**REMOVAL OF ARSENIC BY PHYTOREMEDIATION**

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**ABSTRACT**

Water is the most essential and basic natural resource for survival of all life. Globally, water is contaminated with arsenic, which cause toxic effect to all well beings. Currently, high concentration of arsenic is reported in most regions of the world. To deal with the arsenic contamination endeavors are made by scientists through the world and different methods have been investigated for the removal of arsenic from water. One of these endeavors is the Phytoremediation method

for removal of arsenic from water. This method involves plants for the removal of arsenic from water. It is considered a clean, cost effective and non-environmentally disruptive technology, as opposed to mechanical cleanup methods such as soil excavation or pumping polluted groundwater. In this study Eichhornia Crassipes plants are selected for phytoremediation of arsenic in water. The maximum efficiency of 98 % for arsenic removal was observed.

**KEYWORDS:** Phytoremediation, Eichhornia Crassipes, Removal, Arsenic, Water.

**1. INTRODUCTION**

Among the different natural assets water is one of the all-important thing which need an exceptional consideration. Water is an essential natural asset which shapes the premise of all the living things. Around 97% of the earth's surface is water covered. The significant

measure of water accessible for human consumption is dirtied due to urbanization. Any Human movement that hinders the utilization of water as a asset might be reason for water contamination. The thriving populace is debilitating the accessible freshwater assets as a consequence of which, the world is going towards water emergencies (Saeijs and Van, 1995; Rosegrant and Cai, 2001). Ensuing to globalization, industrialization and urbanization makes the issue of contamination including substantial metal contamination. The contamination because of substantial metals and metalloids is a broad issue and causes a major ecological debasement in each fragment of the environment (Hogan, 2012). Among the different metals, Arsenic is notable poisonous metal that is examined as priority contaminant. The unfriendly impacts of these two metals are all around reported (Zhao et al., 2012). People for all over the globe are exposed to the arsenic contamination through water. Via various sources such as oceans, this poison might have its harmfulness changed and might perhaps enter the natural way of life, could cause skin, lung, bladder, and kidney disease in people. The International Agency for Research on Cancer (IARC) has classified arsenic as a Group I cancer-causing agent (IARC, 2004). In this manner, natural cordial options are expected to eliminate arsenic from the climate (Elisa C. Berg, Alisson C. Borges et al. 2020). Arsenic is a normally happening substance that can be delivered into the climate by certain agrarian and modern cycles, for example, through volcanic eruptions and rocks enduring (Sodhi, Kumar, Agrawal, and Singh, 2019), mining, metal purifying, and utilization of arsenic pesticides and herbicides (Mandal and Suzuki, 2002). In spite of the fact that arsenic happens to be the twentieth most plentiful component in the geosphere, arsenic is exceptionally poisonous to the biota. In numerous spaces, arsenic levels in the climate have surpassed the protected edge for human wellbeing, 10 lg/l (WHO 1993). During the most recent thirty years, high centralization of arsenic in groundwater have been accounted for in various districts of the world, for example, the Bengal Delta (West Bengal-India and Bangladesh (Mandal et al. 1996; Bhattacharya et al. 1997, Chowdhury et al. 2000), Madhya Pradesh (Pandey et al. 1999, 2009), and numerous nations, for example, China, Mexico, Chile, USA, Argentina, Vietnam, and Taiwan (Bhattacharya et al. 2002; Smedley and Kinniburgh 2002; Bundschuh et al. 2009; Polya and Charlet 2009). High Arsenic focus in waterway and ground water were referenced in a few spaces of Pakistan e.g., Jamshoro locale (J. A. Baig, et al. 2009), Matiari (S. Q. Memon, et al. 2008) and Khairpur (A. H. Shar, et al. 2008), Manchar lake (M. B. Arain, et al. 2009), Tharparkar (K. D. Brahman, et al. 2013), Muzaffargarh (R. T. Nickson, et al. 2005), Kohistan (S. Muhammad, et al. 2010). The data for arsenic concentration in various regions of Pakistan is compiled in Table 1. In Pakistan, water from different sources is contaminated with as

