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Development of Zinc Removal Process from Contaminated Water Using Statistical Approaches

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Abstract

A serious, complex environmental and public problem is contaminated water with heavy metals in the environment is due to rapid industrialization, bioaccumulation and non-degradability. Therefore, the reuse of agricultural waste in the process of purifying water from pollutants is an attractive and promising method. Almost inexpensive materials are used to purify water, thus achieving the desired economic and environmental goal. In this study, banana peel was used enhance the removal of Zn(II). The effects of various parameters were studied such as effect of pH, time, and dose at15 ppm. The removal percentage was found to be 90 % Zn(II), The data obtained from sorption isotherms were fitted to linear form of Langmuir and freundlich isotherm models but especially well fitted for the Langmuir model. The correlation coefficient values R^2 for Langmuir were (0.9951) while that for freundlich were (0.9804. The rate of adsorption follows pseudo-second-order kinetics. This work proved that banana peels could be used as an efficient adsorbent material for removal of heavy Zn(II) from aqueous solutions. A response surface methodology (RSM) based on a factorial design was performed to investigate the effects of different factors at once on the removal process of Zinc using banana peels as an effective adsorbent material. Application of RSM revealed that the combination of different factors helped the system to reach its maximum potential (Removal = 98 %) that was at pH 7, contact time (95 min.), bioadsorbent material (0.36 g) and initial metal ion concentration 5 ppm.

Keywords: Zinc; banana peels (BP); adsorption; statistical design.

1. Introduction

Water is the most essential substance and an extremely precious natural resource for human civilization and also for all kinds of life on the earth. It has a wide impact on all aspects of our life including health, food, energy, and economy [1]. Nowadays, the continuous increase in discharged wastewaters that comes from urban run-offs, domestic sewage and different industries, cause an adverse effect on human health and ecosystem, due to the fact that these discharged wastewater contains large amount of various types of inorganic (such as heavy metal ions) and organic pollutants (dyes, PAHs etc.). The negative effects of these pollutants owing to their persistence, toxicity, long-distance transport [2] and bioaccumulation ability [3], therefore, these pollutants have a severe influence on all living beings [4-11]. The World Health Organization stated that about 70-80 % of diseases in developing countries attributed to water contamination [12].

To protect our environment from some or all of these pollutants, it is desirable to purify wastewater prior to its discharging to our environment using ecofriendly and at the same time low cost technique. The purified water can be then used for different purposes such as drinking, irrigation recreation and so on. There are different technologies that are used to purify wastewater from such these pollutants [13-15]. Among of these different technologies, the adsorption is considered as a popular method and easy to operate, economically viable and to a greater degree affect the toxicity and transport biological availability of inorganic and organic contaminants in aqueous system [16].

This alternative technique (Biosorption) also is preferred over other conventional techniques such as membrane filtration, chemical precipitation, solvent

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extraction, oxidation, reverse osmosis and others and this may be attributed to its high affinity, capacity, and selectivity of the materials from the solution. In addition to there are different mechanisms involved in biosorption phenomenon [17]. Many plants can be employed in this process, including the salvinia natans [18, 19] Spirulina maxima [20] and others [21].

In this work, Banana peel has been used as a bio sorbent for zinc ions from contaminated waters at different media because banana peel is recognized to be an economically viable and environmentally sound adsorbent for removal of heavy metals from contaminated waters [22-24]. Banana peels generally contain organic compounds such as cellulose, hemicellulose, chlorophyll pigments, pectin substances, and some other low molecular weight compounds. For example, pectin substances, a complex heteropolysaccharides containing galacturonic acid, arabinose, galactose and rhamnose where the banana peel presents a high adsorption capacity for metals and organic compounds, and this aspect is primarily due to the presence of the hydroxyl and carboxyl groups of the pectin.

All traditional experiments apply variation of one factor while the other factors are constants, but in the current study we employed statistical design to avoid this point. In this design, common statistical tools, such as analysis of variance, F-test, and others were used to define the most important variables affecting the metal removal efficiency process [25]. In this design, all independent variables will be changed at the same time at each trial. The reason for this may be due to the fact that these variables can influence each other, and the ideal value for one of them can be affected by the values of the others which in turn affect the value of dependent variables (removal or removal capacity). This interaction between different variables is a frequent phenomenon [25].

2. Experimental

2.1. Chemicals and reagents

All used chemicals and reagents which of certified analytical grade are $ZnSO_4.7H_2O$, muroxide indicator, EBT indicator, NaOH, H_2SO_4, HNO_3, NH_4Cl, NH_4OH, EDTA, tartaric acid, HCl and NaCl which were purchased from Fluka chemicals in addition to first distillated water for washing and second distillated water is used for the preparation of all solutions. The adsorbent sample of Banana peel (BP) is collected from a fruit juice seller within the city of Assiut.

