



Utilization of Banana (*Musa sapientum*) Peel for Removal of Pb^{2+} from Aqueous Solution

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Received : April 28, 2021

Revised : July 19, 2021

Accepted : July 29, 2021

Online : July 31, 2021

Abstract

Biosorption is a convenient process for heavy metal remediation. In this study, banana peel was experimented to eliminate lead (Pb^{2+}) from an aqueous solution following batch experiments. The functional groups of banana peel were identified by Fourier-transform infrared spectroscopy (FTIR). The adsorption mechanism was studied by the Langmuir and Freundlich adsorption isotherm model and determined the separation factor from the Langmuir adsorption isotherm. The adsorption of Pb^{2+} on dried banana peel had been studied at different adsorbent doses, pH, initial concentration of Pb, contact time, temperature, and agitation speed. After adsorption, Pb^{2+} was measured using atomic absorption spectroscopy (AAS). Maximum adsorption had taken place at pH 5 for adsorbent dose 45 g L^{-1} . The optimum contact time and agitation speed was 30 minutes and 150 rpm, respectively for the initial Pb concentration of 100 ppm at 25°C . Both, Langmuir and Freundlich adsorption isotherm models shows the best fitting ($r^2 = 0.9978$ and 0.9595) for Pb^{2+} adsorption. The maximum Pb^{2+} adsorption capacity was 2.1 mg g^{-1} . The findings indicate that the banana peel waste could be a potential adsorbent for heavy metal removal. Moreover, the waste management problem could be solved in an eco-friendly manner by utilizing it for the eradication of Pb^{2+} from wastewater.

Keywords: adsorption, Langmuir isotherm, Freundlich isotherm, separation factor, heavy metal remediation

1. INTRODUCTION

Heavy metal pollution has become a severe environmental problem, mainly in developing country due to the rapid growth of urban and industrial activities [1]. In Bangladesh, rapid industrialization, urbanization, and multiple anthropogenic activities have addressed the wide dispersal of cadmium (Cd), lead (Pb), and chromium (Cr) in the environment [2]. Pb contamination is one of the major concerns due to its toxic effect on living organism even present at low concentrations [3]. According to the World Health Organization (WHO), a maximum contaminant level of lead in drinking water is 0.01 mg L^{-1} , which assembles easily and causes fatal kidney damage and reduced neural development [4].

Therefore, it is necessary to remove lead from the wastewater before releasing into aquatic ecosystem. Different processes like adsorption, precipitation, coagulation, ion exchange, cementation, electro-dialysis, electro-winning, electro-coagulation and reverse osmosis have been developed to remedy the lead pollution [5-8]

Yet, it is essential to develop easy, cost effective and fruitful methods to exclude Pb^{2+} from wastewater. Biosorption was examined have high capacity to remove heavy metals like Pb from aqueous solutions [9][10]. Most popular agricultural waste products applied for Pb^{2+} removal are banana peel [11], coconut shell [12], orange peel, corn stover, pistachio shell [13], peanut husk [14], sugarcane bagasse [3], rice husk [15] etc.

As reported by Ahsan et al. [16], waste generation rate in various cities of Bangladesh is ranging from 0.2 to 0.56 kg/cap/day . The composition of the waste is about 74.4% organic matter [17]. Banana (family Musaceae) is one of the highest consumed fruits in the world which creates notable agro-waste problems [18]. According to the Food and Agriculture Organization of the United Nations (FAO), Bangladesh produced 810,347 tons of banana in 2018 [19]. It can be assumed that a vast pile of banana peel waste has been creating because Bangladesh is regarded as one of the most banana-producing countries based on banana production. The fate of the banana peel waste is

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First Publication Right:

