest separation, carbonized *Bombax buonopozense* had the least

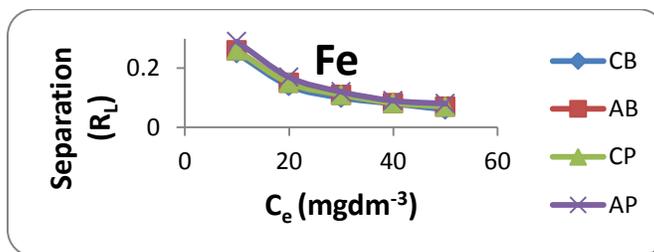


Fig. 9. Plot of separation factor against initial Fe(II) ion concentration (Volume = 40 cm³, Mass of adsorbent = 0.5 g, pH= 6.9)

of Pb(II) ions at 40 cm³ volume of the adsorbate, 0.5 g of adsorbent and pH 6.9. All the factors decreased with increase in the initial concentrations of the adsorbate.

Figure 10 indicates the plot of separation factors against the initial concentrations

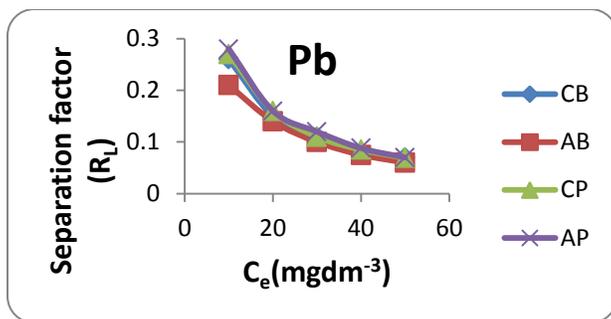


Fig. 10. Plot of separation factor against initial Pb(II) ion concentration (Volume = 40 cm³, Mass of adsorbent = 0.5 g, pH= 6.9)

Table 2 gave the kinetic parameters of the adsorption of Fe(II) and Pb(II) ions by the adsorbents. The kinetics of this process fitted the second order for all the adsorbents.

Table 2: Kinetic parameters for Fe(II) and Pb(II) ion adsorption onto spines of *Bombax buonopozense* and *Polyalthia longifolia* leaves

Kinetic	Parameter	Fe				Pb			
		CB	AB	CP	AP	CB	AB	CP	AP
First-order	(mg/g)	0.032	0.027	0.061	0.064	0.025	0.014	0.081	0.108
		0.001	0.001	0.001	0.001	5×10 ⁻⁵	0.001	0.001	0.003
		0.117	0.133	0.051	0.184	0.035	0.058	0.037	0.610
Second-order	(mg/g)	0.336	0.351	0.301	0.321	0.359	0.387	0.376	0.362
		6.30	6.96	1.631	0.697	4.144	19.12	0.130	0.140
		0.909	0.965	0.874	0.664	0.742	0.716	0.858	0.769

Tables 3 and 4 estimated the bacteria and fungi count on both the carbonized and activated adsorbent samples. Table 4 shows that all the adsorbents had the

ability of reducing counting in water samples. Although that the activated had highest effect.

Table 3: Estimated Bacteria and Fungi Count using spines of *Bombax buonopozense* and *Polyalthia longifolia* leaves

Time	Adsorbent	<i>Bombax buonopozense</i>			<i>Polyalthia longifolia</i>		
		Bacterial count	Fungi count	MPN/100cm ³	Bacterial count	Fungi count	MPN/100cm ³
		cfu/cm ³	cfu/cm ³		cfu/cm ³	cfu/cm ³	
20min	Carbonized	7 × 10 ⁶	3 × 10 ⁶	14	15 × 10 ⁶	5 × 10 ⁶	20
	Activated	4 × 10 ⁶	3 × 10 ⁶	11	7 × 10 ⁶	3 × 10 ⁶	14
40min	Carbonized	4 × 10 ⁶	2 × 10 ⁶	4	6 × 10 ⁶	2 × 10 ⁶	14
	Activated	3 × 10 ⁶	2 × 10 ⁶	7	5 × 10 ⁶	3 × 10 ⁶	11
60min	Carbonized	2 × 10 ⁶	2 × 10 ⁶	3	5 × 10 ⁶	2 × 10 ⁶	11
	Activated	2 × 10 ⁶	1 × 10 ⁶	4	3 × 10 ⁶	2 × 10 ⁶	7
80min	Carbonized	2 × 10 ⁶	1 × 10 ⁶	0	4 × 10 ⁶	1 × 10 ⁶	11
	Activated	2 × 10 ⁶	1 × 10 ⁶	3	3 × 10 ⁶	1 × 10 ⁶	4

