Journal of Forensic Chemistry and Toxicology
Volume 1 Number 1, July - December 2015

Original Article

Removal of Lead from Drinking Water using Banana Peels

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Abstract

Presence of heavy metals in drinking water has lead to studies for developing methods to make water safe. Among other methods, biosorption of heavy metals by agricultural waste has gained popularity. Our study is inspired by the work of Gustavo Castro and colleagues who have successfully established the use of banana peel for removal of lead from waste water. In our finding at neutral pH also lead was biosorbed by fresh banana peel and water could be purified upto 83 % without any chemical treatment.

This method may be applied household drinking water especially supplied to rural household where use of modern water purifying systems is yet not common. The method may be explored to develop more sensitive techniques.

Keywords: Heavy metals; Banana peel; Lead; Chemical treatment.

Introduction

Unsafe drinking water is a major cause for con cern especially in developing and under developed nations. Drinking water is usually obtained from either fresh water sources such as rivers, lakes and ponds, or quite commonly, ground water, especially in areas that are not served by rivers. The Central Ground Water Board, a sub-office under the Ministry of Water Resources in India, aims to scientifically establish and fully utilize ground water facilities throughout the country, to provide for the needs of the people [1].

While this is a noble effort, the unfortunate truth is that very often ground water may be highly contaminated, by harmful pathogens, heavy metals, pesticide run off and other chemicals [2]. This results in long and short term physical ailments, as well as developmental disorders in both adults and especially children[3]. In India, where in a number of villages, towns and cities bore wells and hand pumps are the only source of drinking water, this is a major cause for concern. In this paper, an attempt has been made to formulate a simple household method, based on scientific fact, which can be used to significantly decrease the concentration of heavy metals, particularly lead, in water.

Lead is a heavy metal with many industrial uses and many more toxicological implications. Although it is a valuable metal, lead is highly toxic to the human body, even in minute quantities of 5 micrograms / dL of blood [4]. In particular, lead causes severe effects on children, old people and pregnant women, due to its tendency to accumulate within the body, replacing calcium in bones [5].

Biosorption [6] of heavy metals from aqueous solutions has been experimented earlier using paper mill sludge [7] and agricultural wastes like peach and apricot stones [8], jamun seeds [9], rice husks, spent grain, sawdust, sugarcane bagasse, fruit wastes, weeds [10], corn, durian, pummelo [11], pumpkin [12], spinach and papaya [13], tubers [14], peach shell and aquatic plant waste [15], mangostene fruit shell [16], orange and lemon peels [17]soybean oil cake [18] etc.

Bananas are a highly popular, easily available and extremely versatile fruit. Apart from the obvious nutritive value, they are used as fertilizers; their leaves are used as plates, in beauty products, as anti depressants, and many others. The peels of bananas have been particularly useful in the treatment of skin ailments. The newest use of banana peels, however, is as a biosorbent for removing phenolic compounds [19] and also heavy metals [20]. Reported by Brazilian researchers Gustavo Castro and colleagues, minced banana peel can quickly remove lead and copper from river water as well as, or better than, many other materials. Banana peel treatment is low in cost and the peels do not need any chemical modification. The nature and composition of the surface of banana peels has been studied, which due to the high fibre content, have an excellent capacity for biosorption of water as well as heavy metals.

In this paper, we look at the biosorption abilities of banana peels with respect to lead, and aim to formulate a method that may be modified further to be used in households to produce pure and safe drinking water.

Materials and Methods

Apparatus and Chemicals

Instrument

Atomic absorption spectrophotometer (EC Electronics Corporation of India Limited AAS4129) was used for determination of lead (Pb) with deuterium lamp for background correction. The hollow-cathode lamp for Pb which modulates the light of 285 Hz for the metal was employed as radiation source. The flame used was air / acetylene. Nitrogen was used as carrier gas.