especially in Sindh and Panjab regions. 16% to 36% individuals of Sindh Province are exposed to 10 ppb and 50 ppb of Arsenic concentration. Arsenic range is 3 to 50 ppb and 13 to 106 ppb in surface and ground water of Jamshoro region (J. A. Baig, et al. 2009). On the left bank of stream Indus Khairpur and Matiari locale 37% of the samples were in the scope of  $50 \geq 50$  ppb Arsenic. While 15% of samples were found to have raised measures of 250 ppb Arsenic (A. H. Shar, et al. 2008). 23% of wells in the region Khairpur were viewed as impacted with as defilement and the general presence of Arsenic and skin related diseases were viewed as 13.5% in the review including a study of in excess of 3,000 people (A. H. Shar, et al. 2008). Methods for Arsenic removal from water incorporate Pre-oxidation of arsenite to arsenate, Adsorption procedures, Membrane techniques, Point-of-utilization techniques (coagulation/adsorption/filtration-precipitation), Biological Arsenic evacuation (A. H. Malik, et al.2009). Reverse Osmosis, water Softening, Electrolysis, Ion Exchange, (Balasubramanian et al.2009; Kim et al. 2006; Kumari et al. 2006). These regular strategies experience the ill effects of certain burdens, these techniques are exceptionally costly, there cycles and components might make risky impact laborers and side-effects results ecological harm and disappointments of these advancements other than financial practicality are significant drawbacks (S. Chaudhari, et al. 2014). Other than these techniques, utilization of aquatic plants to ingest metals from encompassing water is amazingly proficient. This technique has been found effective and large satisfying and is on normal ten times less expensive than other physical, compound or warm remediation strategies (Hosamane, Sateesh N, et al. 2012) Phytoremediation includes the utilization of plants to eliminate harmful substances from the climate (I. Raskin, B.D. Ensley (Eds.) et al. 2000). Phytoremediation takes of the remarkable, particular and normally happening take-up capacities of plant root frameworks, along with the movement, bioaccumulation and poison stockpiling/debasement capacities of the whole plant body. A wide scope of plant species has been recognized as being arsenic resistant. Numerous analysts announced that plants can profoundly retain poisonous and carcinogenic substances, weighty metals, from defiled soils, that opened up the possibility for its utilization for remediation of soils. Effective application of phytoremediation to arsenic contamination soils relies upon numerous factors, among which plant biomass and arsenic concentration are the most essential. Plant species are used to separate arsenic ought to be receptive to farming practices intended to improve arsenic accumulation and to allow repeated planting and reaping of arsenic-rich biomass (TU, C.; Ma, L.Q. et al. 2002). Phytoremediation is considered a clean, cost effective and non-ecologically problematic innovation, as opposed to physical treatment techniques, for

example, soil excavation or pumping polluted groundwater. Over the past twenty years, this innovation has become progressively popular and has been utilized in situ in soil and water, contaminated with lead, uranium, and arsenic. Notwithstanding, one significant impediment of phytoremediation is that, it requires a long haul commitment, as the cycle relies upon plant development, resilience to harmfulness, and bioaccumulation capacity (Salt et al., 1995; Glick, 2004).

### 1.3 Objectives

In this study, we present an overview of:

- To check the survival of water hyacinth in arsenic enriched water
- Phytoremediation as technique for arsenic removal using macrophytes
- Examining the optimization by changing the factors (TDS, pH).