2.2. Apparatus

The BP and Zn(II) ion adsorption was characterized via several instrumental analysis tools starting with the use of the digital balance of 5 digits Citizen [CX 265], and shaking standard testing sieves [model: RX-29-10, made in U.S.A]. FT-IR analysis was recorded on a Thermo Fisher [Nicolet iS10 FT-IR spectrometer] in a wave number range 4000-400 cm^{-1} using an ATR module. Raman analysis was conducted at room temperature using a micro-Raman Horiba Jobin Yvon LabRam spectrometer [HR800] at excitation wavelength 632 nm from a He-Ne laser source. The sampling technique was applied in an aqueous concentrated suspension of NPs was poured into a small tray, and the laser beam was focused just at the suspension surface. The Raman shifts in the wave number were recorded at the spectral region in range 500-1200 cm^{-1}. The morphology of the Zn(II) ion on BP adsorption was investigated using scanning electron microscopy [SEM; JSM IT 200], pH-meter Mettler Toledo [Seven Multi].

2.3. Preparation of adsorbent

The collected peels was washed with tap water then washed by distilled water before air-dried. The dried BP was grinding into powder then boiling with double distilled water for 10 min. BP was washing with hot double distilled water several times using a magnetic stirrer and was separated by decantation and filtration. Finally BP was dried in oven at 70 ºC until reaching a constant weight and was sieved for particle size 125 µm then packed in a clean plastic polypropylene air tightly bottles until use.

2.4. Adsorption process

There were several factors that affect the metal ion sorption Zn(II), by the active sites on the adsorbent surface such as pH of the solution, contact time, the amount of the adsorbent and the initial concentration of the metal ion. These factors were studied at fixed circumstances; room temperature, particle size 125 µm, and agitation speed 100 rpm [26]. Erlenmeyer flasks and orbital shakers were used to carry out the tests. From the results of preliminary experiments; pH, contact time and dosage of adsorbent were selected as 6.5, 60 min and 2 g/L for Zn(II) and these data were kept constant throughout the study. After 60 min of contact time for Zn(II) the suspension was filtered, and the concentration of the metal in the filtrate was analyzed by complexometric EDTA titration [27, 28]. The amount of Zn(II) adsorbed onto biosorbent was calculated using Eq. (1) [29]:

$$q_e = V\,(C_i - C_e) / m \qquad (1)$$

where q_e is the amount of the adsorbed metal ion (mg/g), C_i and C_e (mg/L) are the initial and final concentrations of Zn(II) in the solution respectively, V is the solution volume (L), and m is the adsorbent mass (g). For calculating the percentage uptake (Removal, %), and the following Eq. (2) is used:

$$\text{Removal (\%)} = (C_i - C_e) / C_i \times 100 \qquad (2)$$

2.5. Isotherm models

The isotherm models used to describe the adsorption process in water treatment were developed by Langmuir and Freundlich models and their constants were calculated. The Langmuir isotherm is generally used for monolayer adsorption at specific homogenous sites on adsorbents surface [30, 31]. The Langmuir isotherm is described mathematically by equation (3) [32].

$$C_e/q_e = 1/(K_L q_m) + C_e/q_m \qquad (3)$$

where: q_m is monolayer sorption capacity (mg/g) and K_L is Langmuir equilibrium constant (L/mg). The fundamental features of the Langmuir isotherm can be described in terms of separation factor or equilibrium parameter RL, which is defined by the following expression equation (4) [33, 34].

$$R_L = 1/(1 + bC_o) \qquad (4)$$

The value of RL indicates the isotherm shape to be unfavorable (RL > 1), favorable (0 < RL < 1) and irreversible (RL = 1).

Freundlich isotherm [35] is usually used for heterogeneous surface energy systems (non-uniform distribution of sorption heat), (Eq. 5).

$$\text{Log } q_e = \log K_F + 1/n \log C_e \qquad (5)$$

where: K_F and n are Freundlich constants, the K_F is adsorption capacity while n is adsorption intensity; while 1/n is a function of the strength of the adsorption process.

2.6. Experimental designing

Here, a commercially available software program was used (Design Expert, Version 11.1.2.0, Stat-Ease Inc.). The experimental design chosen was Response Surface methodology, central composite design, which is commonly used in engineering and industrial chemistry [36], and in analytical chemistry [37]. The variables investigated were coded as; pH (A), Contact time (B), adsorbent dosage (C) and initial metal concentration (D). These variables were coded at five levels between -2 and 2 (Table 1) including 6 central points (0) to give a total of 30 experimental runs (Table 2). Experiments were performed in duplicate and results were averaged. Dependent variable (Removal %) was calculated according to the above equation (Eq. 2).

