Sindh Univ. Res. Jour. (Sci. Ser.) Vol. 47 (4) 843-846 (2015)

SINDH UNIVERSITY RESEARCH JOURNAL (SCIENCE SERIES)

Effective Removal of arsenite by *Musa Paradisica*

J. R. MEMON[++], G. Z. MEMON, M. I. BHANGER*, M. Y. KHUHAWAR**, P. J. HEARD***, K. R. HALLAM***, G. C. ALLEN***

Received 8th March 2015 and Revised 19rd August 2015

Abstract: Banana peel, a green and economical material, has been explored for its capability to eliminate arsenite ions from ground water as a function of pH, contact time, and initial metal ion concentration. Arsenite ions were entered into micropores of banana peel. Experiments on different pH were conducted and found to have no effect on the sorption process. Adsorbed species were desorbed using 5×10^{-3} L of 2 mol dm^{-3} NaOH. The kinetics of sorption was seen to follow the pseudo first order rate equation. The sorption data pursued Freundlich and D-R isotherms. The energy value obtained using D-R isotherm indicated that the sorption was physical in nature for arsenite species. Our study has shown that banana peel has the ability to remove arsenic species from ground water samples.

Keywords: Banana peel; Arsenite ions; Sorption.

1. INTRODUCTION

There are different compounds of arsenic present in environment most of which are difficult to characterize (Beijer and Jernelov, 1986). Arsenic is likely to be present as As(III) (arsenite) in anaerobic conditions. It is reported that As^{3+} is much more toxic than As^{5+} and its long term exposure can cause skin, lung, kidney and bladder cancers (Li *et al*., 2012). Anthropogenic sources of arsenic that add arsenic to raw materials, manufacturers of pesticides, herbicides and other agricultural products. It has been reported that millions of peoples in no. of different countries are possibly affected by arsenic-contaminated drinking water (Acharyya *et al*., 1999). The drinking water guideline recommended by the WHO for total arsenic is 10 µg L^{-1} (WHO, 2011).

Due to its toxic effects, a method for safe removal of arsenic form contaminated waters is required. Removal of arsenic by sorption has been studied on hydrated cement, marble powder and brick powder (Bibi *et al*., 2015), akaganeite decorated graphene oxide composite (Chen *et al*., 2015), bagasse fly ash-iron coated and sponge iron char (Yadav *et al*., 2014), leonardite char (Chammui *et al*., 2014), raw and acidified laterite (Glocheux *et al*., 2013), blue pine (Pinus wallichiana) and walnut (Juglans regia) (Saqib *et al*., 2013), immobilized rice husk (Chaudhuri and Mohammed, 2013), iron coated rice husk (Pehlivan *et al*., 2013), sorghum biomass (Haque *et al*., 2007) and red mud (Altundogan *et al*., 2000).

In the current study, an effort has been made to explain the utility of an efficient and economical banana waste material for the removal of arsenite species from ground water samples. The consequence of relevant parameters has been investigated and we have demonstrated its higher sorption capacity for arsenic than the above materials reported.

2. MATERIALS AND METHODS

2.1 Materials

Sodium arsenite (Merck) was used to prepare a stock standard solution. Buffer solutions of different pH range were prepared and utilized for conducting experiments.

2.2 Methods

2.2. 1 Preparation of sorbent

Material preparation and its analysis were already reported in the literature (Memon *et al*., 2008).

2.2.2 Equipment and instruments for chemical analysis

The equipments and instrument used for chemical analysis was same as reported by the authors in the literature (Memon *et al*., 2015).

