

Removal of some heavy metals using banana leaves ash and nano ash of banana leaves

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ABSTRACT: This research aimed to check heavy metal removal using waste biomass adsorbent, banana leaves, in an aqueous solution. Therefore, this research successfully removes a different concentration of heavy elements, including Al, Fe, Pb, and Cd, in an aqueous solution using dried banana leaves adsorbents. The order of removal performance was found to be Fe > Pb > Cd > Al. Different factors are studied, such as the amount of banana adsorbents, contact time, temperature, and pH. The results are compared with removing heavy elements of banana leaves nano adsorbents, where an amount of banana adsorbents is converted to nano one using a Ball mill of banana leaves converted to nanopowder of 40 nm size. It is found that the removal of Pb and Cd from aqueous solutions of the nano banana leaves is more functional than normal banana leaves. Normal banana leaves powder was applied to two samples; the first was a sewage water sample, and the other was ground water. This experiment, in which heavy metals are removed using the waste biomass of banana leaves, is an eco-friendly bio-adsorbent method because it can remove heavy metals without using chemicals.

KEYWORDS: *Banana leaves, Adsorption, Agricultural waste, Adsorbent, Heavy metals*

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I. INTRODUCTION

Pollution of water by heavy metals is one of the most dangerous environmental problems nowadays due to its toxicity. Elimination of heavy metals from the environment is of special concern due to their persistence (Karnibet al., 2014). Exposure to heavy metals, even at trace levels, is known to be a risk for human beings (Demirbas, 2008). Heavy metals cause serious health effects, including reduced growth and development, cancer, organ damage, nervous system damage, and in extreme cases, death (Barakat, 2011). Techniques used for the removal of heavy metals, like chemical precipitation, lime coagulation, ion exchange, reverse osmosis, and solvent extraction, are expensive and non-environmental friendly, as compared to adsorption. (Chingombe et al., 2005). Adsorption is the most effective technique for removing heavy metal ions from aqueous media. (Fu and Wang, 2011). The origin of bananas (*Musa sp.*; banana from Arabic for "finger") is located in South East Asia. (Hui, 2007). Banana leaves are large, flexible, and waterproof. Banana leaves have been used for cooking, wrapping, and serving food all over the world. Reports show that they contain large amounts of polyphenols, especially polyphenol oxidase, which is used in the treatment of Parkinson's disorder (Chu et al., 1993). The total phenolic content of the petroleum ether extract of banana leaf is 12.196 mg/mL (Meenashree et al., 2014).

Composition of banana leaves (Abdullah et al., 2013)

Component	(mf wt.%)	Component	(mf wt.%)
Holo cellulose	49.5	Moisture	7.34
Alpha-cellulose	31.7	Volatile Matter	82.0
Hemi-cellulose	17.8	Ash	7.5
Lignin	39.1	Fixed carbon	10.5
Extractives	9.4		

II. MATERIALS AND METHODS

Instruments:-

- 1- Atomic Absorption spectrometer, Thermo Scientific, ICE 3000 Series, England.
- 2- pH meter model Thermo Scientific Orion 2 star, serial no.: b30555, USA.
- 3- Spectrophotometer Aquarius, CECIL CE7400S, serial No.146-456, England.
- 4- Hot plate, Torrey pines hp11, Serial No.: 05051108, USA
- 5- Oven Medline, England.

Chemicals:-

None of the compounds were further purified before usage, and double distilled water was used: Aluminum Nitrate, $\text{Al}(\text{NO}_3)_3$, Mo.Wt 375.13, Sigma-Aldrich, USA. Ferric Chloride hexahydrate, $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$, MW 270.3, POCh Gliwice, Poland. Cadmium Sulfate octa hydrate, $\text{CdSO}_4 \cdot 8\text{H}_2\text{O}$, MW 352, Sigma-Aldrich, USA. Lead acetate trihydrate, $\text{Pb}(\text{CH}_3\text{COO})_2 \cdot 3\text{H}_2\text{O}$, MW 379.33, Sigma-Aldrich, USA. Hydrochloric acid, HCl, MW 36.46, J.T. Baker (USA). Sodium hydroxide, NaOH, M.W. 40, Fluka. Nitric acid, HNO_3 , MW 63.01, Panreac Quimica S.LU. 1,10-phenanthroline, $\text{C}_{12}\text{H}_8\text{N}_2 \cdot \text{H}_2\text{O}$, MW 180.21, Sigma-Aldrich, USA. Ammonium acetate, $\text{CH}_3\text{COONH}_4$, MW 77.08, Panreac Quimica S.LU. Acetic acid, CH_3COOH , MW 60.05, Sigma-Aldrich, USA. Sodium acetate, $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$, MW 136.08, Panreac Quimica S.LU. Erio chrome cyanine R, $\text{C}_{23}\text{H}_{15}\text{N}_3\text{O}_9\text{S}$, MW 536.39, Sigma-Aldrich, USA.