Table 1: Factors and levels used in the biosorption of Zn using Banana peel dried biomass

Item	Symbol	-2	-1	0	1	2
pH	A	4	5.5	7	8.5	10
time (min.)	B	10	52.5	95	137.5	180
Dose (g)	C	0.02	0.19	0.36	0.53	0.7
Conc. (mg/l)	D	5	16.25	27.5	38.75	50

Table 2: Experimental factorial design for the biosorption process of zinc using Banana peel dried biomass

No	A	B	C	D
1	0	0	0	2
2	0	2	0	0
3	1	1	-1	1
4	0	0	0	0
5	1	1	1	1
6	0	0	0	0
7	-1	-1	1	1
8	0	0	0	0
9	-1	-1	1	-1
10	-2	0	0	0
11	1	-1	1	-1
12	1	-1	1	1
13	-1	-1	-1	-1
14	0	0	-2	0
15	-1	1	-1	1
16	0	0	0	0
17	-1	1	1	-1
18	0	0	0	-2
19	0	0	0	0
20	1	1	-1	-1
21	0	0	2	0
22	2	0	0	0
23	-1	1	1	1
24	0	-2	0	0
25	0	0	0	0
26	1	-1	-1	1
27	-1	-1	-1	1
28	1	-1	-1	-1
29	-1	1	-1	-1
30	1	1	1	-1

3. Results and discussion

3.1. Characterization of the adsorbent

The elemental analysis of the BP as shown in Table 3.

Table 3: The elemental analysis of BP

Sample	Elemental results (% dry basis)				
	H%	C%	S%	O%	N%
BP	5.14	42.55	10.11	41.06	1.14

3.2. Fourier-transform infrared spectroscopy (FT-IR)

The FT-IR provides important information on the surface functional groups utilized by bio sorbents for pollutants abstraction. Figure 1a, b, c & d, curves depict the FT-IR of free BP and BP-Zn by abstraction processes. The FT-IR of free BP showed the presence of O–H, N–H, C–H, C=O, C=C, C–N, C–O and C–H vibrations on the surface thereby providing sufficient surface functionality for pollutant interaction [38]. Also, BP showed the absorptions peaks that are oxidized carbon materials and are assigned to C–O and/or C–O–C stretching in acids, alcohols, phenols, ethers and/or esters groups. The FT-IR spectrum in Figure 1a show that weak bands of BP were comprised for the stretching bands of CH, CH_2 and CH_3 at 2921, 2856 cm^{-1} is assigned to the overlapping of the stretching vibrations of the hydroxyl (O–H) and amine (N–H) groups [39]. The absorption peaks at 1025 and 3324, 3248 cm^{-1} are ascribed to stretching vibrations of C–O, bending vibration of $–NH_2$ and broad hydroxyl groups respectively. The appearance of the stretching bands of carbonyl groups at 1654 cm^{-1} associated to C=O stretching of ketones, aldehydes, lactones or carboxyl groups [40]. Apart from this the major visible change is the increase in the C–O carboxyl band1383 cm^{-1} and 1236 cm^{-1}. Changes in this band usually result from complexation of the carboxyl oxygen [40, 41]. It was noticed that there were weak changes in the infrared bands of the basic functional groups of the BP after contact with the Zn(II) ion by absorption process. But there are some new bands that indicate the presence of Zn(II) ions on the surface of the banana peel. Figure 1 b, c & d, shows peak at 525 cm–1for Zn–O or Zn–N vibrational stretching. The wave number at 1137, and 708 cm^{-1}correspond to the vibration of O–Zn–O group [42, 43].There are new absorption peaks at 677 cm^{-1} and 611 cm^{-1} which are due to the attachment of amino group (Zn–N) and vibration mode of Zn–O [44]. The strong bands at 2921 cm^{-1}, 2856 cm^{-1} were assigned to the C−H stretching mode which represents the aliphatic nature of the peels after absorption processes. The absorption bands at around 1657−1637 cm^{-1} to1384−1438 cm^{-1} were characteristics of C=C in aromatics rings. The adsorption process of Zn(II) ions showed that with the increase in the contact time between the BP and Zn(II) ions, the intensity of the bands in the FT-IR increased, indicating an increase in the concentration of Zn(II) ions adsorbed on the surface of the banana peel.

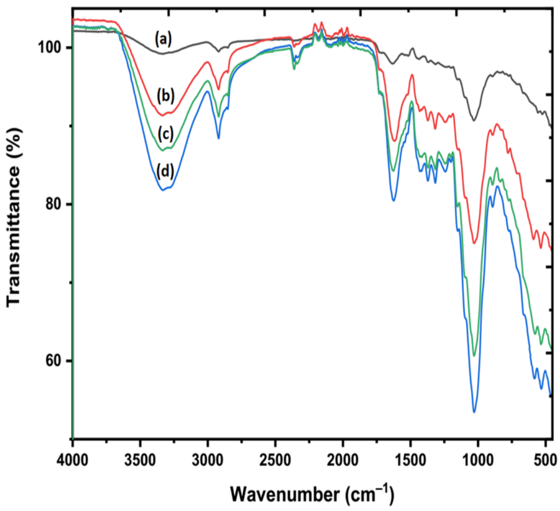

Fig. 1. FT-IR of free BP (a) and BP (dose 2 g) with Zn(II) ions (500 ppm) biosorption with contact time 30, 60 & 90 min for b, c & d, respectively.