Journal of Multidisciplinary Applied Natural Science

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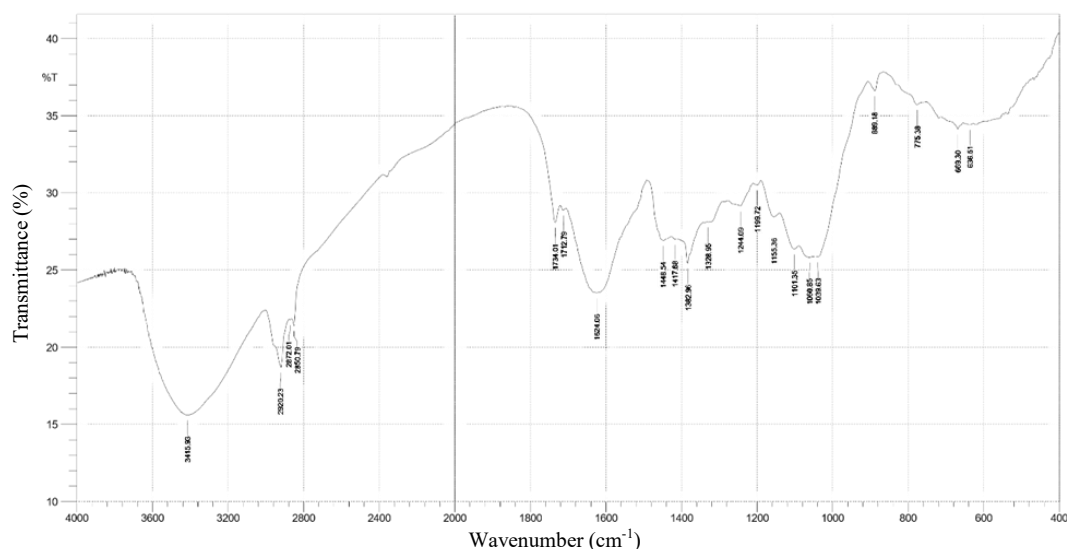


Figure 1. FTIR spectra of dried banana peel powder (1 mm).

landfilling which can contribute to the existing environmental problems. The major constituents of banana peel are cellulose, hemicellulose, pectin, and other low molecular weight species [20]. The banana peel presents a high adsorption capacity for metals and organic compounds due to the presence of the hydroxyl and carboxyl groups of the pectin. These functional groups exchange hydrogen ions for metal ions in solution or donation of an electron pair to form complexes from the metal ion in solutions [11]. The principal mechanism of adsorption process involves the accumulation of molecules of a solvent on the inner and outer surface (e.g., pore) of the adsorbent [21].

Therefore, banana peel (*Musa sapientum*) could be used as an adsorbent for Pb^{2+} removal and agricultural waste management. Most researchers prepared the adsorbent material by chemical or physical activation to get more treatment efficiency [22][23]. The present study emphasizes untreated dried banana peels for removal of Pb^{2+} from water considering the relation of six different experimental condition/parameters (adsorbent dose, metal ion concentration, pH, temperature, agitation speed and contact time), which are cost-reducing and eco-friendly adsorbent preparation techniques for large scale treatment. From literature it has been proven that banana peel is an efficient adsorbent for Pb^{2+} removal [18][23]. Different initial concentrations, adsorbent doses, contact time, agitation speed and temperature have great influence on the removal efficiency. Present

study also focuses on these different experimental conditions to figure out the maximum removal efficiency.

The objective of the present research is to evaluate the efficiency of banana peels as low-cost agricultural waste-based bio-adsorbent (AWB) for Pb^{2+} removal from water under different conditions and get rid of banana peel residue in an eco-friendly method. The study also determined Langmuir and Freundlich isotherms to represent the sorption data.

2. MATERIALS AND METHODS

2.1. Materials

Banana peels (BPs) were collected from the Jahangirnagar University Campus area. Lead nitrate $Pb(NO_3)_2$ was applied as a stock solution for the experiment. 0.1 M Hydrochloric Acid (HCl) and 0.1 M Sodium Hydroxide (NaOH) were used for maintaining pH levels. Nitric acid (HNO_3) was utilized for digestion purposes. For Fourier Transform Infrared Spectrophotometer (SHIMADZU IRPrestige-21), Dichloromethane (DCM) was used for cleaning purposes, and Potassium Bromide (KBr) was used for the analysis of the functional group. The metal ions were determined by Atomic Absorption Spectrometry (SHIMADZU AA-7000).