2.2.3 Equilibrium metal sorption experiments

Using batch mode, the metal sorption performance of banana peel was explored. 100 mg of sorbent was equilibrated with 2×10^{-2} L of arsenite species (100 mg L^{-1}) sustained at optimum pH and 20 ± 1 ^{o}C and agitated at 40 rpm for 0–24 h. The mixtures were filtered and retained metal ions were eluted by agitating with 5×10^{-3} L of 2 mol dm^{-3} NaOH before being examined after dilution using ICP-OES. The same was

[++]Corresponding author Dr. Jamil R. Memon E-mail: memon.jamil@gmail.com Phone: +92-22-2771379
* Dr. M. A. Kazi, Institute of Chemistry, University of Sindh, Jamshoro, Pakistan.
**International Centre of Biological and Chemical Sciences, University of Karachi, Karachi, Pakistan.
** Institute of Advanced Research Studies in Chemical Science, University of Sindh, Jamshoro, Pakistan.
***Interface Analysis Centre, University of Bristol, Bristol BS8 1TL, UK.

performed three times and the outcomes presented here are the mean of these replicate. Precision is approximately 1%.

3. RESULTS AND DISCUSSIONS

The analysis of utilized sorbent has already been done using FT-IR and scanning electron microscopy (SEM) coupled with the energy dispersive X-ray analysis (EDX) (Memon *et al*., 2008). Furthermore, focused ion beam (FIB) was used to analyze the porosity (Memon *et al*., 2015) which helps to evaluate the sorption behavior of the arsenite ions.

3.1 Influence of aqueous solution pH on the arsenite sorption

The sorption experiments were carried out over a pH range of 1–11, whilst maintaining all other parameters constant. The sorption of As(III) onto sorbent as a function of pH is shown in Fig. 1. The sorption of arsenite species was found to be independent of pH. 85% sorption was observed at all pH values, suggesting no interaction of the arsenite species with surface groups. The major species of arsenite ions in the pH range 6-13 are: (i) mononuclear species, e. g. $As(OH)_3$, $As(OH)_4^-$ and AsO_2OH^{2-}; and (ii) polynuclear species e. g. $As_3(OH)_{10}^-$, $As_2(OH)_8^{2-}$ and, at pH 9-10, As_4O_6 (Baes Jr. and Mesmer, 1976). However, in this present work, it was arsenite species entering into the banana peel micropores (Fig. 1). Pauling has calculated and reported the ionic radius of arsenite (AsO^{2-}) ion to be 0.74×10^{-16} μm (Pauling, 1960) which is v.v. much smaller than the pore size of banana peel (2.67 μm) as calculated from **(Fig. 1).**

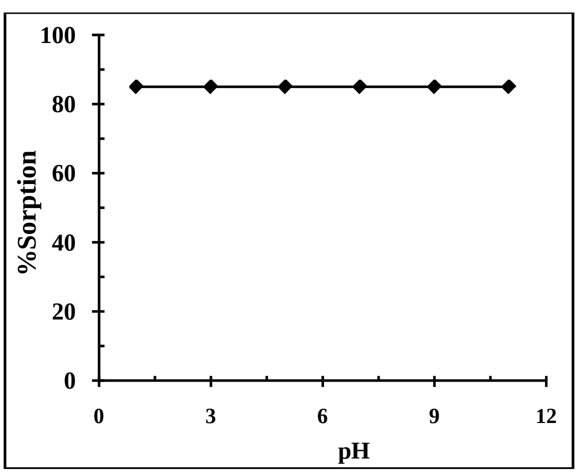

Fig. 1: Sorption of As(III) ions onto banana peel as a function of pH.

3.3 Recovery of arsenic species

Elution of As(III) ions from the sorbent surface was investigated using 5×10^{-3} L of different concentrations of HNO_3, H_2SO_4, HCl and NaOH. Desorption was found 100% with 5×10^{-3} L of 2 mol dm^{-3} NaOH. HNO_3, H_2SO_4 and HCl do not formed soluble As(III) compounds. Therefore, 5 mL of 2 mol dm^{-3} NaOH can recover the As(III) ions from the banana peel surface.