Chemicals

Water used in all experiment as reagent was ultrapure and obtained from Milli-Q-water purification system (Ranken Rion Ltd, India).

All apparatus were thoroughly cleaned before use. All glassware was soaked for a minimum of 16 hours in 50% nitric acid and then rinsed in reverse osmosis deionised water.

Preparation of standard solutions

Working lead standard solutions were prepared from 1000ppm stock solution by dilution in water.

Lead standard solution (1000ppm) was used as stock solution. Six lead solutions of different concentrations (1.0, 2.0ppm, 4.0ppm, 6.0ppm, 8.0ppm and 10.0ppm) were prepared by serially diluting the stock solution immediately before use.

The solutions thus prepared were divided into two batches each. The first batch solutions were used as calibrators to calibrate the instrument with every batch and the second batch solutions were used for sample preparation.

Sample Preparation and Analysis

The second batch solutions were again divided into five batches A, B, C, D and E for analyzing them at 0, 0.5, 1, 1.5 and 24 hours respectively. 100ml each of samples were taken in glass beakers and labelled accordingly.

Fresh banana peel was taken and minced manually with the help of a mortar and pestle to form a paste and then washed several times with distilled water, then in 0.001M HCl so as to remove surface impurities and then in again with distilled water until free from chloride ions. No modification was done by any chemical agents to increase the biosorption capacity of the banana peel.

0.02 g of minced banana peel paste was added to each sample in batches B, C, D and E at time T=0 hours and the sample suspensions were stirred mechanically. Batch A samples were analyzed for lead concentration without adding minced banana peel paste and the readings were considered to be taken at time T=0 hours. Batch B, C, D and E samples were analyzed after 0.5, 1, 1.5 and 24 hours respectively. Manual stirring of the samples was done at intervals of 15 minutes. All biosorption experiments were carried out at neutral pH (=7.0) after adjustment with 0.001M NaOH at temperature 18±1^{0}C.

Quality Assurance

Appropriate quality assurance procedures and precautions were taken to ensure reliability of the results. All the measurements were made in triplicate for the samples and calibrator solutions. The instrumental conditions during the analysis lead are given in Table 1.

Table 1: Instrumental Conditions for Analysis of Samples

Element	Current (mA)	Slit Width (nm)	λmax (nm)	Flame Color	Flame Type	AAS Technique
Pb	5 mA	1.0	217.6	Blue	Air/C_2H_2	Flame

The accuracy of the method was determined by measuring the recovery of lead in the matrix containing known concentrations of lead solutions using method of standard addition. The recovery and reproducibility of the method was carried out by spiking and homogenizing several already analyzed samples with varied quantities of standard solutions of lead (Pb) and processed as previously described. The analytical recovery for 'spiked' samples with lead is given in Table 2.

Table 2: Recovery studies for lead

Metal	Base Value (ppm)	Quantity Added (ppm)	Quantity Detected[a] (ppm)	Recovery(%)[b]
Pb	2.0	5.0	6.96	99.2

Recovery test, a=Mean value (n = 3), b=100× [(found-base)/added]

Results and Discussion

Regression data for the standard calibration plots

There was a good linear relation between absorbance and standard concentration of lead and copper. The regression equations and coefficient of determinations obtained for each calibration plot are summarised in Table 3**.** Linearity was evaluated for three runs of samples for lead.

Table 3: Regression data for analysis of standard solutions

S. No.	AAS calibration for Pb	Regression equation	Coefficient of determination (R^2)
1.	1st run	y = 0.0178x - 0.0018	0.9915
2.	2nd run	y = 0.0249x - 0.0008	0.9926
3.	3rd run	y = 0.0232x - 0.0024	0.9908

Pre and Post-treatment analysis results

The spectrophotometer automatically determined concentration of lead present in the samples by extrapolating the calibration curve recorded earlier in parts per million. All samples were run in triplicate and the mean values were used along with the respective standard deviation values for statistical analysis. Table 4 gives the mean concentration values of lead in pre-treated at 0 hours and post-treated samples recorded at 0.5,1, 1.5 and 24 hours.

