Asian Journal of Water, Environment and Pollution, Vol. 9, No. 1 (2012), pp. 25–29.

A Study on Arsenic Uptaking Capacity of Water Hyacinth

M.A. Islam, M.S. Rahman[1], S. Islam[*2], A.N.M. Zakaria[1] and K.M.R. Islam[1]

Department of Chemical Engineering and Polymer Science, Shahjalal University of Science and Technology (SUST), Sylhet, Bangladesh

[1]Department of Civil and Environmental Engineering, Shahjalal University of Science and Technology (SUST), Sylhet, Bangladesh

[2]Department of Civil Engineering, International University of Business, Agriculture and Technology (IUBAT) 4 Embankment Drive Road, Sector #10, Uttara Model Town, Dhaka, Bangladesh

✉ sharif_sust_cee@yahoo.com

Received July 7, 2011; revised and accepted December 12, 2011

Abstract: Water hyacinths are free-floating aqueous weeds which can accumulate metals. They have fibrous roots and obtain all of their nutrients from the water. Determination of arsenic uptaking capacity of water hyacinth in arsenic-contaminated water is the main objective of the study. Total of 1350 grams wet water hyacinths were taken from adaptation tank which was collected from the Lake of Shahjalal University of Science and Technology (SUST) campus and were maintained in 27 L tap water supplemented with 0.4, 0.5, 0.6, 0.8, 1.0 and 1.5 mg/L of As in three glass tanks and the test durations were 0, 6, 12, 24, 36, 48 and 72 hours. Samples were collected from three glass tanks and arsenic remained in the solution was measured by Silver Di-ethyl Di-thyo Carbamate (SDDC) method. It was found that the remaining concentration reached below the permissible limit 0.05 mg/L (Bangladesh drinking water quality standard) on or before 48 hours for initial concentration 0.4, 0.5 and 0.6 mg/L of As. But for higher initial concentration (0.8, 1.0 and 1.5 mg/L) the remaining concentration started to increase after 48 hours. So the gross effective floating period for water hyacinth is 48 hours up to initial concentration 0.6 mg/L.

Key words: Arsenic contamination, free-floating aqueous, hyperaccumulation.

Introduction

Since the 1970s, ground water has been the major source of safe drinking water in Bangladesh. It is estimated that 95% of the population relies on ground water for drinking purposes (APSU, 2006). Groundwater based water supply programmes which provide safe drinking water in order to control diseases like diarrhoea, dysentery, typhoid, cholera and hepatitis have exposed population in the affected areas to arsenic related health problems. The first reported case of arsenic contamination in ground water (greater than 0.05 mg/L) from the Bengal Basin was recorded in 1978 in West Bengal (Acharyya et al., 2000). The arsenic contamination of ground water in Bangladesh was first confirmed by the Department of Public Health Engineering (DPHE) in the district of Chapai Nawabganj (the western part of Bangladesh) in late 1993 following reports of extensive contamination in the adjoining area of West Bengal. Extensive contamination in Bangladesh was confirmed in 1995 when additional surveys showed contamination of shallow tubewell across much of southern and central Bangladesh (BGS, 2000). Recently it has been estimated that 30% to 40% area of Bangladesh have arsenic contaminated groundwater and as many as 29 million people could be at serious risk from arsenic poisoning. Water samples collected from the arsenic infected areas of the country showed that 28% of the affected people had more than 100% to 1500% arsenic in their urine (normal level: 0.005–0.04 mg/day), 47% had 8% to 20%

[*]Corresponding Author

in their nails (normal level: 0.043–1.08 mg/kg), and 98% had 100% to 15000% more than normal level of arsenic in their skin (normal level: 0.466–0.896 mg/kg). Therefore an urgent approach is needed to encounter the problem of arsenic contamination (Shams, 2002).

A major part of rural people suffer from arsenicosis due to consuming arsenic contaminated water. About 80 million people in 59 districts out of 64 districts pose a serious health threat (BGS, 1999). Numerous recent investigations have indicated that arsenic constitutes a serious health risk at different places and it has been confirmed by the medical studies (Saha, 1999). Ingestion via food or water is the main pathway of this metalloid in the organism where its absorption takes place in the stomach and intestines, followed by its release into the blood stream. Arsenic is then converted by the liver to a less toxic form, which is eventually largely excreted in the urine (Caroli et al., 1996). Due to the illness of people the nation is loosing millions of manpower–hour as well as impoverishes strength, knowledge, economy, development and finally it begins to kill slowly and painfully. The removal technology of arsenic and disposal of arsenic-bearing waste presents a challenging task to the environmental engineers (Saha, 1999).