Table 4: Estimated Bacteria and Fungi Count after 24-48hours using spines of *Bombax buonopozense* and *Polyalthia longifolia* leaves

Time	Adsorbent	<i>Bombax buonopozense</i>			<i>Polyalthia longifolia</i>		
		Bacterial count cfu/cm ³	Fungi count cfu/cm ³	MPN/100cm ³	Bacterial count cfu/cm ³	Fungi count cfu/cm ³	MPN/100cm ³
20min	Carbonized	6 × 10 ⁶	3 × 10 ⁶	14	6 × 10 ⁶	4 × 10 ⁶	11
	Activated	4 × 10 ⁶	2 × 10 ⁶	7	2 × 10 ⁶	3 × 10 ⁶	7
40min	Carbonized	6 × 10 ⁶	2 × 10 ⁶	11	6 × 10 ⁶	2 × 10 ⁶	7
	Activated	3 × 10 ⁶	1 × 10 ⁶	4	1 × 10 ⁶	2 × 10 ⁶	4
60min	Carbonized	4 × 10 ⁶	2 × 10 ⁶	4	5 × 10 ⁶	2 × 10 ⁶	7
	Activated	3 × 10 ⁶	1 × 10 ⁶	3	1 × 10 ⁶	2 × 10 ⁶	4
80min	Carbonized	3 × 10 ⁶	1 × 10 ⁶	4	3 × 10 ⁶	1 × 10 ⁶	4
	Activated	2 × 10 ⁶	1 × 10 ⁶	0	1 × 10 ⁶	1 × 10 ⁶	3

DISCUSSION

Contact Time

Figures 1 and 2 showed that as the residence speed increased the adsorption also increased. Therefore, at a low speed, sequestering of metal ions occurred by top layers while underneath layers do not take part in the process as there was no contact with metal (Anwar *et al.*, 2009). Equilibrium times were attained at 40, 60 and 80 min for lead (II) and iron (II) in both adsorbents used. At these optimum times, the collision rate of adsorbent particles with each other increased due to detachment of loosely bound ions. The initial fast adsorption rate could be as a result of sufficient surface binding sites on the substrates (Jimoh *et al.*, 2013). The higher percentage removal of metal ions could be due to the availability of large surface area of adsorbent for the adsorption of metals and decrease in the percentage removal of metal ion below the optimum time could be due to the exhaustion of the remaining surface site and repulsive forces between solute molecules and the bulk phase (Saravanane *et al.*, 2002). Desorption of the metal ions from the surface of

adsorbents occurred at further increase in contact time.

Effect of pH

The effects of solution pH on removal of lead(II) and iron (II) are shown in Figures 3 and 4. The adsorption was as a result of attractive interactions between the metal ions and some of the functional groups of the adsorbent (Elmaci *et al.*, 2007). At pH 6 or less, the metals uptake increased with the increase in pH within the range of 2 to 6 for the two metal ions (Fe and Pb) for both activated and modified adsorbents. This shows that the metal ions were the dominating species within this pH range but as the pH rises, their concentrations gradually decrease. At lower pH, the overall surface charge on the adsorbents become positive, which inhibits the approach of positively charged metal cations. It is likely that protons compete with the metal ions for binding sites, thereby decreasing the interaction of the metal ions with the adsorbents (Mustapha *et al.*, 2014). The solubility of metal complexes decreases to a great extent allowing metal hydroxide precipitation at higher pH, making adsorption process complicated. Similar