3.3. Raman analysis

To further identify and confirm the structure of the pure BP and BP with Zn(II) ions biosorption Raman analysis was applied (Figure 2a, b, c & d). The Raman spectra of BP is shown in the Figure 2a. It was assigned that the bands by analogy to the data as follows: 911 cm^{-1} for stretching vibration of C=O, 1049 cm^{-1} for stretching vibration of C−O−C (single bond), and 1559 cm^{-1} for wagging vibration of (CH3), and 2814 cm^{-1} for stretching vibration of (CH_2) [45]. The new two peaks at 614 cm^{-1} and 628 cm^{-1} are associated to Zn−O or Zn−N after biosorption of Zn(II) ions on BP surface (Figure 2b, c & d).

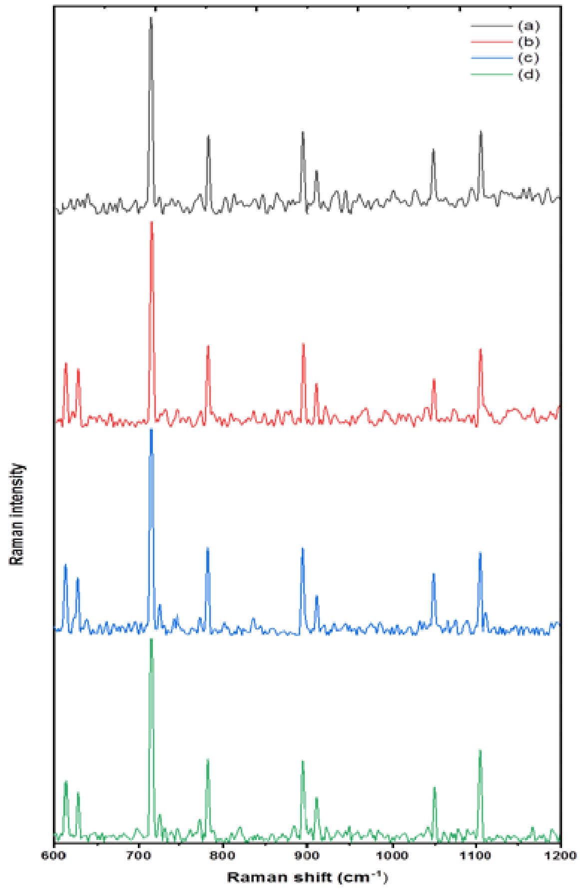

Fig. 2. Raman spectrum of the BP (2 g of adsorbent dose) (a) and biosorption of Zn(II) ions (500 ppm) on BP surface b, c & d at contact time 30, 60 and 90 min respectively in Raman shift 600-1200 cm^{-1} and rpm 300.

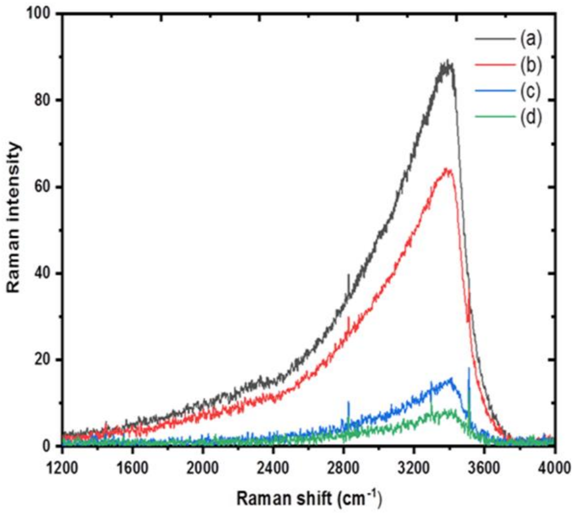

Fig. 3. Raman spectrum of the BP (2 g of adsorbent dose) (a) and biosorption of Zn(II) ions (500 ppm) on BP surface b, c & d at contact time 30, 60 and 90 min respectively, in Raman shift 1200-4000 cm^{-1} and rpm 300.

3.4. Scanning electron microscopy

Figure 4 showed the SEM of (a) BP, (b) BP-Zn samples. There is difference in the surface morphology of the BP (a) and BP-Zn biosorption after contact time 30, 60 & 90 min for b, c & d, respectively. For some apparent pore widening on BP that have occurred from the bonding between BP and zinc ions to the formation of phenolic or carboxylic-Zn complexes (Zn-OH or COO-Zn) bridging bonds on the BP surface during the biosorption with Zn(II) ion. By increases the contact time of biosorption for zinc on BP surface the pore widening increases due to the bounding of the zinc ions on the surface of the BP substance (b, c & d) [46, 47].