It is a complex task to decide on a unique technique for arsenic removal. Some methods are effective but economically not viable. Some are not user responsive, technologically not sound, energy reliant; require post treatment, skill manpower and quality of treated water. Considering the limitations of the other treatment systems the concept of biological treatment is developed. In past few years a great interest has been shown for research with aquatic macrophytes as good candidates for pollutant removal or even as bioindicators for heavy metals in aquatic ecosystems (Aoi and Hayashi, 1996; Maine et al., 1999). The process of using aquatic plants to remove pollutants from soil or water is called phytoremediation. In this context, water hyacinth can be a good option to be taken into consideration for effective phytoremediation in order to remove arsenic from water. The water hyacinth (*Eichhornia crassipes*) is a true water plant and floats by means of spongy petioles. Of all the aquatic plants the water hyacinth is the most prolific and spectacular. The first person to recognize the full potential of water hyacinth was the brilliant agricultural scientist Sir Albert Howard, founder of the organic farming movement, while working in India in the 1920s (Dymond and A.I.R.C., 1949).

The main objective of the study was to find the maximum concentration of arsenic in the water which can be treated below Bangladesh water quality standard by water hyacinth. For this analysis, water hyacinth was taken from the lake of SUST campus.

Mechanisms of Arsenic Removal

There are two things that occur when a plant takes up arsenic: it can store the arsenic in the roots, or it can transport the arsenic to its above ground/water parts. Arsenic accumulation in the roots of a plant can be an arsenic exclusion strategy used by non-accumulators. When most of the arsenic ends up in the top part of the plant, however, it means the plant has an efficient root to top transport system. This efficient transport can lead to hyperaccumulation (Zhang et al., 2002). According to Knudson, Meikle and DeLuca (2003), some plants take up arsenic through their phosphate uptake system. This would make sense because in a phosphate compound (PO_4^{3-}), the phosphorus has an oxidation number of 5+. In a metaarsenate ion (As_3^-) , the arsenic has an oxidation number of 5+. This lack of ability to distinguish could lead to uptake of arsenate by plants as they try to take up phosphate. Zhang, Cai, Tu and Ma looked at the different types of arsenic (arsenate (As V) and arsenite (As III)) in the plant. They found, 60%–74% of the arsenic in the fronds was in the form of arsenite, but only 8.3% of the arsenic in the roots was in the arsenite form. The soil started with equal amounts of arsenate and arsenic, but after eighteen weeks of the experiment, most of the arsenic left in the soil was in the arsenite form, meaning that the plant had taken up most of the arsenate, probably through the phosphate system. Based on these data, the researchers believe that the plant reduced the As V in the arsenate to free As III as part of its detoxification system. Generally, arsenite is usually more toxic to organisms (Zhang et al., 2002).

Material and Methods

Experimental Set-up

Based on the above mechanism of arsenic uptake by natural plants such as water hyacinth, the whole experiment was carried out in the water supply and sanitation laboratory of Department of Civil and Environmental Engineering of Shahjalal University of Science and Technology, Sylhet, Bangladesh. The test of arsenic uptake by water hyacinth was done in triplicate tank made of glass. The length and width of each tank was 24 and 8 inches respectively. The depth of water in each tank was 10 inches. The schematic diagram of triplicate tank is shown in Figure 1. Top of the tank was open for providing adequate sunlight and air. Temperature and pH of water was 26º–29ºC (lab temperature) and 7 respectively.

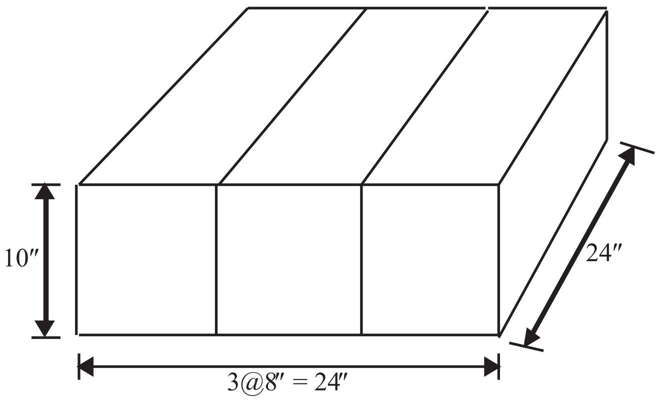

Figure 1: Schematic diagram of triplicate water tank made of glass.

Experimental Procedures

E. crassipes was collected from the Lake of Shahjalal University of Science and Technology, Sylhet, Bangladesh and rinsed with tap water to remove any epiphytes and insect larvae grown in plants. The plants were placed in glass tank with tap water for three days to let them adapt to the new environment, shown in Figure 2, then the plants were taken for further experiment.