3.4 Kinetics of sorption

A kinetic study was conducted at optimized conditions over times of 0 to 30 min. The adsorption process was initially found to be fast, 80% at 0 min, but became slower as time increased. Equilibrium was found within 30 min and 85% sorption was recorded for As(III) ions. After 30 min., no considerable increase in the sorption was recorded. Consequently, for other analysis 30 min shaking time was decided. The collected kinetic facts were used in different equations namely, Morris–Weber and Lagergren. The adsorbed concentration q_t (μmol g^{-1}) at time t, was plotted against $\sqrt{t}$ to test the Morris-Weber equation (Morris and Weber, 1963) in the following form:

$$q_t = R_d \sqrt{t} \qquad (1)$$

where, R_d is the rate constant of intra-particle transport. Up to 20 min, Eq (1) held well, with a regression coefficient of 0.991, but it deviated as the shaking time increased. From the slope of the plot in the initial stage **(Fig. 2),** the value of R_d, was found to be 1.62 ± 0.07 μmol g^{-1} $min^{-1/2}$. The Lagergren equation (Lagergren, 1898)

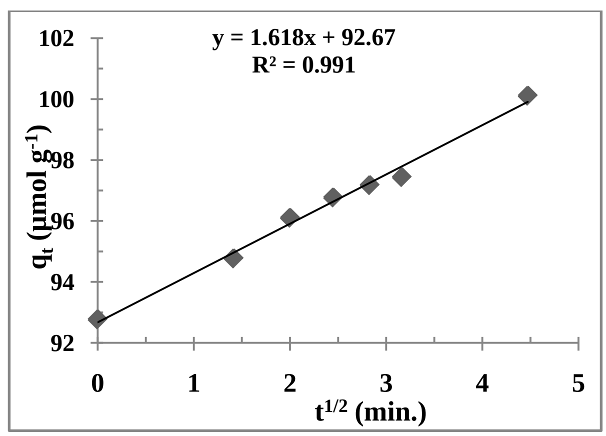

Fig. 2: Morris–Weber plot for the sorption of As(III) ions onto banana peel.

$$\log(q_e - q_t) = \log q_e - \frac{kt}{2.303} \qquad (2)$$

was tested by plotting $\log(q_e - q_t)$ versus time t **(Fig. 3),** where q_e is the adsorbed concentration of As(III) ions on banana peel (mol g^{-1}) at equilibrium. In the initial stage up to 10 min,

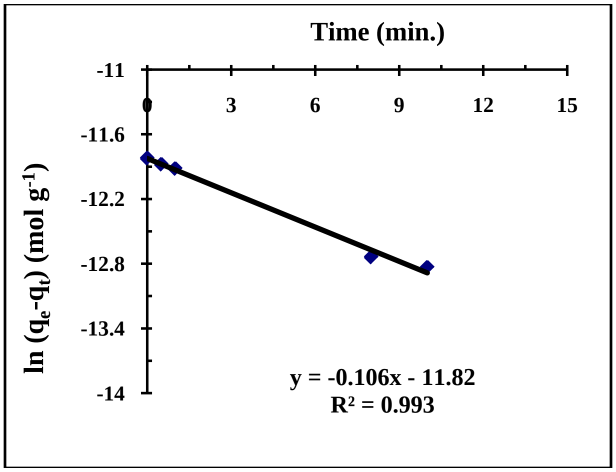

Fig. 3: Lagergren plot for the sorption of As(III) ions onto banana peel.

