# BATCH STUDIES OF ADSORPTIVE REMOVAL OF ARSENITE FROM WATER USING COCONUT (*Cocos nucifera L.*) FIBER

## A.L. Nashine [1],   A.R. Tembhurkar [2]

[1]*Research Scholar, Department of Civil Engineering,*
*Visvesvaraya National Institute of Technology, Nagpur 440011, Maharashtra, India.*
*Email: alnashine@gmail.com*
[2]*Head, Department of Civil Engineering, Visvesvaraya National Institute of Technology, Nagpur 440011,*
*Maharashtra, India.*
*Email: artembhurkar@rediffmail.com*

-----------------------------------------------------------------------***-------------------------------------------------------------------------

**Abstract-** *Biosorption studies were conducted for Arsenite [As(III)] ion removal from water using Coconut (Cocos nucifera L.) fiber. The effects of various process parameters namely Adsorbent dose (1-20 g/l), Contact time (1-8 h), Initial arsenic concentration (0.2-2.0 mg/l), pH (2–12) and Mixing speed (30-110 rpm) for the removal of As(III) onto Coconut fiber adsorbent were examined. A maximum As(III) ion adsorption uptake is found  to be 95.56%  at operating  conditions of adsorbent dose 10 g/l, contact time 8 h, pH 4 and mixing speed 80 rpm at ambient temperature 34℃. The present equilibrium studies show that the experimental data fits well with Freundlich isotherm.*

*Key Words:* Arsenic, Biosorption, Adsorbent,
Isotherm

## 1. INTRODUCTION

The presence of arsenic in ground water is a public health issue. Consuming arsenic-containing water can have severe adverse effect on health, both acute and chronic. In natural water, arsenic is mostly found in an inorganic form as oxyanions of trivalent arsenite [As(III)] or pentavalent arsenate [As(V)]. Inorganic arsenic is an established potent human carcinogen. In addition, consumption of arsenic causes several diseases like dermatitis, peripheral vascular disease, hypertension, respiratory, neurologic and liver [1-2]. Trivalent arsenic is about 60 times more toxic than oxidized pentavalent state [3]. As a result, many regulatory agencies have revised the maximum contaminant level of arsenic in drinking water from 0.05 mg/l to 0.01 mg/l.

Different treatment technologies such as coagulation, membrane processes, ion exchange and adsorption are used to remove arsenic from drinking water. Coagulation is chemical intensive technology, whereas membrane processes and ion exchange are high cost technologies.

Many adsorbents such as activated carbon [4-7], activated alumina [8-9] have been used for arsenic removal. These commercial adsorbents are expensive.

Biosorption is new promising field of research for removal of metal ions. The use of adsorbents prepared from waste natural materials is advantageous than conventional adsorbents because they are much cheaper, locally available and environmentally favorable [10]. Agricultural or plant Product likeshelled moringaoleiferalamarck seed powder[11], maize leaves[12], cupressus female cone[13]etc were studied as biosorbents for arsenic removal. In the present study, the efficiency of coconut (*Cocos nucifera L.*) fiber as an adsorbent for removing As(III) was investigated. The effects of adsorbent dose, contact time, initial arsenic concentration, pH and mixing speed on the removal of As(III) from water by coconut (*Cocos nucifera L.*) fiber  adsorbent were studied.

## 2. MATERIALS AND METHODS

### 2.1 Preparation of Adsorbent

Coconut (*Cocos nucifera L.*) fiber was sun dried and crushed by grinder. It was sieved through 2 mm copper sieve. 40 g of crushed material was taken in a beaker and mixed with 400 ml of 1N nitric acid.The mixer was  heated on hot plate maintaining a temperature of 70° to 80°C for 20 min., cooled and washed with distilled water till the dirty color was removed. Washed material was, then mixed with 400 ml of 1N sodium hydroxide, again heated at 70° to 80 °C for 20 min. and washed thoroughly. Then the biomass was sun dried, grinded, sieved through 600 micron sieve and stored in capped bottle.