Solutions

Aluminum (III) standard solution: Al (III) solution (10 ppm) was prepared in a measuring flask by taking 10 mL of (1000 ppm) ready solution and completing it to 1000 mL with distilled water. Ferric (III) standard solution: Fe (III) solution (1000 ppm) was prepared by dissolving (2.42 g) from Ferric Chloride hexa hydrate in 500 mL of distilled water and then standardized, according to (Baird et al. 2017). Lead (II) standard solution: Pb (II) solution (1000 ppm) was prepared by dissolving (0.9153 g) from Lead acetate tri hydrate in 500 mL of distilled water and then standardized. Cadmium (II) standard solution: Cd (II) solution (1000 ppm) was prepared by dissolving (1.571 g) from Cadmium Sulfate octa hydrate in 500 mL of distilled water. The above solution was standardized according to (Baird et al. 2017), (Eugene W et al. 2005). Phenanthroline solution: Dissolve 100 mg 1,10-phenanthroline monohydrate in 100 mL water by stirring and heating to 80°C, then complete to 100 mL with distilled water. Eriochrome cyanine R solution: Dissolve 150 mg in about 50 mL water. Adjust pH from about 9 to about 2.9 with 1:1 acetic acid. Dilute with distilled water to 100 mL. Sodium acetate buffer solution: Dissolve 136 g sodium acetate, $\text{CH}_3\text{COONa} \cdot 3\text{H}_2\text{O}$, in water, add 40 mL 1N acetic acid, and dilute to 1 L (Walpole G.S.1914). Ammonium acetate buffer solution: Dissolve 250 g $\text{CH}_3\text{COONH}_4$ in 150 mL water. Add 700 mL conc. (glacial) acetic acid, and dilute to 1 L (Mcilvaine T. C.1921).

Procedures

Collection banana leaves

One kilogram of banana leaves was collected from a banana farm in Sharkia, Egypt. The above amount was washed several times with distilled water, then dried at room temperature 25°C for one week. Crushed with blender, sieved through 150 mesh sieved, and kept in 100 mL plastic bottle.

Preparation of banana leaves sorbent

Banana leaves were divided into five parts, four dried at different temperatures (85,105,150 and 170)°C for two hours to form banana leaves powder_sorbent, and the fifth part converted to nanopowder.

General procedures

0.5 gm of banana leaves powder was placed in five conical flasks and mixed with 50 mL with a concentration of 6 mg/L of metal ions solutions which were studied and shaken for 30 minutes. Then filtration of the metal ions solution from the flask using filter paper. The concentration of each ion was measured by Spectrophotometer for (Al, Fe) and Atomic Absorption spectrometer for (Pb, Cd).

Factors affecting the removal of Al (III), Fe (III), Pb (II), and Cd (II) from water samples.

- **Effect of quantity of adsorbent**

The effect of the quantity of adsorbent on the efficiency of absorption of both Al (III), Fe (III), Pb (II), and Cd (II) was studied. (0.1, 0.25, 0.5, 1.0, 1.5 gm) of banana leaves powder placed in five conical flasks, which contained 50 mL of 6 mg. L⁻¹ metal ions solutions were studied and shaken for 30 minutes. Then filtered using filter paper. The concentration of each ion was measured by Spectrophotometer for (Al, Fe) and Atomic Absorption spectrometer for (Pb, Cd).

- **Effect of pH**

50 mL of the metal ion solution of Al (III), Fe (III), Pb (II), and Cd (II) were contacted with 0.5 gm of the adsorbent in five conical flasks, and the pH of the solution was varied with 0.1M HCl and 0.1M NaOH to

obtained pH of 1,3,5,7 and 9. The solution was equilibrated for 30 min, then filtered using filter paper. The concentration of each ion was measured by Spectrophotometer for (Al, Fe) and Atomic Absorption spectrometer for (Pb, Cd).