## 2. MATERIALS AND METHODS

### 2.1 Experimental setup and procedure

#### 2.1.1 Plants selection

Bunch of matured plant of water hyacinth *Eichhornia Crassipes* (Class is Liliopsida and family is Pontederiaceae) as shown in Fig 2.1 were collected from ponds near Kotri, Sindh, Pakistan. Both the land and Arial view of location is shown in Fig2.2 & Fig 2.3. In the presence of natural sunlight the plants were added in to the plastic containers along with tap water for 3 days to take up the new conditions of environment. The experiments were conducted in a series of round plastic containers containing volume capacity of 10L and surface area 3.5 m<sup>2</sup>, there were Three containers, and each container containing three plants of *Eichhornia Crassipas*. The containers were named as Container 1,2 & 3 Respectively, Container 1 was having 3 child specie of *Eichhornia Crassipas*, Container 2 has 3 adult and Container 3 containing 3 old specie, as shown in Fig 2.4, Fig 2.5 & Fig2.6. The size and weight of individual plant of each sample is given in Table 2.1 and visuals are shown in Fig 2.7.



Figure 2.1 Water hyacinth *Eichhornia-Crassipes*



Fig2.2 Aerial view of collected plant site



Fig 2.4 Container 1



Fig 2.5 Container 2



Fig 2.6 Container 3



Fig. 2.3: Land view of collected plant Location.



Plant 1



Plant2  
Container 1



Plant 3



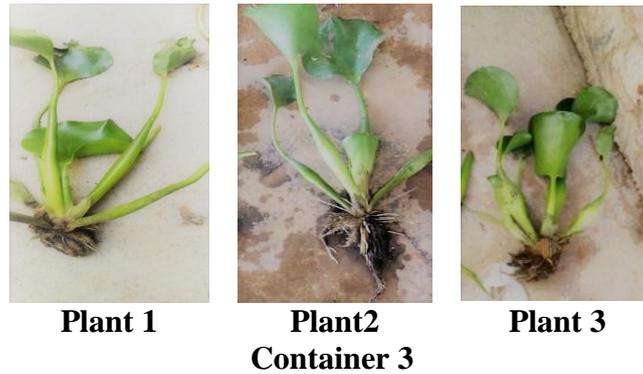
Plant 1



Plant2  
Container 2



Plant 3



**Fig. 2.7: Pictures of each individual plant.**

**Table 2.1 weight and size of each plant of every sample.**

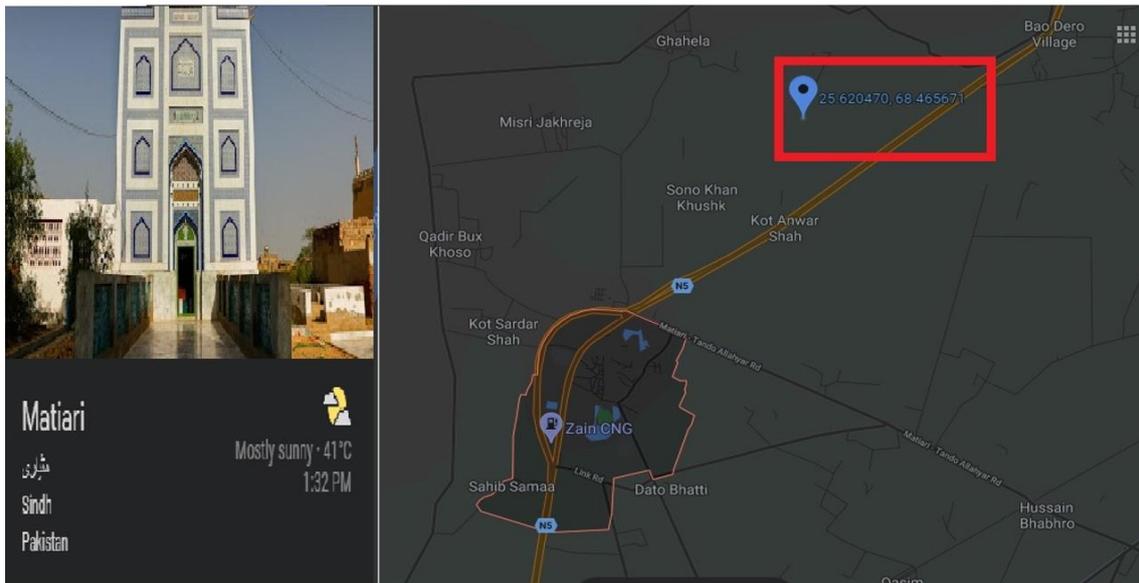
	<b>Plant</b>	<b>Weight (gram)</b>	<b>Length (inches)</b>
<b>Container 1</b>	Plant 1	15	9.1
	Plant 2	25	12
	Plant 3	21	11
<b>Container 2</b>	Plant 1	55	12
	Plant 2	62	12.1
	Plant 3	67	12.5
<b>Container 3</b>	Plant 1	20	111
	Plant 2	15.5	105
	Plant 3	17.5	120