2.2 Experimental Procedure
Stock solution containing 1000 mg/l of As(III) was prepared by dissolving Analytical Grade $As_2O_3$ (SD Fine Chem.) in distilled water. Working solutions were freshly prepared from the stock solution as per the requirements. In the present adsorption study batch experiments were conducted to investigate the effect of adsorbent dose,

contact time, initial arsenic concentration, pH and mixing speed. Experiments were conducted by varying one parameter and keeping other parameters constant. Known amount of adsorbent was added in beakers containing 250 ml of water sample. The contents of all the beakers were simultaneously stirred at 100 rpm for 10 min and 80 rpm afterwards. After stirring, suspensions were allowed to settle for 30 min and the supernatants were filtered. The filtrates were analyzed to determine residual As(III) by silver diethyl dithiocarbamate method using UV–VIS Spectrophotometer (Elico, Model no. SL 210) at a wavelength of 535 nm. To study the effect of other parameters, the optimum value of previous parameters were considered and same procedure was repeated.

## 3. RESULTS AND DISCUSSION

The knowledge of effect of various parameters and their optimum values is necessary for successful application of adsorption process. Hence, batch experiments were conducted to determine optimum conditions for various operating parameters.

### 3.1 Effect of Adsorbent Dose on As(III) Biosorption

To study the effect of adsorbent dose experiment was performed by varying adsorbent doses from 1 to 20 g/l. The study was conducted at mixing speed of 80 rpm, 6 h contact time and 0.380 mg/l initial As(III) concentration when room temperature was 25°C. The influence of adsorbent dose on As(III) biosorption is illustrated in Fig.1. The adsorption of As(III) increases rapidly upto 10 g/l adsorbent dose. Percentage removal is almost constant thereafter. The result indicates that biosorbent removes 21.18% As(III) at a dose of 1 g/l, which increases to 91.37% at 10 g/l. The initial increase in the efficiency of removal may be due to the availability of more surface area for arsenic to be adsorbed with increase in adsorbent dose. Further increase of adsorbent does not affect significantly because of non-adsorbality of arsenic ions as a result of sorbent-sorbate interaction. Further studies were conducted at an optimum dose of 10 g/l.
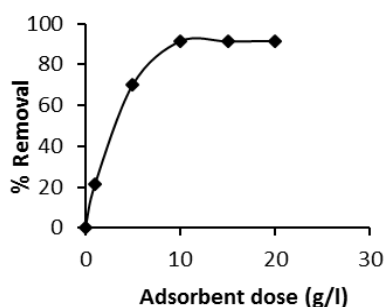


**Fig- 1: Effect of adsorbent dose on As(III) biosorption**

(initial As(III) conc. - 0.380 mg/l, contact time - 6 h, mixing speed - 80 rpm, room temp - 25°C)

### 3.2 Effect of Contact Time on As (III) Biosorption

The effect of contact time on As (III) adsorption was studied by varying it from 1 to 8 h at initial As (III) concentration of 0.40 mg/l, adsorbent dose of 10 g/l and mixing speed of 80 rpm when room temperature was 25°C.The effect of contact time on As (III) biosorption is shown in Fig. 2. It is evident from Fig. 2 that adsorption increases with increase in contact time. Maximum removal of 94.40% of As(III) was achieved at 8 h contact time.The adsorption of arsenic is rapid upto 6 h and gradual thereafter. This may be due to the reduction of driving force after longer period of operation [14] or saturation of adsorbent sites. Reported equilibrium contact times are 20 h for polymeric Al/Fe modified montmorillonite [15], 6 hfor waste iron slag [16], 4 h for maize leaves [12] and 22 h for iron impregnated potato peels [17]. For further studies 8 h contact time is considered.
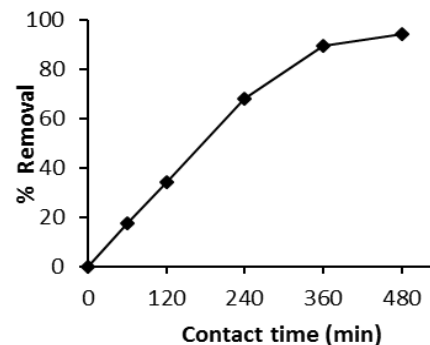


**Fig- 2: Effect of contact time on As(III) biosorption (initial conc. – 0.40 mg/l, adsorbent dose -10 g/l, mixing speed - 80 rpm, room temp – 25°C)**