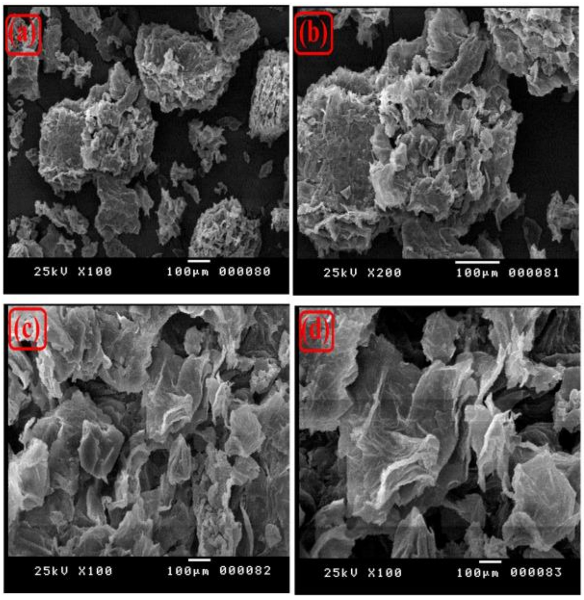

Fig. 4. SEM images of the free BP (a) and BP-Zn biosorption with contact time 30, 60 & 90 min for b, c & d, respectively.

In most treatment experiments, the process involves variation of one variable at a time, while keeping all other variables constant, but designing the experiments using the factorial designs statistical program enable all factors to vary at the same time resulting in evaluation of the main and mutual interaction effects of the studied variables on the biosorption process [25, 48], in addition to The application of this statistical design in industrial sectors will contributes to improve productivity, reduce process variability, development time and overall processing costs [49]. It will give us the best possible combination of factors that will lead to the achievement of the highest rate of removal process [50].

As a first step in this design, regression analysis was used to find the best model that fit with our obtained data. The removal percent (%) of zinc from contaminated water was fitted and represented in terms of coded factors with the following equation (Eq. 6) and regression coefficients given in Table 4.

$$\text{Removal }\% = 71.76 - 5.55{*}A - 0.8146{*}B + 5.35{*}C - 6.19{*}D \quad (6)$$

The statistical significant of the model and its different terms were evaluated from ANOVA (Table 4).

From this Table we concluded that the model is significant at 95% confidence level ($P < 0.05$). All model terms that have P-values less than 0.05 indicate that these model terms are significant. In this case A, C, D are significant model terms. Values that are greater than 0.05 indicate the model terms are not significant.

Contribution of each model term and their interactions with each other are important to understand the role of each factor in controlling and optimization of biosorption process. From analysis of variance we concluded that most influential factors on the removal process were D, A, and C that represented by the following percentages 24.9 %, 20.0 %, 18.6 %, respectively. The prediction of best results can be produced based on studying the main effects and contribution of each factor [51]. The interaction effects of different factors on the removal process of zinc from contaminated water are described in three-dimensional surface plot (Fig. 5).

The maximum removal percent (98 %) was achieved at pH 7, contact time (95 min.), bioadsorbent material (0.36 g) and initial metal ion concentration 5 ppm. Figure 6 shows comparison between predicted versus observed values for Zn removal percent.

From Figure 6, we observed that, there are high correlations and a good agreement between the observed and the predicted values according to obtained model, confirming that the RSM model effectively used to represents the removal process.

3.5. Adsorption isotherms

Experimental isotherm is important for describing sorption capacity to facilitate the evaluation of the feasibility of the process for a given adsorbent. The isotherm plays a critical role in the predictive modeling procedures for the design of sorption systems and analysis [52, 53]. Various adsorption isotherm models were proposed. Among these models, the most used to describe the adsorption process in water treatment were developed by Langmuir and Freundlich modes.

3.5.1. Langmuir isotherm

In this study, the plot of C_e/q_e versus C_e (mg/L) yields a straight line shown in Figure 7a, and calculated values are listed in Table 5. The results revealed that the adsorption process suited well to the Langmuir model with R^2 value of 0.9951, for the BP. Better fitted Langmuir isotherm model suggested the homogenous adsorption of Zn(II) cation with the adsorption active site of equal affinity. The separation factor, R_L, values determined from the Langmuir model for Zn(II) removal was 0.22 suggesting that the removal of Zn(II) was favorable.