2.2. Methods

2.2.1. Preparation of Adsorbent

The collected BPs were washed at least three

times thoroughly with regular tap water and Milli Q water for removing impurities and other dust particles that may be clinging to the peels. The cleaned BPs cut into small pieces and dried in sunlight for 5 days. Later the peels were dried in an oven (Daihan Labtech, Model LDO-030E) for 72 hours at 100 °C for removing the moisture from banana peels properly. Dried peels were crushed via mortar and pestle and subsequently screened by a sieve to get uniform particle size of 1 mm. Dried and minced BPs surface functional groups were characterized by Fourier Transform Infrared Spectrophotometer (SHIMADZU IRPrestige-21). The prepared BPs was stored in a desiccator until further use.

2.2.2. Preparation of Lead (Pb) Solution

Lead nitrate $\text{Pb}(\text{NO}_3)_2$ solution was prepared separately by dissolving suitable quantity of analytical grade lead nitrate (Sigma–Aldrich). For the preparation of 1000 ppm of the Pb stock solution, it is needed to add 1.6 g $\text{Pb}(\text{NO}_3)_2$ in one-liter deionized water. Through successive dilutions of the corresponding stock solutions, standard solutions of the desired concentrations were obtained. 50 ppm, 100 ppm, 150 ppm and 200 ppm

working solutions were employed for the analysis. The solutions of different pH were prepared with adding Sodium Hydroxide (NaOH) and Hydrochloric Acid (HCl) in the stock solution to the expected solution.

2.2.3. Batch Adsorption Experiments

The sorption study was carried out batch adsorption method to estimate the capacity of the adsorbent and analyzed the impact of six parameters. They were adsorbent dose, pH, Pb^{2+} concentration, contact time, temperature, and agitation speed. For considering the consequence of a particular parameter, that parameter has been changed gradually holding the other five constants [18].

2.2.3.1. Optimal Dose of Adsorbent

The optimal adsorbent dose was determined by varying the amount of 25, 45, 65 and 85 gL^{-1} BPs put into the separate beakers of 100 ppm of working solutions of pH 5 at the agitation speed of 100 rpm for 30 minutes at 25°C temperature. One 50 mL of lead solution was contained in control beakers without adding the adsorbent. Each mixture was agitated by shaking incubator (GFL - Gesellschaft

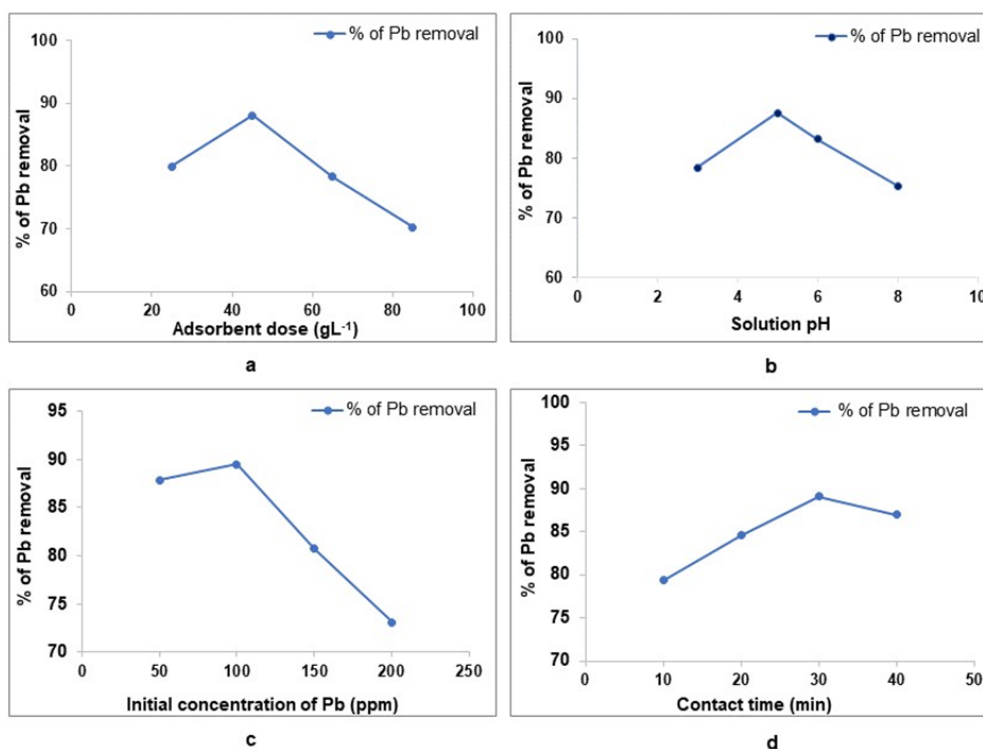


Figure 2. Effect of various factors on Pb^{2+} removal (a) Effects of BP adsorbent dose on removal of Pb^{2+} (b) Effects of pH of the solutions on adsorption of Pb^{2+} (c) Effects of initial concentration of Pb^{2+} on the adsorption through BP (d) Effect of contact time on removal of Pb^{2+} .