A stock solution (1000 mg/L) was prepared in distilled water with analytical grade As_2O_3 which was later diluted as required. Total 1350 grams wet water hyacinths were taken from the adaptation tank. The water hyacinth were maintained in 27 L tap water supplemented with 0.4, 0.5, 0.6, 0.8, 1.0 and 1.5 mg/L of As. All experiments were performed in triplicate glass tank. The tests were performed for 0, 6, 12, 24, 36, 48 and 72 hours. Samples were collected from triplicate glass tank and arsenic remained in the solution was measured by SDDC method.

Figure 2: Adaption tank.

Results and Discussion

Figure 3 shows that 48 hours from starting of As uptake by water hyacinth is a transition point. Up to 48 hours, remaining concentration continued to decrease for each initial concentration (up to 0.6 mg/L). But for higher initial concentration (0.8, 1.0 and 1.5 mg/L) the remaining concentration started to increase after 48 hours when the natural cation accumulation capacity of water hyacinth was lost because of the disruption of the natural metabolic activities which was visualized with the blackish colour of the leaves of water hyacinth leading to their death. Thus, we can infer that gross effective floating period for water hyacinth is 48 hours up to initial concentration of 0.6 mg/L and even safely 0.5 mg/L.

It can be said that the reduction of arsenic concentration to 48 hours (except for initial concentration 1.5 mg/L) follows first order removal kinetics. Analysis of the reduction of As concentration was performed to find the As removal rate constant along with correlation coefficient (values are shown in Table 1) for each initial concentration up to 48 hours except for initial concentration 1.5 mg/L up to 36 hours. As removal rate constant is highest for initial concentration of 0.5 mg/L.

Table 1: As removal rate constants from the analysis

Initial concentration of As (mg/L)	*Removal constant (h^{-1})*	*Removal kinetics*	*R^2 rate*
0.4	First-order	0.056	0.869
0.5	First-order	0.071	0.932
0.6	First-order	0.059	0.955
0.8	First-order	0.032	0.923
1.0	First-order	0.027	0.952
1.5	First-order	0.044	0.959

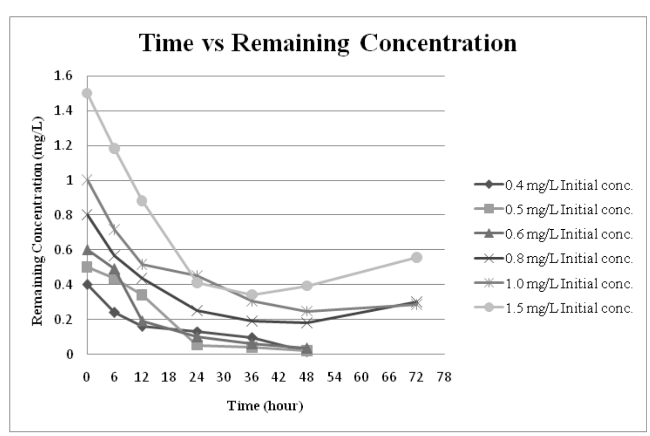

Figure 3: Arsenic removal for different initial concentration.

Comparison of initial concentrations with remaining concentration of arsenic in the sample through the series of experiments, as shown in Figure 4, reveals that remaining concentration of arsenic in water increases with the increase of initial concentration of arsenic in water. Relation between initial concentration of arsenic water with the percentage reduction of arsenic in water, as shown in Figure 5, depicts that percentage reduction of arsenic diminishes with the raise of initial concentration. It means that arsenic removal efficiency of water hyacinth decreases with the increase of arsenic concentration in water beyond the natural cation (for instance arsenic) accumulation capacity of water hyacinth.

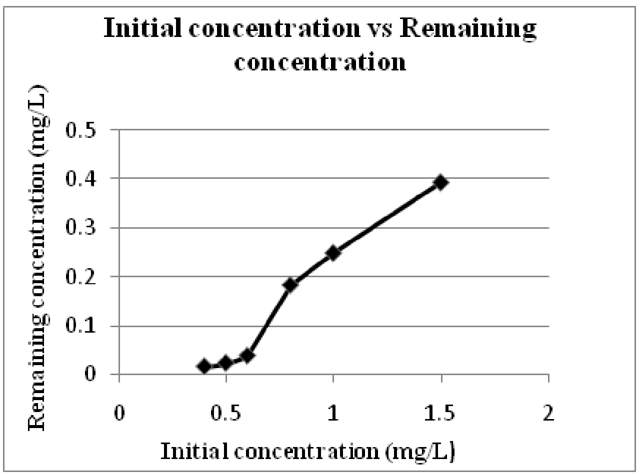

Figure 4: Remaining concentration at 48 hour vs. initial concentration.