### 3.3 Effect of Initial Concentration on Biosorption

The study on the effect of initial As(III) concentration was conducted by varying it from 0.2 mg/l to 2.0 mg/l) and keeping previous optimum and other conditions similar i.e adsorbent dose 10 g/l, contact time 8 h, mixing speed 80 rpm.The effect of initial As(III) concentration on biosorption is shown in Fig. 3. It is observed that at lower initial ion concentration the removal efficiency is high. The removal decreased from 93.72% to 61.51% when initial concentration increased from 0.5 mg/l to 2 mg/l. This may be due to the insufficient number of active sites available than the number of As(III) ions present in solution.
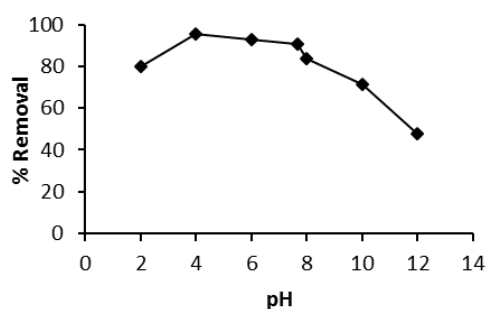
### 3.4 Effect of pH on Biosorption

To study the effect of pH on the adsorption of As(III) onto coconut husk adsorbent, pH of water was adjusted to various values from 2 to 12. 1N or 0.1N HCl and 1N or 0.1N NaOH solutions were used for coarse and fine pH adjustment respectively. The experiment was conducted at initial concentrations of 0.5 mg/l, adsorbent dose of 10

g/l and a contact time of 8 h, when room temperature was 34°C. Fig. 4 shows the effect of pH on the biosorption of As(III).
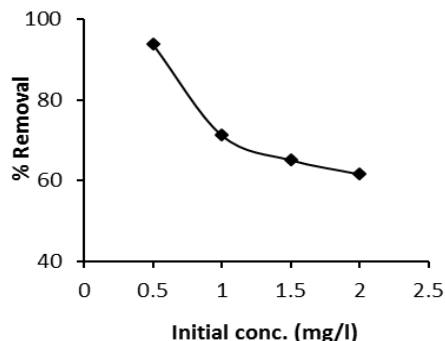


**Fig-3: Effect of initial solution conc. on As(III) biosorption (adsorbent dose -10 g/l, contact time – 8h, mixing speed - 80 rpm, room temp - 25°C)**

It was found that maximum uptake occurs at pH 4. 95.56% of As(III) was adsorbed at pH 4. The percentage removal slowly decreases with further increase in pH and the decrease is rapid above pH 7.65. This may be due to change in characteristics and charge of As(III) species at different pH.As(III) exists in non-ionic ($H_3AsO_3$) species in the pH range of at 2.0–7.0 and anionic species ($H_2AsO_3^{-1}$ and $HAsO_3^{-2}$) in the pH range of 7.5–9.0[12,18]. The type and ionic state of As(III) in the solution are related to As(III) adsorption. At pH 10 and above, the adsorption of As(III) drop may be due to the influence of charged repulsion forces [5]. For conduct of further batch studies pH 4 was considered.
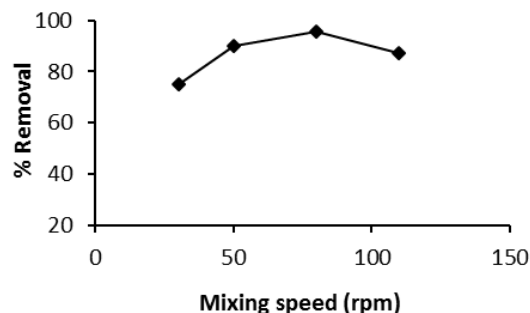


**Fig- 4: Effect of pH on As(III) biosorption (adsorbent dose -10 gm/l, contact time - 8 h., initial conc. - 0.5 mg/l, room temp - 34oC)**

### 3.5 Effect of Mixing Speed on Biosorption

The study of effect of mixing speed on As(III) removal by biosorption was conducted by changing the mixing speed from 30 to 110 rpm at initial As(III) concentration of 0.5 mg/l, an adsorbent dose of 10 g/l and a contact time of 8 h when room temperature was 34°C.The pH was adjusted to optimum value of 4. The effect of mixing speed on As(III) removal is shown in Fig. 5. It shows thatAs(III) removal increases with the increase in mixing speed up to 80 rpm and decreases thereafter. This may be due to the fact that

the increasing agitation rate decreases the boundary layer resistance to mass transfer from bulk solution to adsorbent and increases the driving force of As(III) ions enhancing the adsorption [18]. But on further increase in agitation it leads to desorption. Arsenic removal of 95.56% at 80 rpm is considered as optimum mixing speed for subsequent experiments.