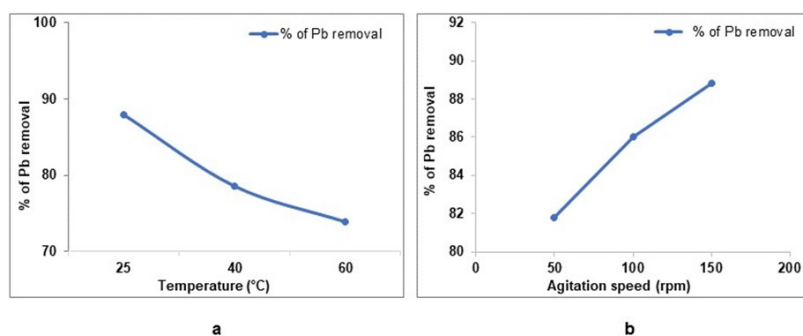


Figure 3. Effect of various factors on Pb^{2+} removal **(a)** Effects of temperature of the solutions on adsorption of Pb^{2+} **(b)** Effects of agitation speed on removal of Pb^{2+} .

für Labortechnik mbH D-30938 Burgwedel) and filtered by Whatman filter paper (grade - 42). Then concentrated nitric acid (HNO_3) was added on the filtrates and heated them on a hotplate for digestion. After that, the mixtures filtered by a suction pump and finally the sample prepared for Atomic Absorption Spectroscopy (SHIMADZU AA-7000). The amount of adsorption at equilibrium, q_e (mg/g) and the percent adsorption (%) was calculated as follows [24]:

$$q_e = \frac{(C_i - C_e)V}{X} \quad (1)$$

$$\text{Percentage of Pb adsorption (\%)} = \frac{(C_i - C_e)}{C_i} \times 100 \quad (2)$$

Where C_i is the initial concentration of metal in solution ($mg\ L^{-1}$), C_e is the final concentration of metal in solution ($mg\ L^{-1}$), V is the volume of solution (L) and X is the dry weight of bio sorbent (g).

2.2.3.2. Optimal pH for Adsorption

The batch biosorption study was inspected at separate pH values to determine the optimum pH for Pb^{2+} uptake by banana peels. 100 ppm working solutions were adjusted to pH values of 3, 5, 6 and 8 (use buffer solution) using 0.1M Sodium Hydroxide (NaOH) and 0.1 M Hydrochloric Acid (HCl). Later fixed 45 g L^{-1} of BP adsorbent was added to each solution at the agitation speed of 100 rpm for 30 minutes at 25 °C. The control batch was handled similar but without BPs. Then the solution was filtered as well digested for AAS.

2.2.3.3. Optimal Initial Metal Ion Concentration

Further adsorption investigation was carried out with the several initial concentrations of 50 ppm, 100 ppm, 150 ppm and 200 ppm Pb^{2+} solutions at

optimum pH 5 with fixed dosage of BP adsorbent 45 g L^{-1} for 30 minutes at 100 rpm agitation speed and at the corresponding temperature 25°C. The supernatant in each beaker was filtered to separate the adsorbent from the solution and prepared for digestion.

2.2.3.4. Optimal Contact Time for Lead Adsorption

100 ppm working solution was determined as the optimum lead solution. The adsorption examination of Pb^{2+} by BP was observed at different time series (10 minutes, 20 minutes, 30 minutes and 40 minutes) among the fixed dosage of 45 g L^{-1} of BP adsorbent by shaken in the orbital shaker at 25 °C, at the agitation speed of 100 rpm. Similarly, the solution of each beaker was filtered and digested for AAS.