3.5 Sorption isotherms

The sorption of As(III) ions was also investigated as a function of its concentration at room temperature in the range 0.5–1000 mg L^{-1} using 0.1 g of adsorbent, 20 mL of adsorbate solution and 30 min. shaking time. The metal ion uptake increased with increasing concentration up to 100 mg L^{-1} but then a decreasing trend was observed. These results reflect the effectiveness of the adsorbent for the removal of As(III) ions from the aqueous solution. The effect of the investigated metal ion concentration on banana peel was analyzed in terms of the Freundlich ($\log C_{ads} = \log A + (1/n) \log C_e$), Langmuir ($(C_e/C_{ads}) = (1/Qb) + (C_e/Q)$), and Dubinin–Radushkevich (D–R) ($\ln C_{ads} = \ln X_m - \beta\varepsilon^2$) and $\varepsilon = RT \ln(1 + (1/C_e))$ equations, where C_{ads} is the concentration of metal ions sorbed per unit mass of sorbent, C_e is the concentration of metal ions in the liquid phase at equilibrium and A and n, Q and b, and X_m and β are the Freundlich, Langmuir and D–R constants, respectively. The sorption data followed the Freundlich and D–R isotherms. Therefore, the Freundlich and D–R isotherms were used to evaluate the sorption capacity of banana peel for As(III) ions. The Freundlich and D–R constants were evaluated using the slopes and intercepts of the linear plots studied at room temperature; results are listed in Table 1. The numerical values of the Freundlich constant 1/n > 1 for arsenite species indicated high adsorptive capacity at high equilibrium concentrations that rapidly diminishes at lower equilibrium concentrations. The value of E evaluated from the slope (β) of the D–R plot using equation ($E = \frac{1}{\sqrt{-2\beta}}$) was (7.58 ± 0.12 kJ mol^{-1}), which is in the range expected for physical adsorption (8–16 $kJmol^{-1}$) (Memon *et al.*, 2009). Therefore, the metal ions were sorbed onto banana peel principally by physical adsorption. The calculated values of sorption capacity were different and in the range of 5.41–5.7 mmol g^{-1}. This difference in sorption capacity can be interpreted in terms of the assumptions taken into consideration while deriving these sorption models.

3.6 Analytical application

The analytical applicability of banana peel was tested for the removal of total arsenic from ground water samples collected from different regions of Sindh, Pakistan. After acid digestion, the samples were analyzed using ICP-OES (Table 2, found values). A 20 mL aliquot of each sample was agitated with 1 g of banana peel for 30 min. (Table 2, removal values). The metal ions were then desorbed with 5 mL of 2 M NaOH and analyzed by ICP-OES, 100% recovery was achieved. The R.S.D. was always within 2%, clearly showing the effectiveness of banana peel for the removal and recovery of As(III) ions from these ground water samples.

Table 1: Freundlich and D-R constants of As(III) ions onto banana peel at room temperature.

Freundlich			Dubinin–Radushkevich			
A (mmol g^{-1})	1/n	R^2	X_m (mmol g^{-1})	$\beta \times 10^{-3}$ (kJ^2 mol^{-2})	E (kJ mol^{-1})	R^2
5.7 ± 0.7	1.01 ± 0.01	0.99	5.41 ± 0.89	-(8.7 ± 0.3)	7.58 ± 0.12	0.99

Table 2: Determination, removal and recovery of arsenic species from ground water samples.

Sample location	Found (µg L^{-1})	Removal (%)
Sonara Muhallah Hala (new)	29.1	100
Pir Pinealdho Coloni Hala (new)	36.6	99
Talib-ul-Mola Coloni Hala (new)	34.2	100
Quaid-e-Awam University of Engineering Science and Technology (QUEST), Nawabshah	18.7	100
Latifabad No. 4 Hyderabad	41.8	98
Matiari (city)	44.1	97
Khairpur (city)	32.8	99

4. CONCLUSION

Removal and recovery of As(III) ions was successfully attained using an effective and inexpensive adsorbent – banana peel. Low materials cost, rapid attainment of phase equilibrium and high sorption capacity, along with the pH independency, were some of the substantial features. The surface groups was observed to have no role but the As(III) ions were entering into pores of banana peel. The kinetics of sorption for As(III) followed a pseudo first order rate equation. Sorption of As(III) on banana peel followed the Freundlich and D–R isotherms. The energy value obtained from the D–R isotherm showed that the sorption was physical in nature. Banana peel can be successfully used to remove and recover As(III) ions from ground water samples.

REFERENCES:

Beijer K., and A. Jernelov (1986) Handbook on the Toxicity of Metals, General Aspects, 2nd Edition, Elsevier, Amsterdam, 68.

Li Q., X.T. H. X. Cui, J. Pang, Z. B. Wei, Z. Sun, J. Zhai (2012) Comparison of two adsorbents for the removal of pentavalent arsenic from aqueous solutions. J. Environ. Manage. 98: 98–106.