trend has been reported by Ozdemira *et*

Effect of Concentration of Adsorbent

The effect of adsorbent concentration on the lead and iron removal were studied and are shown in Figures 5 and 6. The biosorption experiments were carried out at different metal concentrations (10, 20, 30, 40 and 50 mgdm⁻³) at the optimum time. Although it is asserted that the biosorption capacities of adsorbents increase with increasing initial metal concentrations and that enhancement in removal of metal ions resulted in the increase in electrostatic interactions between that ions and the sites which lower the affinity for metal ions (Al-Gami, 2005). It was observed that the percentages of sorbed metals decreased with increased initial metal concentrations. This observation is similar to the report of El-Ashtoukly *et al.* (2008) and Mustapha *et al.* (2014).

Effect of Adsorbent Dosage

The effect of adsorbent dosage which was varied from 1 to 3.5 g under specific conditions of fixed contact time and at room temperature is presented in Figures 7 and 8. The availability of adsorption sites are controlled by adsorbent dosage (Rafeah *et al.*, 2009). From the result, increased adsorbent loading increased the removal of metal ions which results in improved adsorption efficiency. This could be due to increase in electrostatic interaction between the surface of the adsorbent and the adsorbate. The higher the electrostatic interaction between the adsorbent and the metal ions, the higher the metal uptake level and this shows that the adsorption of cations with large ionic radii would be less than that of metal ions with smaller ionic radii (Dundar *et al.*, 2008). In principle, with the more adsorbent present, the available adsorption sites or functional groups increase. Thus leading to a general increase in the amount of metal ions adsorbed with the increase in adsorbent dosage. Similar trends in metal uptake

al. (2009).

have been reported by Gong *et al.* (2006) and Mustapha *et al.* (2014) on lead biosorption from its synthetic aqueous solutions by *Spirulina maxima* and adsorption of copper from aqueous solutions by raw and activated spines of *Bombax buonopozense* respectively.

Equilibrium Isotherms

Freundlich Isotherm

This model is used to describe the heterogeneous surface as well as multilayer sorption. This also accounted for the adsorption intensity of the adsorbate on the adsorbent. The Freundlich isotherms for the metal ions on the adsorbents are shown in Table 1. Adsorption intensities of Fe²⁺ and Pb²⁺ on the biosorbent are provided Al-Ilil, (2015) by the Freundlich constants and designated as sorption capacity and adsorption intensity respectively. For both metal ions, the adsorption intensity values are in the range of 2.73 to 2.89. The values of n were within 0 and 10, suggesting that the adsorption processes of Fe²⁺ and Pb²⁺ onto the surface of the activated *Polyalthia longifolia* leaves and spines of *Bombax buonopozense* adsorbents are governed by physisorption as observed by Bouguerra *et al.* (2007). The activation of adsorption sites may cause an increase in adsorption probably through the surface exchange mechanism. This finding is in line with the report made by Ozer and Pirincci (2006) and El Batouti and Ahmed (2014).

Langmuir Isotherm

Data for Langmuir plots are presented in Table 1. The Langmuir model assumes that adsorption occurs at homogeneous adsorption sites within the adsorbent (Foo and Hameed, 2010). The (mg/g)

and (L/mg) are Langmuir constants associated to the maximum adsorption capacity and heat of adsorption respectively. The maximum sorption capacity values determined from the experimental equilibrium isotherms for Pb(II) and Fe(II) ions for activated *Polyalthia longifolia* leaves and spines of *Bombax buonopozense* adsorbents were in the range 1.95 to 2.35 mg/g. However, the maximum biosorption capacities obtained from these adsorbents are found to be higher compared to the studies of Mustapha *et al.* (2014) and Jimoh *et al.* (2013). Thus, the applicability of the isotherm models and their high values of correlation coefficients (R^2) suggest favourable and monolayer adsorption (Hu *et al.*, 2009). The higher R^2 values suggest that the Langmuir isotherm describes the adsorption process better than the Freundlich isotherm model. These conform with the findings of Li *et al.* (2010) on the removal of Pb(II) ion from aqueous solution onto modified areca waste and Selvarani and Prema (2012) on the removal of toxic metal from aqueous solution using starch-stabilized nanoscale zero valent iron. From the Langmuir's equation,

$$R_L = \frac{1}{1 + K_L C_0} \quad (8)$$

The value of R_L indicates either biosorption system unfavorable ($R_L > 1$), linear ($R_L = 1$), favorable ($0 < R_L < 1$) or irreversible ($R_L = 0$) in a batch process