2.2.3.5. Optimal Temperature for Lead Removal

The study was conducted out to define optimal temperature by varying the temperature at 25°C, 40°C and 50°C with the fixed dosage of BP adsorbent (45 g L^{-1}) that included lead solution of 100 ppm. Beakers without BPs were set as the control batch. All the solutions of the beakers at pH 5, were agitated in the orbital shaker at 100 rpm for 30 minutes. The solution from each beaker was filtered to isolate the banana peel residues and set for digestion.

2.2.3.6. Optimal Agitation Speed for Adsorption

The analysis was carried out fixed BP adsorbent dosage (45 g L^{-1}) in 100 ppm working solution of lead at pH 5 to set optimal agitation speed by changing speeds at the level of 50 rpm, 100 rpm and 150 rpm for 30 minutes. The mixtures were agitated by orbital shaker at 25 °C. After 30 minutes, supernatants from beakers were filtered,

digested and prepared for AAS.

2.2.4. Study of Adsorption Isotherm

2.2.4.1. The Langmuir Isotherm Model

The Langmuir isotherm represents quantitatively the formation of a monolayer adsorbate on the outer surface of the adsorbent and after that, no further adsorption takes place. The Langmuir represents the equilibrium distribution of metal ions between the solid and liquid phases [25]. The linear form of the Langmuir isotherm equation is expressed as follows [26]:

$$\frac{C_e}{q_e} = \frac{1}{bq_m} + \frac{C_e}{q_m} \tag{3}$$

Where, q_e is the amount of metal adsorbed (mg g^{-1}), b is the Langmuir isotherm constant (L/mg), q_m is the maximum adsorption capacity (mg g^{-1}) and C_e is the concentration at equilibrium (mg L^{-1}). The values of q_m and b were computed from the slope and intercept of the Langmuir plot of $1/q_e$ versus $1/C_e$.

2.2.4.2. The Freundlich Isotherm Model

The Freundlich model deals with the heterogeneous adsorption. The Freundlich equation of adsorption isotherm can be written as follows [18]:

$$\log q_e = \log K_F + \frac{1}{n} \log C_e \tag{4}$$

Here, q_e is the amount of metal adsorbed (mg/g), K_F is the measure of sorption capacity (mg/g), $\frac{1}{n}$ is the sorption intensity and C_e is the concentration at equilibrium (mg L^{-1}). A plot of $\log q_e$ versus $\log C_e$ gives the value of n and K_F . When $\log C_e$ is plotted on the x-axis versus $\log q_e$ on the y-axis, $\log K_F$ and $\frac{1}{n}$ becomes the intercept and the slope of the line respectively [27]. The constant K_F is an estimated indicator of adsorption capacity, while

$\frac{1}{n}$ is a function of the intensity of adsorption in the adsorption process [28]. If $\frac{1}{n} = 1$, the separation within the two phases is not dependent on the concentration. If the value of $\frac{1}{n}$ is below 1, it means a normal adsorption. On the contrary, $\frac{1}{n}$ being above 1 shows cooperative adsorption [29].

2.2.4.3. Analysis of Separation Factor for Langmuir Isotherm

The separation factor is a dimensionless constant which is an important aspect of the Langmuir isotherm. In a batch adsorption system, the shape of the isotherm can be applied to analyze if the adsorption system is favorable or unfavorable [30]. It can be calculated as follows [31]:

$$\text{Separation Factor, SF} = \frac{1}{1+bC_i} \tag{5}$$

Where, b is the Langmuir isotherm constant (L/mg) and C_i is the initial metal ion concentration (mg L^{-1}). If SF is greater than 1 then the adsorption isotherm will be unfavorable. Similarly, if SF is equal to 1 then it will be linear isotherm, SF is equal to 0 then it will be irreversible Isotherm and SF is greater than zero but smaller than one at that time it will be favorable isotherm [32].

2.2.5. Statistical Analysis

All statistical analysis was done employing Microsoft Excel 2019. The slope, intercept, correlation coefficient (R^2) and the equation of the linear form of Langmuir isotherm and Freundlich isotherm model were devised by using the statistical function of Microsoft Excel 2019.

3. RESULTS AND DISCUSSIONS

3.1. Characterization of Banana Peel (BP)

Banana peel is a good source of lignin (6%-12%), pectin (10%-21%), cellulose (7.6%-9.6%)

Table 1. Langmuir and Freundlich isotherm parameters.