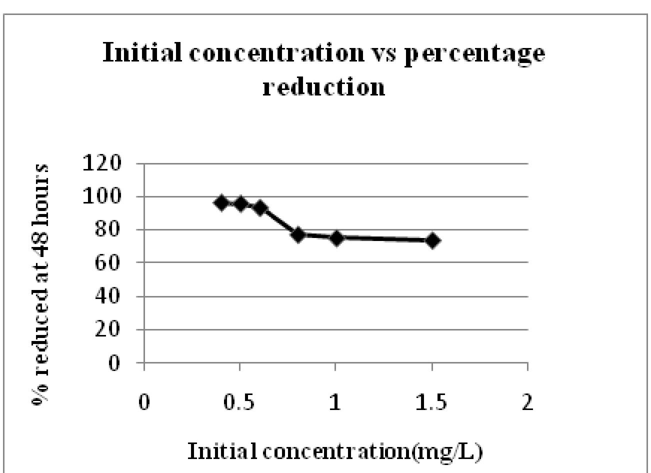

Figure 5: Percentage removal of arsenic at 48 hour vs. initial concentration.

Conclusion

Water hyacinth acts like a scavenger during water treatment. By testing the samples taken at different durations it was found that the remaining concentration reached below the permissible limit 0.05 mg/L (Bangladesh drinking water quality standard) before 48 hours for initial concentration of 0.4, 0.5 and 0.6 mg/L. Further study will find the contamination by water hyacinth itself along with its easier treatment. This research is done in small scale in the laboratory; the researchers strongly recommended that it should be checked by conducting a pilot project before implementing in practical purposes.

Acknowledgement

The authors put across their earnest gratitude to Shahjalal University of Science and Technology, Sylhet, Bangladesh for providing the facilities for this research.

References

Acharyya, A.K., Lahiri, S., Raymahashay, B.C. and A. Bhowmik (2000). Arsenic toxicity of groundwater in parts of the Bengal basin in India and Bangladesh: The role of Quaternary stratigraphy and Holocene fluctuation. *Environmental Geology,* **39:** 1127–1137.

Aoi, T. and T. Hayashi (1996). Nutrient removal by water lettuce (*Pistia stratiotes*). *Water Sci. Tech*., **34:** 407–412.

APSU (2006). Selected papers on the social aspects of arsenic and arsenic mitigation in Bangladesh. Arsenic Policy Support Unit, Dhaka, Bangladesh.

BGS (1999). Groundwater studies for arsenic contamination in Bangladesh. British Geological Survey, Final Report.

BGS (2000). Arsenic contamination of groundwater, Bangladesh phase 1, Applied geosciences for our changing earth. http://www.bgs.ac.uk/arsenic/bphase1/B_find.htm. Accessed 19 May 2010.

Caroli, F., Torre, L.A., Petrucci, F. and N. Violante (1996). Element speciation in bioinorganic chemistry. *Chemical Analysis Series*, **135:** 445–463.

Daymond, G.C. and A.R.I.C. (1949). The Water-Hyacinth: A Cinderella of the Plant World, its use in sewage effluents, as a trapper of salts and a water purifier. http://www.journeytoforever.org/farm_library/dymond.html. Accessed 20 May 2010.

Knudson, J.A., Meikle, T. and T.H. DeLuca (2003). Role of

Mycorrhizal Fungi and Phosphorus in the Arsenic Tolerance of Basin Wildrye. *J. Environ. Qual.,* **32:** 2001–2006.

Maine, M.A., Sune, N.L., Panigatti, M.C. and M.J. Pizarro (1999). Relationships between water chemistry and macrophyte chemistry in lotic and lentic environment. *Arch. Hydrobiol,* **145 (2):** 129–145.

Saha, J.C. (1999). Removal of Arsenic from Water Environment by New Adsorbent. Ph.D. Dissertation, Indian Institute of Technology, Kharagpur, India.

Shams, S. (2002). Prototype GIS and Expert System for Arsenic Evaluation and Mitigation: A Case Study of Chapai Nawabganj District in Bangladesh. TRITA-LWR Master Thesis, Royal Institute of Technology (KTH), Stockholm, Sweden.

Than, M.M. (1990). Cation polluted water treatment: Cu, Fe, Pb uptake by water hyacinth. M.Sc. Thesis, Yangon University, Yangon, Myanmar.

Zhang, W., Cai, Y., Tu, C. and L.Q. Ma (2002). Arsenic Speciation and Distribution in an Arsenic Hyper-accumulating Plant. *Sci. Total Environ.,* **300:** 167–178.

Asian Journal of Water, Environment and Pollution

Volume 7 Number 4 **October – December, 2010**

Contents