Table 4: Concentration of Lead in Pre-Treated and Post-Treated Samples

S N	Sample Name	Pre-Treatment Conc. (ppm)	Post- Treatment Mean Concentration (ppm)			
		At Time T= 0 hrs	At Time T=0.5 hrs	At Time T=1 hr	At Time T=1.5 hrs	At Time T=24 hrs
1	**S1**	1.0	0.7 ± 0.1474	0.5 ± 0.0351	BDL	BDL
2	**S2**	2.0	1.1 ± 0.1069	1.0 ± 0.1015	0.95 ± 0.1069	0.6 ± 0.0462
3	**S3**	4.0	1.8 ± 0.0351	1.7 ± 0.0551	1.6 ± 0.0153	1.2 ± 0.0529
4	**S4**	6.0	3.1 ± 0.1253	2.2 ± 0.0603	2.0 ± 0.0889	1.3 ± 0.0153
5	**S5**	8.0	4.3 ± 0.0557	3.4 ± 0.0153	3.2 ± 0.0458	1.5 ± 0.0030
6	**S6**	10.0	5.3 ± 0.1387	4.2 ± 0.1015	3.9 ± 0.0200	1.7 ± 0.1137

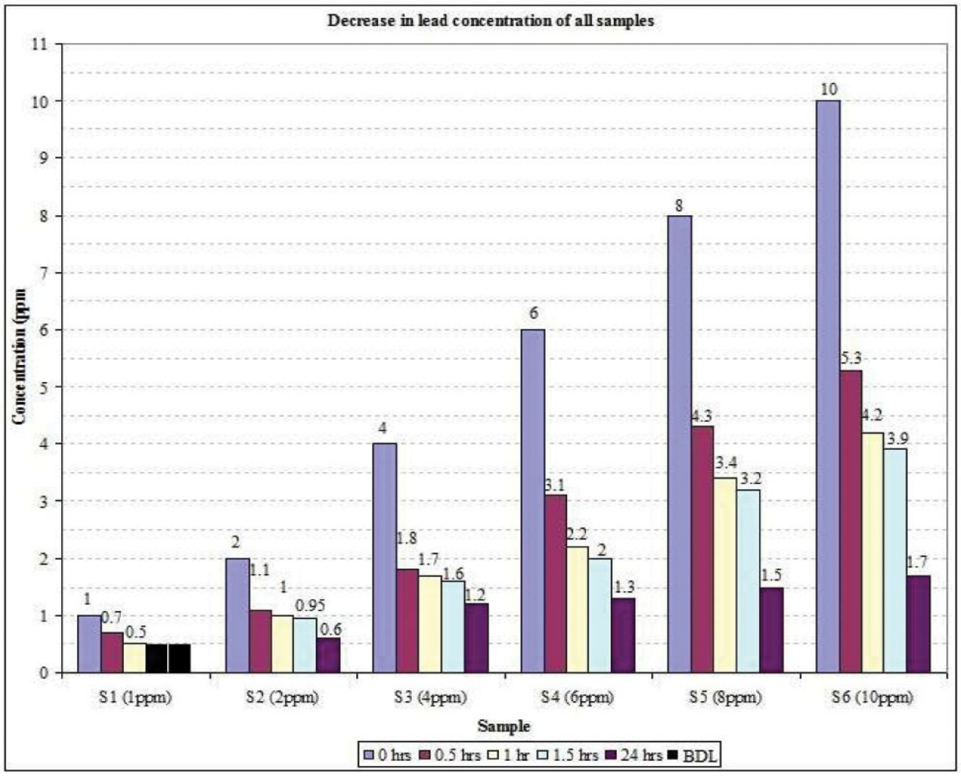
Where, BDL stands for "Below Detection Limit" as Detectable range of Lead by the AAS instrument used is 0.4 – 30.0ppm

Effect of contact time on biosorption of lead

Time-dependent study of biosorption of lead from 100ml neutral aqueous solutions of different concentrations (1.0 to 10.0ppm) by 0.02% minced banana peel was done up to 24 hours at room temperature 18±1^{0}C and manual stirring. Sample was tested at different time intervals i.e. 0.5, 1.0, 1.5 and 24 hours for residual lead concentration.