**Fig- 5: Effect of mixing speed on As(III) biosorption (adsorbent dose – 10 gm/l, contact time – 8 h, initial conc. - 0.5 mg/l, pH – 4, room temp - 34°C )**

### 3.6 Adsorption Isotherm

The experimental data obtained at various initial concentrations (0.2 to 2.0 mg/l) is applied to the Langmuir and Freundlich model for evaluation of the adsorption experimental results.

Freundlich isotherm is given by equation 1.

$$q_e = k\ C_e^{1/n} \qquad (1)$$

The linearised form is given by equation 2.

$$\log q_e = \log k + 1/n \log C_e \qquad (2)$$

where, $q_e$ is the amount of adsorbate adsorbed per unit weight of adsorbent (mg/g), $C_e$ is the equilibrium solute concentration (mg/l), k and n are the Freundlich constants representing the adsorption capacity and the adsorption intensity. Larger value of kmeans larger capacity of adsorption and larger value of $1/n$ means that the formation of bond between adsorbate and adsorbent is relatively weak. Freundlich isotherm is plotted with log $q_e$ verses log $C_e$ and shown in Fig. 6.
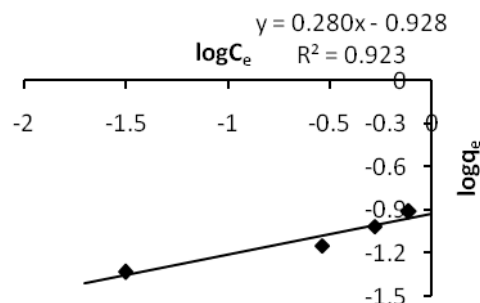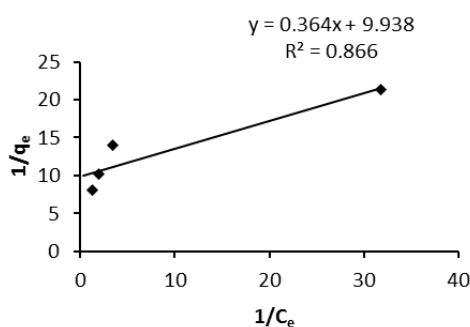


**Fig- 6: Freundlich isotherm for biosorption of As(III) (adsorbent dose – 10 mg/l, contact time – 8 h, mixing speed – 80 rpm, room temp - 25°C)**

Langmuir isotherm is based on the assumption that all the sites have same energy and adsorption is restricted to

monolayer of molecule [19]. Langmuir isotherm is given by equation 3.

$$1/q_e = 1/abC_e + 1/a \qquad (3)$$

where, a and b are Langmuir constants related to adsorption capacity and binding energy of sorption system. Langmuir isotherm is plotted with $1/q_e$ verses $1/C_e$, which is shown in Fig. 7.



y = 0.364x + 9.938
$R^2 = 0.866$

**Fig- 7: Langmuir isotherm for biosorption of As(III) (adsorbent dose – 10 mg/l, contact time – 480 min, mixing speed – 80 rpm. room temp - 25°C)**

The values of constants are give in Table 1. As evident from the $R^2$ values in Fig 6 and 7, the best fit of the experimental data is obtained using the Freundlich isotherm, having $R^2$ value of 0.923.

**Table 1  Adsorption isotherm parameters for As(III) adsorption on coconur husk adsorbent**

| Parameters | K | n | a | b | $R^2$ |
|---|---|---|---|---|---|
| Freundlich isotherm | 0.118 | 3.5714 | - | - | 0.923 |
| Langmuir isotherm | - | - | 0.1006 | 27.3224 | 0.866 |

## 4. CONCLUSIONS

Based on the present study it can be concluded that As(III) from water can be successfully removed using adsorbent prepared from coconut (*Cocos nucifera L.*) fiber. The operating conditions for maximum removal of As(III) from water with coconut (*Cocos nucifera L.*) fiber as adsorbent are: Dose of coconut fiber adsorbent as 10 g/l; Contact time were found to be and 8 h; pH 4 and mixing speed of 80 rpm. About 95.56% of As(III) removal can be achieved at these condition . The present study shows that the adsorption data fits better for Freundlich isotherm.

## REFERENCES

[1]    NRC (National Research Council), "Arsenic in Drinking Water: 2001 Update," *Washington, DC: National Academy Press*, 2001.

[2]    IARC (International Agency for Research on Cancer), "IARC Monographs on Arsenic in Drinking Water;" Vol. 84, 2004.

[3]    J. F. Ferguson and J. Gavis, "A Review of the Arsenic Cycle in Natural Water," 1972, In Jain C.K. and Ali I., "Arsenic: Occurrence, Toxicity and Speciation Techniques," *Water Research*, Vol. 34(17), pp. 4304-4312, 2000.