- **Effect of initial metal ions concentration**

The effect of initial metal ions Concentration was studied; different concentrations of the metal ions were prepared by serial dilution of the stock metal ion solution(2, 4, 6,8, and 10 mg/L) and then contacted with a fixed dosage(0.5 g) of the adsorbent and 50 mL of the metal ion solution for both Al(III), Fe (III), Pb (II) and Cd (II) in a flask, and shake for 30 min. at the end of time the mixture was filtered and analyzed using Spectrophotometer for (Al, Fe) and Atomic Absorption spectrometer for (Pb, Cd).

- **Effect of contact time**

The reaction time is one of the important factors that influence the adsorption process of heavy metals in a medium. The effect of contact time on the uptake of Al(III), Fe (III), Pb (II), and Cd (II) onto banana leaves powder was studied. Experiments were carried out to investigate the effect of different contact times (5, 15, 30, 60, and 120 min) on the removal of Al (III), Fe (III), Pb (II), and Cd (II). 50 mL of 6 mg. l⁻¹ of the metal ion solution for Al (III), Fe (III), Pb (II), and Cd (II)were contacted with 0.5 gm of the adsorbent in a flask and shaken for 30min. Then filtered using filter paper, and concentration was measured as above.

- **Effect of foreign ion interference**

The effect of foreign ion interference was studied by mixing 0.5 gm banana leaves powder with 50 mL from series of solutions containing 6 mg/l Al(III) and 6mg/l of (Na⁺,k⁺, Ca²⁺, SO₄²⁻, CO₃²⁻, I) separately for Al(III), and for Fe(III)adsorbent mixed with 50 mL from series of solutions contain 6 mg/l Fe(III) and 6 mg/l of (Na⁺, K⁺, Ca²⁺, SO₄²⁻, CO₃²⁻, I) separately, and for Pb(II)adsorbent mixed with 50 mL from series of solutions contain 6 mg/l Pb(II) and 6 mg/l of (Na⁺, K⁺, Ca²⁺, SO₄²⁻, CO₃²⁻, I) separately, and for Cd(II)adsorbent mixed with 50 mL from series of solutions contain 6 mg/l Cd(II) and 6 mg/l of (Na⁺, K⁺, Ca²⁺, SO₄²⁻, CO₃²⁻, I) separately, in a flask, and shake for 30 min. Then filtered using filter paper. An atomic Absorption spectrometer & Spectrophotometer were used to measure the ions concentration.

Applications

Removal Pb (II) and Cd (II) from the water samples taken from Bahr Elbaqar and groundwater by using banana leaves adsorbent two liters of sewage water and two liters of groundwater were collected and boiled to 250 mL separately then 50 mL of each sample was added to 0.5 gm of banana leaves powder and shacked for 30 minutes then filtered using filter paper and the concentration of Pb (II) and Cd (II) was determined using atomic absorption spectrometer.

Nano banana leaves powder

- **Conversion of banana leaves powder to nano banana leaves powder.**

The fifth part of the banana leaves powder was dried at 170 °C for 2 hours. Then 10 g form of banana leaves powder is Ground in a Ball mill device to convert banana leaves powder to a particular nano size.

- **General procedures**

0.1 gm of banana leaves powder was placed in five conical flasks and mixed with 50 mL metal ions solutions which were studied and shacked for 30 minutes. Then filtration of the metal ions solution from the flask using filter paper. The concentration of each ion was measured by Atomic Absorption spectroscopy.

2.7.3- Factors affecting removal of Pb (II) and Cd (II) by nano banana leaves powder sorbent

- **Effect of quantity of nano banana leaves powder**

The quantity of nano banana leaves powder's effect on the efficient absorption of both Pb (II) and Cd (II) was studied. (0.05, 0.075, 0.1, 0.125, 0.15 gm) of banana leaves powder placed in five conical flasks, which contained 50 mL of 6 mg.L⁻¹ metal ions solutions which were studied and shacked for 30 minutes. Then filtered using filter paper. The concentration of each ion was measured using an Atomic Absorption spectrometer.

- **Effect of contact time**

The effect of contact time on the uptake of Pb (II) and Cd (II)ions onto nano banana leaves powder was studied .experiments were carried out to investigate the effect of different contact times (5,15,30,60and 120 min) on the removal of Pb (II) and Cd (II), 50 mL of the metal ion solution for Pb (II) and Cd (II)were contacted with 0.1gm of the adsorbent in a flask, and shake for 30minutes then filtered with filter paper then Pb (II) and Cd (II)concentration were measured by using Atomic Absorption spectrometer.