Figure 1 shows the comparative graph of decrease in concentration of lead of in all samples by treatment with banana peel. Figures 2(a), (b), (c), (d), (e) and (f) show decrease in lead concentration of individual sample at concentrations 1, 2, 4, 6, 8 and 10ppm respectively with time. On plotting a the values of lead concentration (in ppm) against time (in hours), a straight line graph is obtained between 0 and 0.5 hours and a hyperbolic graph between 0.5 and 24 hours in all the samples. This shows that there is a sharp linear decrease in concentration of lead in the first 30 minutes of treatment with banana peel.

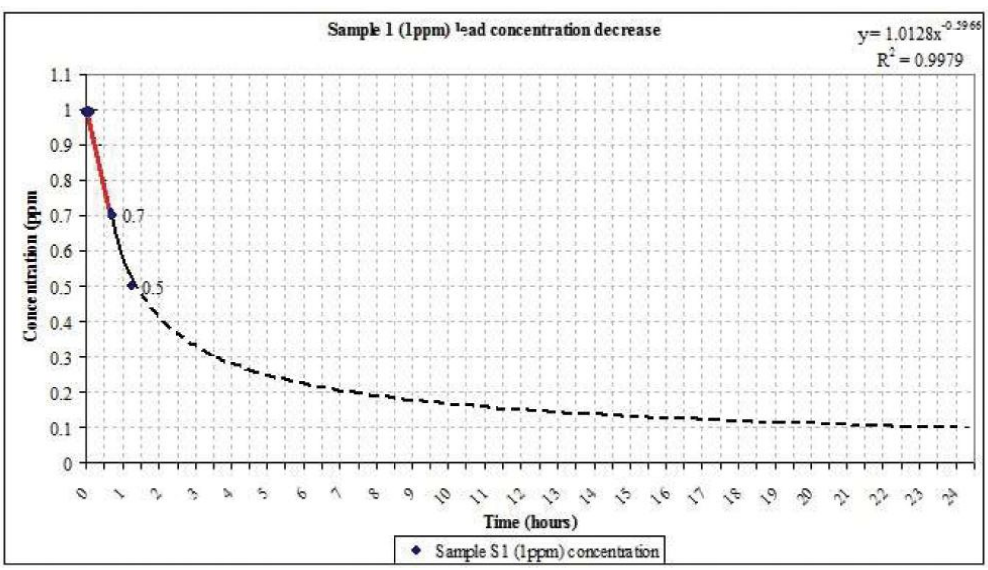
Fig. 1: Graph showing Decrease in Concentration of Lead of all Samples by Treatment with Banana Peel



Where, BDL stands for "Below Detection Limit" as Detectable range of Lead by the AAS instrument used is 0.4 – 30.0ppm