Isotherm	Parameters		
	q_m (mg g^{-1})	b (Lg^{-1})	R^2
Langmuir	2.1	2.35	0.9978
Freundlich	K_F (mg g^{-1})	$\frac{1}{n}$	R^2
	1.93	0.0258	0.9595

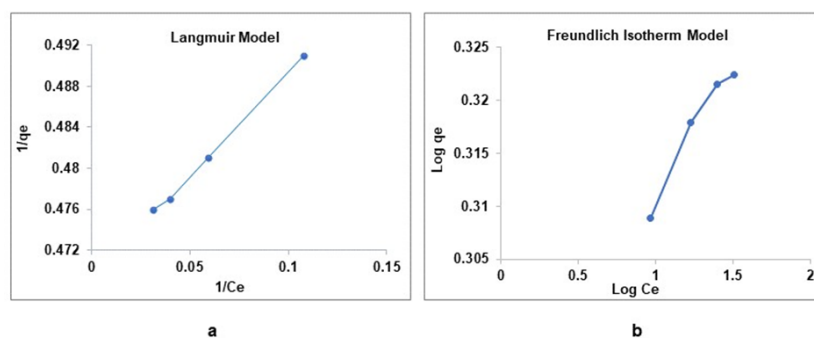


Figure 4. (a) Langmuir adsorption isotherm for Pb^{2+} (b) Freundlich adsorption isotherm for Pb^{2+} (Metal concentration, 50-200 ppm; contact time, 30 minutes; agitation speed, 150 rpm; temperature, 25°C; pH, 5).

and hemicellulose (6.4%-9.4%) [33]. An FTIR spectrum of minced BP was perceived to recognize its functional groups using data from Yadav [34]. These functional groups are responsible for metal ion coordination [35]. Figure 1 clarifies the FTIR spectrum of dried BP with a particle size of 1mm. The band in the region of 3415.93 cm^{-1} depicted OH stretching. The bands in the region of at 2920.23 , 2872.01 and 2850.79 cm^{-1} indicated C-H stretching of alkane because of the presence of polysaccharides (cellulose, hemicellulose) as well as phenylpropanoids (lignin). The band appearing at 1734 and 1712.89 cm^{-1} associated to the C=O bond of carboxylic acids. Increasing the number of carboxylate ligands can intensify metal binding. Band 1624.06 cm^{-1} is indicated C=C stretching and 1448.54 , 1417.68 , 1382.96 cm^{-1} designated C-H bending in the alkane. 1328.95 cm^{-1} recognized C-N stretching and the bands at 1244.09 , 1199.72 , 1155.36 , 1101.35 , 1060.85 and 1039.63 cm^{-1} attributed C=O bending. The weak band in the region of 889.18 and 775.38 cm^{-1} meant N-H deformation of amine groups of the protein. Among of these several functional groups, carboxylic acid and hydroxyl groups of polyphenols and polysaccharides play a key role in the metallic cations removal [36]. Biological components (protein, carbohydrate, and lipid) are associated with the interaction of metal salts via these functional groups [37]. Those functional groups exchange hydrogen ions for metal ions in solution or contribute an electron pair to make complexes by the metal ions in solutions [38]. Banana peel contains a high amount of pectin [39]. The carboxylic acid groups of pectin are responsible for binding Pb^{2+} [40].

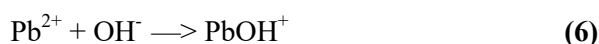
3.2. Effect of Various Factors on Pb^{2+} Removal

3.2.1. Effect of Adsorbent Concentration

The effect of various dosages of BP (25, 45, 65 and 85 g L^{-1}) was analyzed on the Pb^{2+} solution (100 ppm) keeping all other parameters even. The results revealed that the performance of adsorption is notably conditional on the added amount of adsorbent. Maximum removal for lead (100 ppm) was 88.06% for the dose of 45 g BP (Fig 2a). More active sites of the surface area of adsorbent become available for metal uptake with raising the concentration of adsorbent [18]. At the higher adsorbent concentration, the adsorption efficiency decreases. It could be for the result of the of bio-adsorbent aggregation when the effective surface area decreases for metal uptake [41]. So, the optimum dosage of BP adsorbent was selected 45 g for lead removal.