- **Effect of initial metal ions concentration**

The effect of initial metal ions Concentration was studied. Different concentrations of the metal ions were prepared by serial dilution of the stock solution (2, 4, 6,8, and 10 mg/l) and then contacted with a fixed dosage of the adsorbent and 50 mL of the metal ion solution for both Pb (II) and Cd (II)a flask, and shake for 30 minutes then filtered with filter paper. At the end of time, the mixture was filtered and analyzed using Atomic Absorption Spectrophotometer.

III. RESULTS

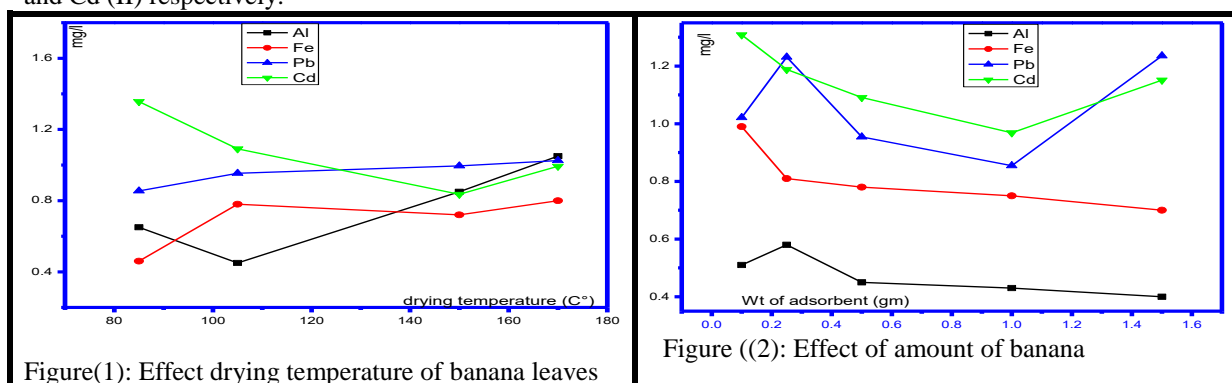
Factors affecting removal of Al (III), Fe (III), Pb (II), and Cd (II) from water samples.

- **Effect of drying temperature**

The drying temperature of banana leaves was evaluated as one of the most important factors affecting the adsorption efficiency. As shown in Fig. 1, it was found that the best drying temperature is 105, 150, 105, 105 °C for Al (III), Fe (III), Pb (II), and Cd (II), respectively.

- **Effect of amount of banana leaves**

The effect of adsorbent dose on the adsorption of Al (III), Fe (III), Pb (II), and Cd (II) was studied, as shown in Fig. 2; it was found that the best amount of persimmon leaves is 1, 0.25, 0.5, 0.5 g for Al (III), Fe (III), Pb (II), and Cd (II) respectively.



Figure(1): Effect drying temperature of banana leaves

Figure ((2): Effect of amount of banana

- **Effect of pH**

pH is one of the most important factors affecting sorption of metal ions. Differences in initial pH directly affect the competitive ability of hydrogen ions with metal ions for the active sites on the sorbent surface. The effect of pH on the sorption of Al (III), Fe (III), Pb (II), and Cd (II) ions onto banana leaves was studied at pH (1,3,5,7,9). As shown in Fig. 3, it was found that the best pH is 9 for Al (III), Fe (III), Pb (II), and Cd (II), respectively.

- **Effect of initial metal ions concentration**

The effect of initial concentrations on the removal of Al (III), Fe (III), Pb (II), and Cd (II) ions by banana leaves was studied. As shown in Fig. 4, it was found that the best initial concentration is 2 mg/L for Al (III), Fe (III), Pb (II), and Cd (II), respectively.

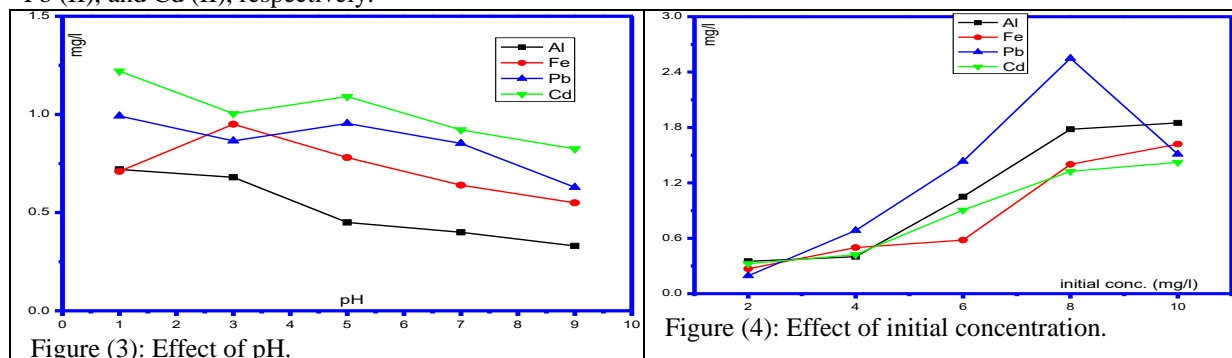


Figure (3): Effect of pH.