Table 4: Analysis of Variance (ANOVA) for RSM linear model parameters

Item	Sum of squares	df	Mean square	F-value	p-value	Comments
Model	2360.65	4	590.16	11.08	< 0.0001	Significant
A- Ph	738.67	1	738.67	13.87	0.0010	Significant
B- Contact time	15.93	1	15.93	0.2989	0.5894	Not significant
C- Dosage	687.39	1	687.39	12.90	0.0014	Significant
D- Conc.	918.66	1	918.66	17.24	0.0003	Significant
Residual	1331.87	25	53.27	-	-	-
Lack of Fit	1222.92	20	61.15	2.81	0.1279	Not significant
Pure Error	108.95	5	21.79	-	-	-
Cor Total	3692.52	29	-	-	-	-

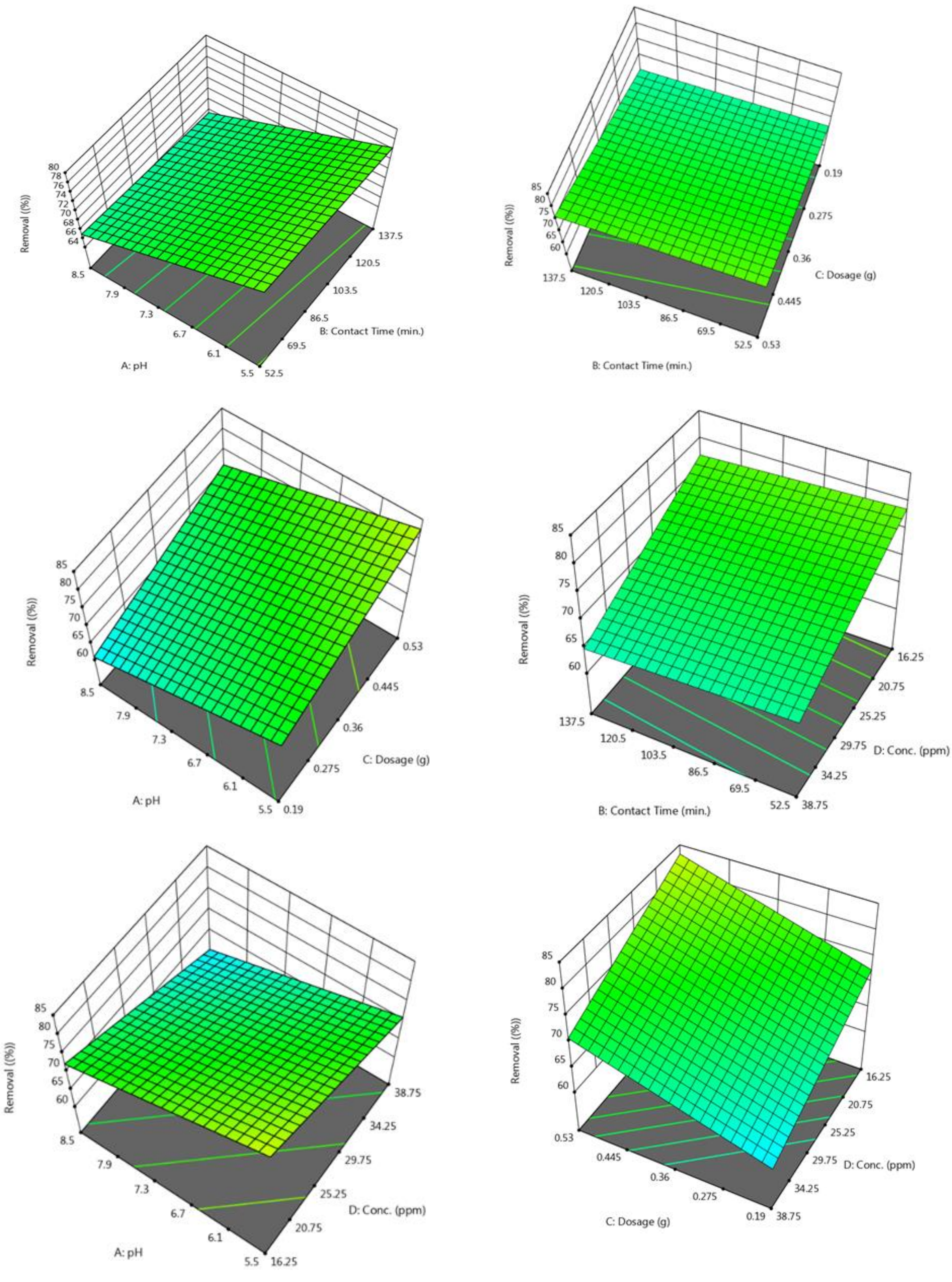

Fig. 5. Three-dimensional surface plot of interaction effects between different factors affecting zinc removal (%) using BP as an eco-friendly adsorbent material.

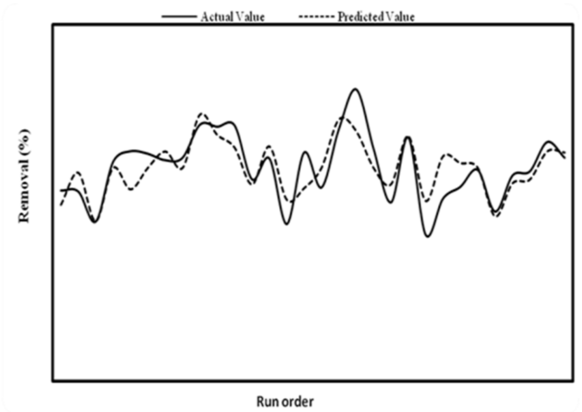

Fig. 6. Comparison between the actual and predicted values of Zn removal (%) using Banana peel dried biomass.