3.2.2. Effects of pH

The most significant parameter influencing the adsorption capacity is the pH of the adsorption medium [23]. The effects of pH (3, 5, 6 and 8) were studied on the Pb^{2+} solution holding all other parameters constant. The experiment showed that the maximum adsorption of lead was 87.5% at pH 5 and exceeding optimum pH adsorption decreases (Fig 2b). H^+ competes with metal cations for the available adsorption site at lower pH although adsorption site does not activate at higher pH [18]. The pH could not be considered higher than 5. Eventually, metal cations react with hydroxide ions and precipitate as the metal hydroxide [18][42].



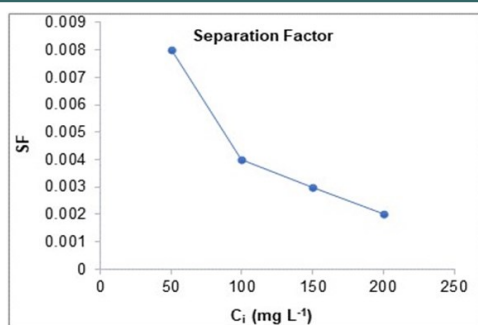


Figure 5. A plot of SF against initial concentration of Pb^{2+} for banana peel powder.

The surface is positively charged in a highly acidic solution and the adsorption of Pb^{2+} and $Pb(OH)^+$ is not favored [43]. The reason is the electrostatic attraction among positively charged adsorbent surfaces and positively charged metal ion surfaces are impossible. It appears that some non-electrostatic forces are involved in adsorption [44] [45]. On the contrary, more negatively charged surface becomes available as the pH increases from 3 and facilitate greater metal uptake [43].

3.2.3. Effect of Initial Concentration

Initial concentration is one of the influential factors on adsorption efficiency. The experiment was carried out with a variable initial Pb^{2+} concentration (50 ppm, 100 ppm, 150 ppm and 200 ppm) with retaining all parameters fixed (Fig 2c). From the experimental results, it was observed that at first with the increase of Pb^{2+} concentration from 50 ppm to 100 ppm removal efficiency also increased from 87.86% to 89.53%. Through from 100 ppm the Pb^{2+} removal rate decreased with the increase of initial Pb^{2+} concentration. When Pb^{2+} concentration is 100 ppm, the ratio of the available adsorption site of BP to the initial number of lead molecules is large. Although at higher concentration (> 100 ppm), the free site of the adsorption become fewer. Therefore, the percentage removal of lead decreases from 100 ppm with the increase of the initial concentration of lead.

3.2.4. Effect of Contact Time

The effect of contact time on adsorption of Pb^{2+} solution onto BP was evaluated over a range of times (10, 20, 30 and 40 minutes). The increased adsorption of Pb^{2+} was observed with the increasing of contact time. Highest adsorption performance of BP has reached after 30 minutes nearly 89.08% of

Pb^{2+} removal (Fig 2d). Significant high removal efficiency is noted for Pb^{2+} during the first 30 minutes because of the availability of the uncovered surface area of the adsorbent. Then eventually a slower metal uptake percentage is marked for approximately an additional 10 minutes. It has happened because the unoccupied site of the adsorption becomes concise due to repulsive forces between the solute molecules on the solid surface of the adsorbent and the bulk phase [46].

3.2.5. Effects of Temperature

The consequences of the removal of Pb^{2+} from solution carried out at different ranges of temperatures (25°, 40° and 60°C) retaining additional parameters constant. The percentage of Pb^{2+} removal and uptake capacity increased from 73.84 to 87.94% as the adsorption temperature was decreased from 60 to 25°C (Fig 3a). The decrease in the adsorption capacity of BP with increasing temperature indicates an exothermic adsorption process [47]. Many researchers proclaimed that biosorption processes are exothermic which indicates that adsorption capacity is inversely proportional to the temperature [48]. Due to temperature increase, the damage of active adsorption sites of bio-adsorbent t escaped from the surface to the solution.

3.2.6. Effect of Agitation Speed

The impact of multiple ranges of agitation speed (50 rpm, 100 rpm and 150 rpm) was examined. The results showed that the adsorption increases with the increase of the agitation speed. Maximum removal for Pb^{2+} was 88.84% at 150 rpm (Fig 3b). Low speed accumulates the adsorbent at the bottom rather than spreading in the solution that results in the burial of various active sites under the above layers of adsorbent. The shaking rate should be sufficient to ensure the binding sites unoccupied for metal uptake [18].