Acharyya S.K., P. Chakraborty, S. Lahiri, B. C. Raymahashay, S. Guha, A. Bhowmik (1999) Arsenic poisoning in the Ganges delta. Nature, 401 (6753): 545–546.

WHO (World Health Organization) (2011) Guidelines for Drinking-water Quality, 4th Edition, ISBN 978–92-4-154815-1.

Bibi S., A. arooqi K. Hussain, N. Haider (2015) Evaluation of industrial based adsorbents for simultaneous removal of arsenic and fluoride from drinking water. J. Clean. Prod. 87: 882-896.

Chen M.L., Y. Sun, C.B. Huo, C.Liu, J. H. Wang (2015) Akaganeite decorated graphene oxide composite for arsenic adsorption/removal and its proconcentration at ultra-trace level. Chemosphere 130: 52-58.

Yadav L.S., B. K. Mishra A. Kumar, K.K. Paul (2014) Arsenic removal using bagasse fly ash-iron coated and sponge iron char. J. Environ. Chem. Eng. 2 (3): 1467-1473.

Chammui Y., P. Sooksamiti, W. Naksata, S. Thiansem, O. Arqueropanyo (2014) Removal of arsenic from aqueous solution by adsorption on Leonardite. Chem. Eng. J. 240: 202–210.

Glocheux Y., M. M. Pasarín, A. B. Albadarin, S. J. Allen, G.M. Walker (2013) Removal of arsenic from groundwater by adsorption onto an acidified laterite by-product. Chem. Eng. J. 228: 565–574.

Saqib A.N.S., A. Waseem. A.F. Khan, Q. Mahmood, A. Khan, A. Habib, A. R. Khan. (2013) Arsenic bioremediation by low cost materials derived from Blue Pine (Pinus wallichiana) and Walnut (Juglans regia). Ecol. Eng. 51: 88-94.

Chaudhuri M., and M.A. Mohammed (2013) Arsenic (III) Immobilization on Rice Husk. J. Sci. Technol. 4 (2): 47–54.

Pehlivan E., T.Tran, W. Ouedraogo, C. Schmidt, D. Zachmann, M. Bahadir (2013) Removal of As (V) from aqueous solutions by iron coated rice husk. Fuel Process. Technol. 106: 511-517.

Haque M. N., G. Morrison G. Perrusquia, M. Gutierrez A. Aguilera, I. Cano-Aguilera, J. Gardea-Torresdey (2007) Characteristics of arsenic adsorption to sorghum biomass. J. Hazard. Mater. 145: 30-35.

Altundogan H. S., S. Altundogan, F. Tumen, M. Bildik (2000) Arsenic removal from aqueous solutions by adsorption on red mud. Waste Manag. 20: 761–767.

Memon J. R., S. Q. Memon, M. I. Bhanger, G. Z. Memon, A. El-Turki, G. C. Allen. (2008) Characterization of banana peel by scanning electron microscopy and FT-IR spectroscopy and its use for cadmium removal. Colloids Surf. B 66: 260-265.

Memon J. R., G. Z. Memon, P. J. Heard, K. R. Hallam, G.C. Allen. (2015) Focused ion beam analysis of banana peel and its application for arsenate ion removal. Pak. J. Anal. Environ. Chem. 16 (1): 24-30.

Baes Jr. C.F., R. E..Mesmer (1976) The Hydrolysis of Cations, Wiley-Interscience, New York, 366-370.

Pauling L. (1960) The Nature of the Chemical Bond, 3rd Edition, N.Y. Ithaca, Cornell University Press.

Morris W.J., C. Weber. (1963) Kinetics of adsorption on carbon from solution. J. Saint. Eng. Div. ASCE 89: 31-59.

Lagergren S. (1898) Zur theorie der sogenannten adsorption geloster stoffe. Handl. 24: 1-39.

Memon J. R., S. Q. Memon, M. I. Bhanger, A. El-Turki, K. P. Hallam, G. C.Allen. (2009) Banana peel: A green and economical sorbent for the selective removal of Cr(VI) from industrial wastewater. Colloids Surf. B 70: 232-237.