3.5.2. Freundlich isotherm

The Freundlich isotherm is usually used for heterogeneous surface energy systems (non-uniform distribution of sorption heat). The log qe vs log Ce plot allows determining the Freundlich constants. The results of Freundlich adsorption isotherm models are shown in Figure 7b. The adsorption constants and the correlation coefficients are also listed in Table 5. If a value of 1/n is below one, it indicates a normal adsorption process. On the other hand, 1/n being above one indicates the cooperative adsorption process. In this study the 1/n values lie between 0 and 1; this indicates a normal adsorption process of Zn(II) adsorption onto BP adsorbent. Also, n value lies between one and ten; this indicates a favorable adsorption process.

3.6. Kinetic study

Kinetic provides information about the possible mechanism of adsorption and the different transition states on the way to the formation of the final adsorbate-adsorbent compound and helps to develop appropriate mathematical models to describe the interactions. The rate-limiting step of Zn(II)

As given in Table 5, the values of R^2 has been recorded 0.9804 for BP adsorbent of Zn(II) ion. This indicates that the Freundlich isotherm was not the best fit for the sorption process of Zn(II) ion onto the surface of the BP adsorbent. Therefore, the removal of Zn(II) ion onto BP surface proceed with some heterogeneity inactive sites. Comparing R^2 values in Table 5, it is found that the highest values were recorded for the Langmuir isotherm model. Therefore, Langmuir isotherm was the best fitted in sorption. The adsorption isotherms are followed in an orderer: Langmuir > Freundlich.

adsorption by BP was explored by fitting the experimental data to two conventional kinetic models including pseudo-first and second-order kinetic models.

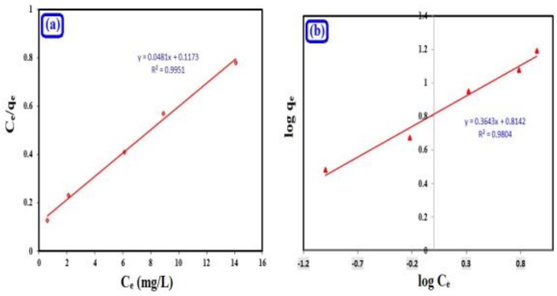

Fig. 7. Plot of Ce/qe versus Ce for estimation of the correlation coefficient, R^2, of the Langmuir model (a) and plot of log q_e versus log C_e for estimation of correlation coefficient; R^2 of the Freundlich model (b).

Table 5: Isotherm parameters for Zn(II) removal onto BP

Cation	Isotherm models	
	Langmuir	Freundlich
Zn(II)	$q_m = 20.77$ $K_L = 0.41$ $R_L = 0.22$ $R^2 = 0.9951$	$K_F = 0.838$ $n = 2.299$ $R^2 = 0.9804$

3.6.1. Pseudo-first-order kinetic model

K_1 is calculated from the slope of plotting log ($q_e - q_t$) vs. time (t), Figure 8a. The correlation coefficient values for the three prepared adsorbents was found to be 0.7935, Table 6, for BP, which indicate that this model fails to interpret the experimental data.

3.6.2. Pseudo-second-order kinetic model

The values of t/q_t are plotted against t (min) as shown in Figure 8b. Experimental values of adsorption capacity (6.50 mg/g for BP) was similar to the calculated values obtained by the pseudo second-order (6.65 mg/g for BP). As seen from the results listed in Table 6, the pseudo-second-order kinetic model fits the experimental data quite well.

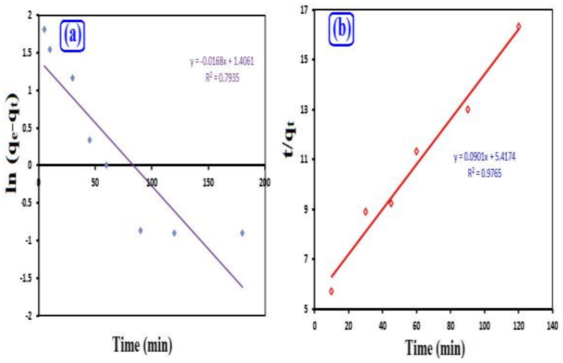

Fig. 8. Pseudo first-order (a) and pseudo-second-order (b) kinetic models plots of Zn(II) removal by BP.

The value of correlation coefficient (R^2 = 0.9765) calculated from the pseudo-second order kinetics, Figure 8b, indicate that the sorption process may be dominated by chemisorption involving valence forces through the exchange or sharing of electrons between the BP and Zn(II) cation. Moreover, it was found that the R^2 value were greatest for the pseudo-second-order model and higher than the kinetic model of pseudo-first-order (Table 6).