[4]    L. Lorenzen, J.S.J. Van Deventer and W.M. Landi, "Factors Affecting the Mechanism of the Adsorption of Arsenic Species on Activated Carbon," *Mineral Engineering,* Vol. 8(4/5), pp. 557-569, 1995.

[5]    YunHai Wu, Bin Li, ShiXun Feng, XianMiaoMi and JingLong Jiang, "Adsorption of Cr(VI) and As(III) on Coaly Activated Carbon in Single and Binary Systems," *Desalination,* Vol. 249, pp. 1067-1073, 2009.

[6]    K. B. Payne and T. M. Abdel-Fattah, "Adsorption of Arsenate and Arsenite by Iron-Treated Activated Carbon and Zeolites: Effects of pH, Temperature, and Ionic Strength." *Journal of Environmental Science and Health,* Vol. 40, pp. 723-749, 2005.

[7]    V.D. Mude, R.M. Dhoble and P.B. Nagarnaik, "Removal of As(III) from Groundwater by Commercial Activated Carbon: Batch Study," *International Journal of Advanced Engineering Sciences and Technologies,* Vol. 8(1), pp. 125-134, 2011.

[8]    T.S. Singh and K.K. Pant, "Equilibrium Kinetics and Thermodynamic Studies for Adsorption of As(III) on Activated Alumina," *Separation and Purification Technology*, Vol. 36(2), pp. 139-147, 2004.

[9]    S. Kuriakose, T.S. Singh and K.K. Pant, "Adsorption of As(III) from Aqueous Solution onto Iron Oxide Impregnated Activated Alumina," *Water Qual. Res. J. Canada*, Vol. 39(3), pp. 258-266, 2004.

[10]   R. Mehrotra, B.S. Kapoor and B. Narayan, "Defluoridation of Drinking Water Using Low Cost Adsorbent", *Indian Jour. of Environmental Health*, Vol. 41(1), pp. 53-58, 1999.

[11]   PushpaKumari, P. Sharmma, S. Shrivastava and M.M. Shrivastava, "Biosorption Studies on Shelled MoringaOleiferaLammark Seed Powder: Removal and Recovery of Arsenic from Aqueous System*." Int. J. Miner. Process*, Vol. 78, pp. 131-139, 2006.

[12]   S. Kamsonlian, C. Balomajumder and Chand, "Removal of As(III) from Aqueous Solution by Biosorption onto Maize (Zea mays) Leaves Surface: Parameters Optimization, Sorption Isotherm, Kinetic and Thermodynamics Studies," *Research Journal of Chemical Sciences*, Vol. 1(5), pp. 73-79, 2011.

[13]   M. Murugan and E. Subramanian, "An Efficient and Reversible Sorptive Removal of Arsenic(III) from Aqueous Solution by The BiosorbentCupressus Female Cone," *Indian Journal of Chemical Technology*, Vol. 11, pp. 304-308, 2004.

[14]   A. Maiti, S. Dasgupta, J.K. Basu, and S. De, "Adsorption of Arsenite Using Natural Laterite as Adsorbent," *Separation and Purification Technology*, Vol. 55, pp. 350-359, 2007.

[15] A. Ramesh, H. Hasegawa, T. Maki and K. Ueda, "Adsorption of Inorganic and Organic Arsenic from Aqueous Solutions by Polymeric Al/Fe Modified Montmorillonite," *Separation and Purification Technology*, Vol. 56, pp. 90-100, 2007.

[16] B. Jovanovic and LjRajakov, "A New Approach: Waste Materials as Sorbents for Arsenic Removal from Water," Journal of Environmental Engineering. Posted Ahead of Print, 2010.

[17] B.J. Godboley and R.M. Dhoble, "Removal of As(III) From Groundwater by Iron Impregnated Potato Peels (IIPP): Batch Study," *International Journal of Advanced Engineering Sciences and Technologies*, Vol. 7(1), pp. 054-064, 2011.

[18] S. Kundu and A.K. Gupta, "Adsorptive Removal of As(III) from Aqueous Solution using Iron Oxide Coated Cement (IOCC): Evaluation of Kinetic, Equilibrium and Thermodynamic Models," *Separation and Purification Technology*, Vol. 51, PP. 165-172, 2006.

[19] A.G. Bhole, "Design of Water Treatment Plants," *Indian Water Works Association, Nagpur Centre, India*, 2003.