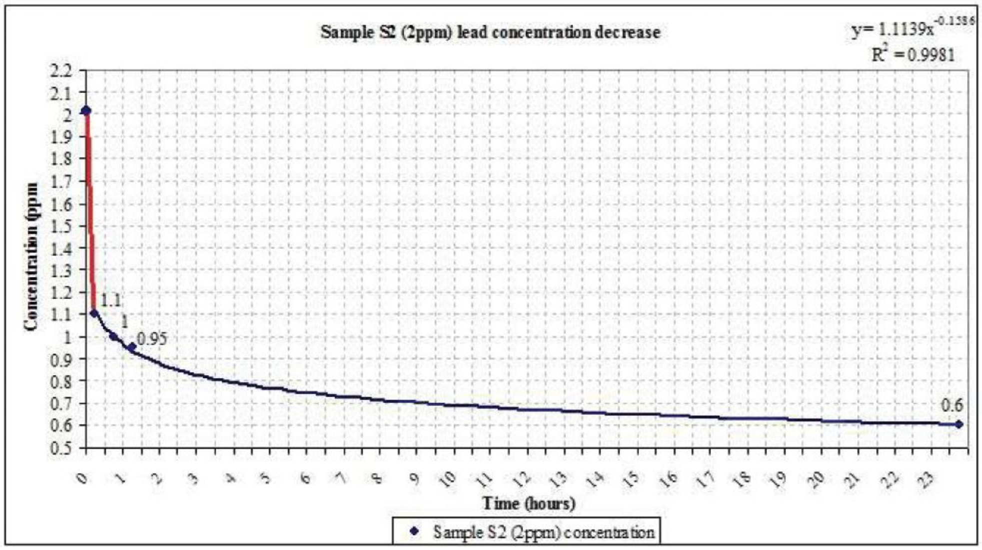
Fig. 2: Decrease in Lead Levels of Different Lead Solutions with Time

(a)

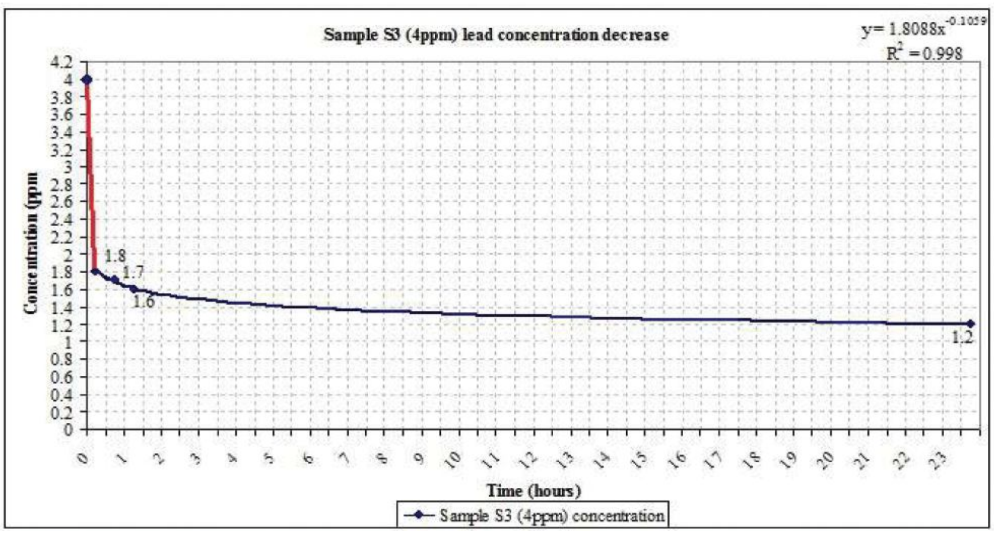


Since, lead concentration beyond 0.5 hours was below detectable limit; therefore the graph was extrapolated and thus shown in dotted lines.