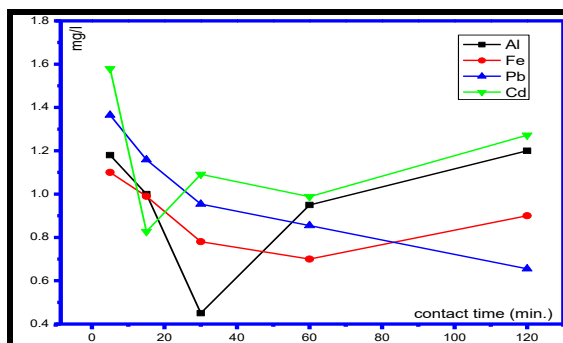
Figure (4): Effect of initial concentration.

- **Effect of contact time**

The effect of time on the adsorption process was evaluated to determine the equilibrium point. The experiments were carried out to investigate the effect of contact time on the removal of Al (III), Fe (III), Pb (II), and Cd (II) ions. As shown in Fig. 5, it was found that the best time is 15, 30, 60, and 120 minutes for Al (III), Fe (III), Pb (II), and Cd (II), respectively.

- **Effect of foreign ion interference**

The effect of foreign ion interference on adsorption Al (III), Fe (III), Pb (II), and Cd (II) by banana leaves. As shown in Fig. 5.



Figure(5): Effect of contact time

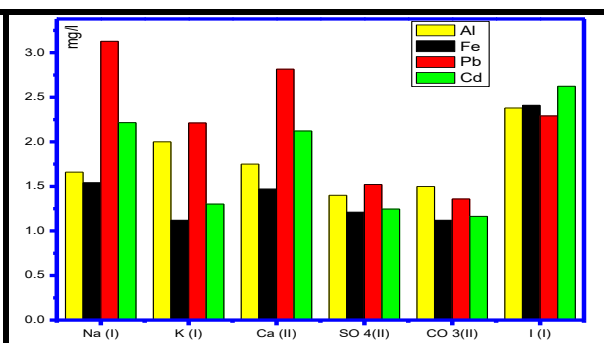


Figure (6): Effect of foreign ion interference

Banana nano ash results

• **Effect of amount of banana leaves**

The effect of the adsorbent dose on the adsorption of Pb (II) and Cd (II) was studied. (0.05, 0.075, 0.1, 0.125, 0.15 g) of banana leaves powder placed in five conical flasks containing 50 ml of 6 mg/L metal ions solutions which were studied and shaken for 30 minutes. They were then filtered using filter paper. The concentration of each ion was measured using an Atomic Absorption spectrometer; as shown in Fig. 7, it was found that the best amount of nano persimmon leaves is 0.15g, 0.075g for Pb (II), and Cd (II), respectively.

• **Effect of initial metal ions concentration**

The effect of initial concentrations on the removal of Pb (II) and Cd (II) ions by banana leaves was studied. Different concentrations of the metal ions were prepared by serial dilution of the stock solution (2, 4, 6,8, and 10 mg/L) and then contacted with a fixed dosage of the adsorbent and 50 ml of the metal ion solution for both Pb (II) and Cd (II) a flask, and shake for 30 minutes then filtered with filter paper. Atomic Absorption Spectrometers were used to measure the concentration of Pb (II) and Cd (II); as shown in Fig. 9, it was found that the best initial concentration is 2 mg/L, 6 mg/L for Pb (II), and Cd (II) respectively.

• **Effect of contact time**

The effect of time on the adsorption process was evaluated to determine the equilibrium point. The experiments were carried out to investigate the effect of contact time on the removal of Pb (II) and Cd (II) ions. Experiments were carried out to investigate the impact of different contact times (5,15,30,60, and 120 min) on the removal of Pb (II) and Cd (II), 50 ml of the metal ion solution. Pb (II) and Cd (II) were contacted with 0.1 g of the adsorbent in a flask, shaken for 30 minutes, and filtered with filter paper. Atomic Absorption Spectrometers were used to measure the concentration of Pb (II) and Cd (II); as shown in Fig. 8, it was found that the best time was 60, 30 minutes for Al (III), Fe (III), Pb (II), and Cd (II) respectively.