(Hall *et al.*, 1966). The calculated Langmuir separation factor (R_L) at different initial Fe(II) and Pb(II) concentrations are in the range of 0–1 which confirms the favorable uptake of the metal ions. Lower values at higher initial metal ion concentrations showed that adsorption processes were more favorable at higher concentrations and a similar report was made by Yao *et al.* (2010).

Kinetic Studies

First-order and second-order Kinetics

The correlation coefficients and other parameters calculated for the pseudo-first-order model and pseudo-second-order models are listed in Table 2. The values for the first-order rate expression did not agree with the computed values from the linear plots. These suggest that the pseudo-first-order model is not fit for proving the adsorption of the metal ions onto the activated carbons. In contrast, values for the second-order model were close to R^2 for the adsorbents. This could be based on the assumption that the rate limiting step of pseudo-second order mechanism is chemisorption which is as a result of valence forces derived from the sharing or exchange of electrons between the adsorbents and adsorbates (Ofomaja, 2008). The second-order kinetic equation is also more likely to show that the sorption behaviour may involve valency forces through electron-sharing between the metal ions and sorbents [36]. These correspond to the findings of Rim *et al.* (2014); Gaven *et al.* (2009); Mamba *et al.* (2009); Chen *et al.* (2008). Higher correlation coefficients (R^2) for the pseudo-second-order equation for the adsorbents which were greater than those obtained for the pseudo-first-order model and the values which were close to the experimental ones indicate that the pseudo-second-order kinetic model are

more suitable to describe the kinetic of ions onto the adsorbents. This shows that the kinetics of the metal ions biosorption by *Polyalthia longifolia* leaves and spines of *Bombax buonopozense* were better described by pseudo-second-order kinetic model which are similar to the findings of Jayaraj *et al.* (2014); Jodeh *et al.* (2014).

Most Probable Number (MPN)

Tables 3 and 4 show the results the most probable number (MPN) per 100 cm³ for dilution in the sequence 10⁻¹, 10⁻² and 10⁻³. The microorganisms were separated and did not affect each other. After the treatment, the bacteria and fungi were reduced to lower MPN/100 cm³ values at contact times of 20, 40, 60 and 80 min. These show that at the higher contact time, lower MPN/100 cm³ were observed. The obtained results showed that lower numbers of the organism were examined after the activated and modified adsorbents were used to treat the inoculated water samples that contained bacteria and fungi which consistently reduced on treatment with activated adsorbents. This indicated that the activated adsorbents have better adsorption capabilities than the carbonized biosorbents. According to the World Health Organization (2011) standard limits for drinking, MPN should be absent for drinking water. The MPN per 100 cm³ of water sample after quantitative estimation of microbial load of the liquid media reduced to the barest minimum at the high contact time, which is an indication of the effects of these adsorbents on the micro-organisms.

the adsorption processes of the metal

CONCLUSION

The carbonized (CB and CP) and activated (AB and AP) samples prepared from spines of *Bombax buonopozense* and leaves of *Polyalthia longifolia* for the adsorption of Pb(II) and Fe(II) ions from aqueous solutions using batch technique parameters was found to be highly efficient. The results from isotherm models indicated that the adsorption equilibrium data fitted well to the Langmuir model and the suitable kinetic model for the adsorption was pseudo - second order. Also, the adsorbents act as good antimicrobial agents against the bacteria and fungi. Thus, if these adsorbents are incorporated in water purification processes, they will serve as good purification agents for drinking and wastewater.

ACKNOWLEDGMENTS

We thank the Laboratory Technologists of Federal University of Technology, Minna, Nigeria for their support.

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