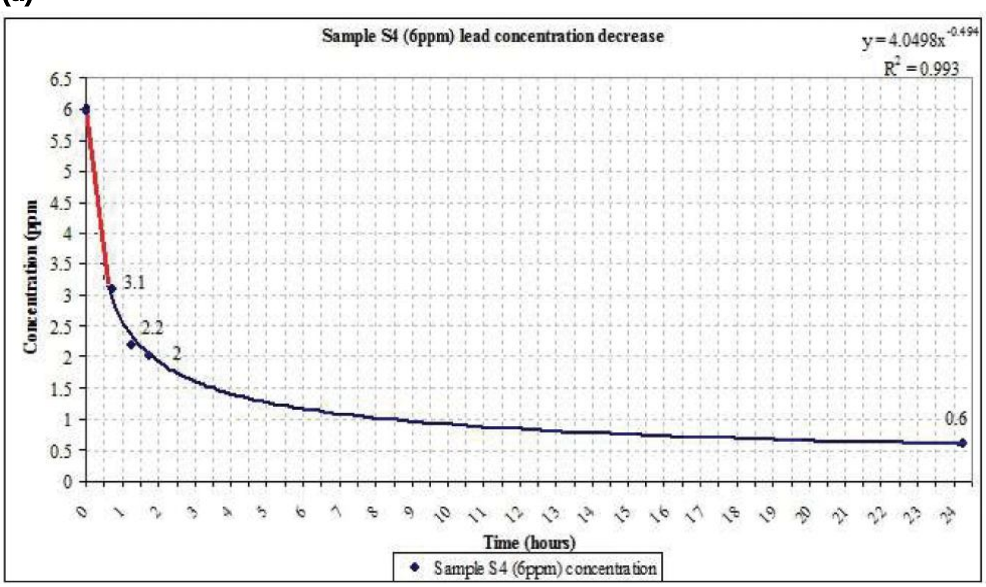
(b)


Sample S2 (2ppm) lead concentration decrease
y= 1.1139x^-0.1586
R^2 = 0.9981
Concentration (ppm
Time (hours)
1.1
1
0.95
0.6
Sample S2 (2ppm) concentration

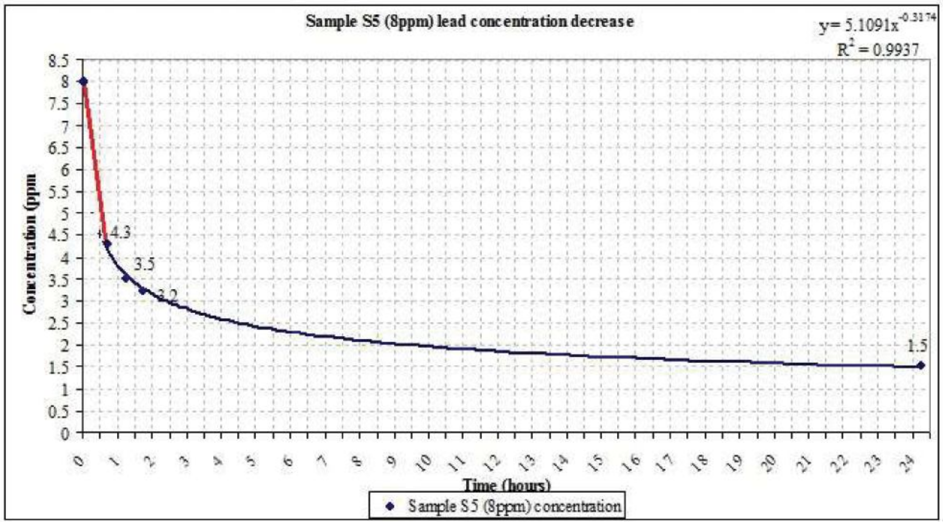
(c)


Sample S3 (4ppm) lead concentration decrease
y= 1.8088x^-0.1059
R^2 = 0.998
Concentration (ppm
Time (hours)
1.8
1.7
1.6
1.2
Sample S3 (4ppm) concentration