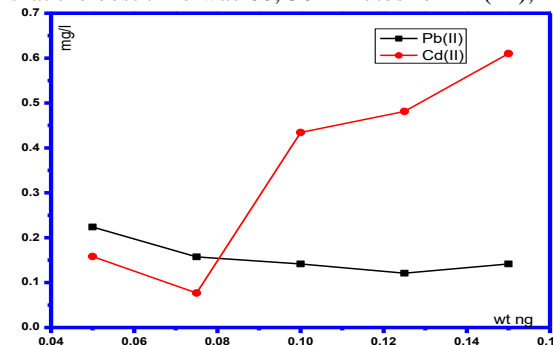


Figure (7): Effect of amount of nano banana leaves.

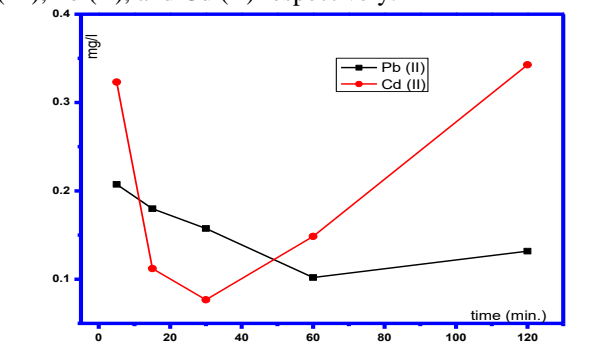


Figure (8): Effect of contact time.

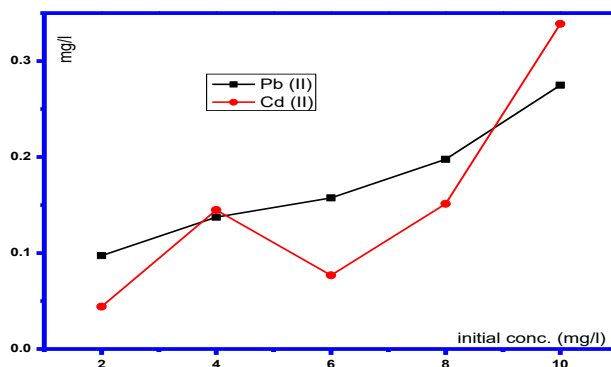


Figure (9): Effect of initial concentration.

Table (1): Statistical analysis of Persimmon leaves on Al³⁺, Fe³⁺, Pb²⁺, and Cd²⁺

Parameter	Mathematical formula	Results			
		Al ³⁺	Fe ³⁺	Pb ²⁺	Cd ²⁺
Mean Value (\bar{X})	$\bar{X} = \sum (Xi / n)$	1.022	0.765	0.993	0.892
Standard deviation (S. D.)	$SD = \sqrt{\frac{\sum (xi - \bar{X})^2}{n-1}}$	0.020	0.018	0.021	0.019
Relative Standard deviation (RSD%)	$RSD \% = (SD / \bar{X}) * 100$	1.850	2.357	1.875	1.602
Standard error of the mean (SEM)	$SEM = S. D. / \sqrt{n}$	0.007	0.006	0.006	0.005
Limit of detection (LOD)	$LOD = 3.3 (SD / K)$	0.074	0.066	0.068	0.063
Limit of quantification (LOQ)	$LOQ = 10 (SD / K)$	0.182	0.169	0.167	0.152
Student t - test	$t - test = ((\bar{X} - \mu) \sqrt{n}) / SD$	0.973	0.935	0.670	0.450

\bar{X} is the mean, S.D. is the standard deviation, and n is the sample size.

Conclusion

Experiments were conducted to adsorb and remove Al, Fe, Pb, and Cd heavy metals in an aqueous solution using banana leaves. Banana leaves include many hydroxyl groups (-O.H.) and contain tannin and phenol, which are effective in removing heavy metals. Based on experimental results, we conclude that banana leaves are an inexpensive, efficient, and commercially valuable new eco-friendly adsorbent for removing heavy metal ions from polluted water. In addition, bio-adsorbent banana leaves are very economical and could be employed as a low-cost alternative to commercial activated carbon in the removal of heavy metal ions from wastewater.

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