3.3. Adsorption Isotherm

Adsorption isotherms determine equilibrium correlations within a sorbent and a sorbate. It is the proportion between the amount adsorbed and that enduring in the solution at a specific temperature at equilibrium. It is essential to establish the most appropriate correlation for the equilibrium curve to

optimize the plot of sorption for eliminating Pb^{2+} from the water. Langmuir and Freundlich isotherm for Pb^{2+} are presented in Figure 4. The associated parameters of these two isotherms are shown in Table 1.

Toward complete monolayer coverage in Langmuir isotherm, maximum adsorption capacity (q_m) is 2.1 mg/g for Pb^{2+} . R^2 (correlation coefficient) values suggest that Langmuir isotherm fits well to explain the adsorption of Pb^{2+} on BP. On the other hand, in Freundlich isotherm n is the measure of adsorption intensity of metal cations on banana peels [18].

Here, $\frac{1}{n}$ is equal to 0.0258 which suggests a normal adsorption as the value is below one. As estimated from Freundlich isotherm, the value of K_F (adsorption intensity) is 1.93. The R^2 value shown in Table 1 is the evidence that the Pb^{2+} adsorption in this study is well fitted to the Langmuir model compare to the Freundlich model.

The separation factor (SF) for Langmuir Isotherm calculated for each initial concentration (C_i) is depicted in Figure 5. The data explicates that the sorption of Pb^{2+} on banana peel decrease as the initial metal ion concentration increase from 50 to 200 ppm. It indicates that biosorption is more convenient for the lower initial Pb^{2+} concentrations comparing to higher concentrations. The data also reveals that the value of SF is greater than 0 but smaller than 1. It means the biosorption process is favorable for Pb^{2+} removal at all concentrations studied. The graph also admits that the banana peel powder is an effective and excellent adsorbent for Pb^{2+} at the lower concentration. It is also shown that the result of the SF values of Pb^{2+} , Cu^{2+} , Zn^{2+} and Ni^{2+} for banana peel biomass are favorable [28].

3.4. Comparative Study

For Pb^{2+} removal from water, a number of

experiments has been conducted by many researchers. Table 2 indicates some comparative analysis of highest removal efficiency of Pb^{2+} by banana peels based on different variables. Present study focuses on different experimental condition to find maximum removal efficient. From literature it has been proven that banana peel is an efficient adsorbent for Pb^{2+} removal [18][23][31]. Different initial concentrations, adsorbent doses, contact time, agitation speed and temperature have great influence on the removal efficiency. Anwar et al., found 85% removal efficiency for 100 rpm agitation speed [18], where present study found 88.84% removal efficiency for 150 rpm agitation speed. More study is necessary to find the optimum condition to achieve highest removal efficiency.

4. CONCLUSIONS

Waste management is one of the most significant environmental challenges for Bangladesh. The industrial sector is battling serious difficulties for wastewater disposal and its treatment. In this regard, banana peel can be a very efficient adsorbent for the removal of Pb^{2+} from wastewater as it has carboxylic acid and hydroxyl groups of polyphenols, and polysaccharides. The current study suggests that the large volume of banana peel waste can be utilized to treat the Pb^{2+} contaminated water after observing its high-grade performance examining six parameters. Langmuir monolayer coverage reveals that 1 g of BP can adsorb 2.1 mg of Pb^{2+} , and the sorption process is favorable for Pb^{2+} removal. Maximum removal for lead (100 ppm) was found 88.06% for the dose of 45 g BP. Development in the field of biosorption should be reflected for practical application and recommend the treatment process as waste minimization and wastewater treatment strategy in

Table 2. Comparison between studies that considered banana peel for lead adsorption with the present study.

Adsorbent	Adsorbent dose (g)	Initial concentration ion of lead (mg/L)	pH	Temperature (°C)	Contact time (min)	Agitation speed (rpm)	Removal efficiency (%)	Ref
Banana Peel	5	50	5	30	720	100	96.37	[31]
	40	50	5	30	20	100	85.30	[18]
	45	100	5	25	30	100	86.00	Present
	45	100	5	25	30	150	88.84	Present

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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