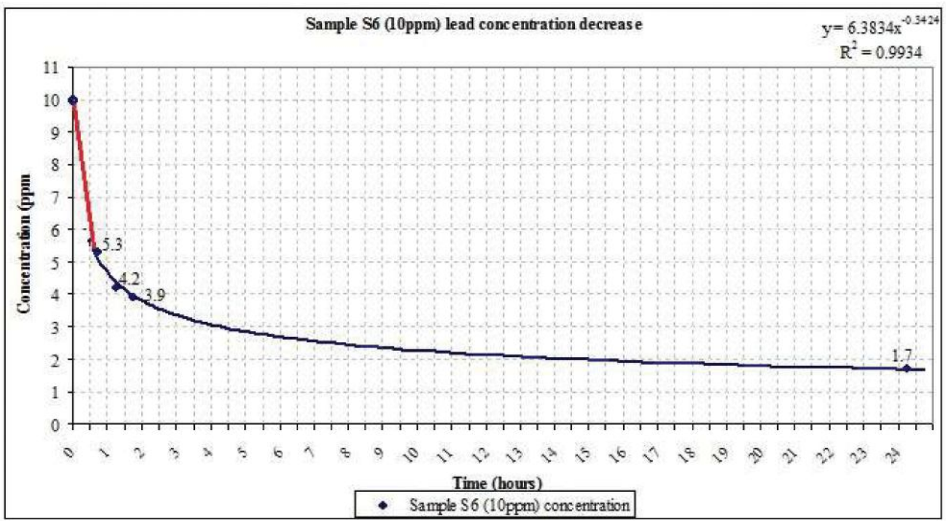
(d)


Sample S4 (6ppm) lead concentration decrease
y=4.0498x^-0.494
R^2 = 0.993
Concentration (ppm
Time (hours)
3.1
2.2
2
0.6
Sample S4 (6ppm) concentration

(e)



(f)



Note: Red straight line in the graph (between values at 0 and 0.5 hours) shows a **linear decrease** whereas blue curve (between values at 0.5 and 24 hours) shows a **non-linear decrease** in lead concentration in all the samples.

Biosorption rate was very fast and contact time of 0.5 hours was enough to reach equilibrium. Post treatment of solutions, the concentration of lead was between 45 and 70 % in the first 0.5 hours, 36.7 and 50 % in 1 hour, 33.3 and 46.7 % in 1.5 hours and in 24 hours it was between 17 and 30 %. Table 5 gives the result of graph analysis.

Results also showed that biosorption was better for higher lead concentration samples than for lower ones. Table 6 gives the percentage decrease in concentration with time.

Table 5: Graph Analysis

S. No.	Sample Name	Original Concentration (ppm)	Coefficient of determination (R^2)
1.	S1	1.0	0.9979
2.	S2	2.0	0.9981
3.	S3	4.0	0.9980
4.	S4	6.0	0.9930
5.	S5	8.0	0.9937
6.	S6	10.0	0.9934

Table 6: Percentage Decrease in Lead Concentration with Time

S No	Sample Name	Concentration (ppm)	Pre-treatment	After 0.5 hrs	After 1 hr	After 1.5 hrs	After 24 hrs
1.	**S1**	1.0	100 %	70 %	50 %	BDL	BDL
2.	**S2**	2.0	100 %	55 %	50 %	47.5 %	30 %
3.	**S3**	4.0	100 %	45 %	42.5 %	40 %	30 %
4.	**S4**	6.0	100 %	51.7 %	36.7 %	33.3 %	21.7 %
5.	**S5**	8.0	100 %	53.8 %	42.5 %	40 %	18.75 %
6.	**S6**	10.0	100 %	53 %	42 %	39 %	17 %

Where, BDL stands for "Below Detection Limit"

Equilibrium studies

Biosorption studies were made in 100ml (0.1 litres) solution of lead at pH 7.0 in different Erlenmeyer flasks (500ml) with 0.02 g of minced banana peel (i.e. 0.2% w / v) by manual stirring at room temperature. Initial concentration of lead (**C_i**) was measured for different concentration solutions after calibrating the atomic absorption spectrometer. Equilibrium was attained at 1 hr, and the amount of lead taken up by banana peel at equilibrium **q_{max}** was calculated using following equation:

$$\mathbf{Q_{max} = (C_i - C_e)\,(V/w)}$$

Where **C_i** and **C_e** are the initial and equilibrium concentration of lead in solution respectively, **V** is the volume of the solution in litres and **w** is the weight of biosorbent in milligrams (Table 7**).**