Table 6: Kinetic parameters for zinc (II) ion onto the BP

Cation	Kinetics models	
	Pseudo-first order	Pseudo second-order
Zn(II)	q_e = 0.711 K_1 = 0.0169 R^2 = 0.7935	q_e = 11.098 K_2 = 0.0014 R^2 = 0.9765

3.7. Effect of pH on Adsorption

The effect of the pH of the aqueous solution on the removal % of Zn(II) by BP is shown in Figure 9. The other parameters are kept constant such as room temperature (30±1) ^oC, agitation speed 300 rpm, initial Zn(II) ion concentration 500 ppm, contact time 60 min and dose of 2 g.

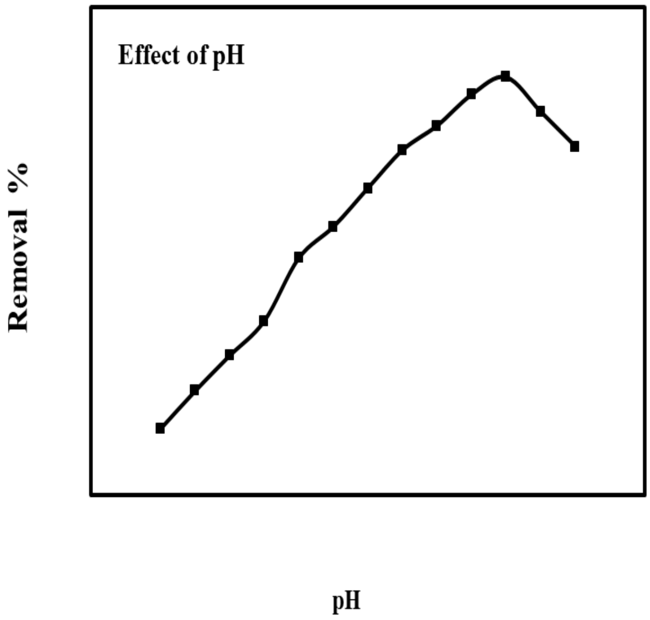

Fig. 9. Effect of pH for BP at initial conc. 500 ppm of Zn(II) ion, contact time 60 min and 2 g of dose.

Figure 9 shows that the removal % of BP for Zn(II) ion increases with increasing of pH, achieving a somewhat constancy at the range 1.5-6.5,then decreases with increasing of the pH. The maximum removal for Zn(II) ion was at optimum pH = 6.5.

3.8. Comparison sorption capacity between the BP adsorbent in this work and other adsorbents

At the end, the sorption capacities data of zinc ion that reported in this work are compared with other reported adsorbents as shown in Table 7.

3.9. Application of the study to analysis of a real water sample

The Nile river sample is injected with known concentration of Zn(II) ion to study the removal capacity by the BP adsorbent. The removal % of the Zn(II) ions from the real water sample is shown in the following Table 8.

Table7: Comparison sorption capacity between BP adsorbent and other reported adsorbents for Zn(II) metal ion

Metal ion	Adsorbent	q(mg/g)	Conditions			Reference
			pH	Temp. (^oC)	Dose (g/L)	
Zn(II)	Sawdust of deciduous trees	2.17	5.2	-	20	[54]
	Coconut shell AC	8.03	-	25	10	[55]
	Corn Cob AC	4.90	-	25	10	[55]
	Natural zeolite	1.32	6	27 ± 2	5	[56]
	Bagasse fly ash	2.54	5	50	10	[57]
	Activated sugarcane bagasse	0.38	6	30	0.5	[58]
	Wheat straw	3.60	6.8	-	20	[59]
	Banana peels (BP)	2.23	6.5	30 ± 2	2	In this work

Table 8: The removal percentage % of Zn (II) ion by the adsorbent for Nile river sample.

Metal ion	Adsorbent	Concentration added, mg/L	Total initial concentration C_i, mg/L	Final concentration C_f, mg/L	ICP method, R %	Proposed method, R %
Zn(II)	BP	5	5.173	0.561	89.2	90

4. Conclusion

This work aimed to use low-cost agricultural waste banana peel as a biosorbent material through studding its characterization and its removal of Zn(II) metal ion from aqueous media. The system pH, contact time, dosage of adsorbent and initial ion

Through the study, both the freundlich and Langmuir adsorption isotherms models were tested onto BP to describe the adsorption behavior.

concentration of the adsorbate were also determined. Langmuir adsorption isotherm model was found to be more fitted for the best description of the adsorption behavior of Zn(II) metal ion. The experimental data showed that the pseudo second-order model provides the best description. FT-IR spectra, Raman analysis, SEM and Experimental designing in three dimensions Characterization of the biosorbent were achieved.

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