Table 7: Amount of lead taken up by banana peel at equilibrium

S No	Sample Name	Concentration (ppm)	q_{max} (mg/g)
1.	**S1**	1.0	1.5
2.	**S2**	2.0	4.5
3.	**S3**	4.0	11.0
4.	**S4**	6.0	14.5
5.	**S5**	8.0	18.5
6.	**S6**	10.0	23.5

Figure 3 shows the graph of effect of concentration on the biosorption of lead.

Fig. 3: Effect of concentration on the biosorption of lead onto banana peel

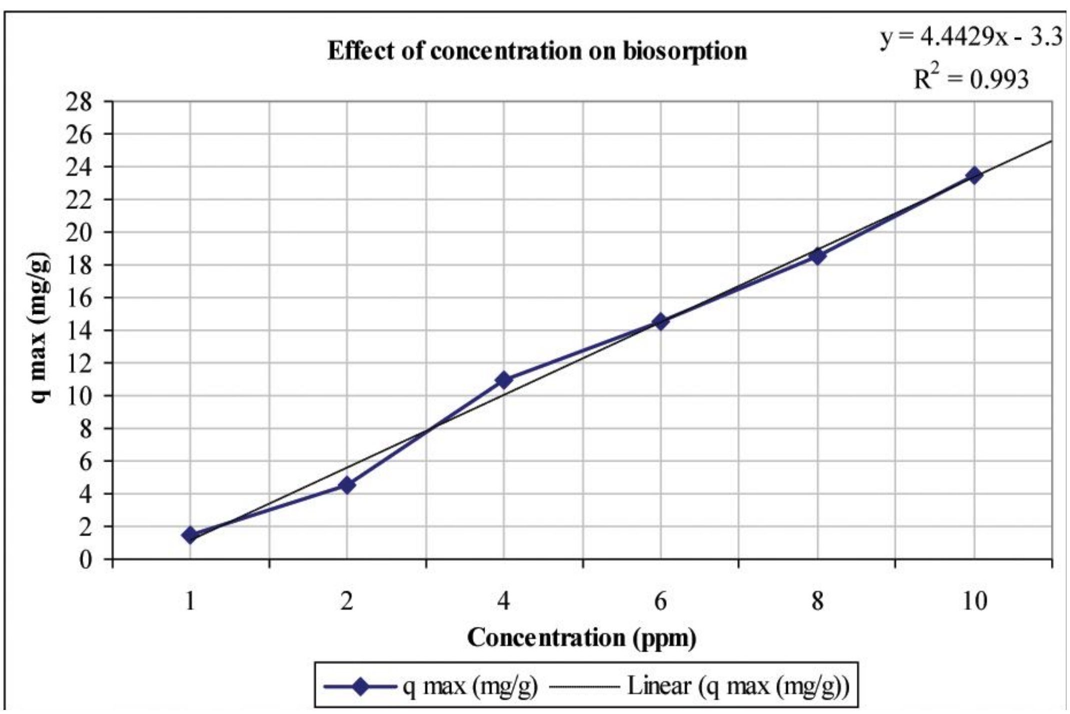


Table 8: Summary of statistics of lead analysis

Number of samples analysed	30
Number of samples with detectable metal	28
% of samples with detectable metal	93.33 %
Minimum conc. of metal ion detected (ppm)	0.6 ± 0.0462
Maximum conc. of metal ion detected (ppm)	10.0

Conclusion

Banana peels seem to be a good contender to be an ideal biosorption technology for treatment of water contaminated by heavy metals such as lead. Their ease of availability, minimal pre-treatment procedures and inexpensive use are factors that create a possibility for the development of an efficient system for the removal of lead. It may also be explored further as a technique for the purification of drinking water, especially in rural settings.

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