### 2.1.2 Water Collection

From the literature the arsenic concentration of ground water in Matiari and Khairpur District region is from 50-250 ug/L which is above the permissible limit i-e, 10 ug/L (G.M. Arain, et al. 2007). The water used for the experiment was natural ground water and taken from the area near Bao Dero Village, District Matiari Sindh, Pakistan, Co-ordinates are **25.620470° N, 68.465671° E** as shown in **Fig 3.8 & Fig 3.9**. The water sample was freshly taken from the handpump in a plastic container and taken to the Institute of Environmental Engineering & Management, MUET.



**Fig. 2.8: Collecting water from 25.620470° N, 68.465671° E.**



**Fig. 2.9: Water collected site (google Map).**

### 2.1.3 Procedure

The experiments were conducted in a series of round plastic containers containing volume capacity of 10L and surface area  $3.5 \text{ m}^2$ , there were three containers. The plastic containers were kept at a place of ambient temperature and exposure of sunlight for specific time. 5Liters of obtained water was added to each container, and 9 plant species added to 3 containers, each of the container contained with 3 plant species and then named according as Container1, Container2 and Container3, as mentioned above.

## 2.2. Removal potential

Arsenic removal rate was measured by noting but the residual arsenic concentration of the obtained water with interval of 3 days. Five runs of the experiment were performed one after the other to test the reproducibility. The 30 ml sample were taken from each container 1, 2 and 3 respectively with time interval of 3 days.

### 2.2.1 Analysis of water samples

The samples taken from the containers were filtered by Whatman 50 filter papers, and then 0.5 ml of HCL 0.5M was added to preserve the sample and then placed at  $-20 \text{ }^\circ\text{C}$  until water sample tested in AAS (Atomic Absorption Spectroscopy) instrument by Hydride generation AAS for being familiar with the concentration of Arsenic to assess the removal potential of Plant.

### 2.2.2 Hydride generation atomic absorption spectroscopy HG\_AAS

Atomic Absorption Spectroscopy is a frequently used instrumental method for the analysis of some metals and metalloids ions, but due to the poor limit of detection, reproducibility and interferences, the alternative method of detecting the metalloids specially arsenic is developed, the method is known as Hydride generation atomic absorption spectroscopy HG-AAS, Perkin Elmer P 200, USA.

The tested sample has been taken as 10 ml with 1 ml of HCL in it i-e, (9 ml of sample+ 1 ml of HCL). For the instrumental calibration solution of 0.3 mg/L arsenic concentration is made from the stock solution of 1mg/L, which was present in Hi-Tech laboratory of department, and solution of sodium borohydride (NaBH<sub>4</sub>) and sodium hydro-oxide (NaOH) was made by dissolving 1250 mg of NaOH in 200 ml of distilled water and 20 grams of NaBH<sub>4</sub>.

### 2.3 Examining optimization

The same process was carried out for the optimized results, The optimized level is examined by changing pH and TDS

#### 2.3.1 pH

The effect of pH on the removal efficiency of *Eichhornia crassipes* was studied by varying the pH. The pH of the sample is analyzed by pH meter, The obtained pH from the water was between 6.8-7.2, and increased by adding 12-16 ml of NaOH into each container which resulted the pH of 8-8.2.

#### 2.3.2 Total Dissolved Solids

Total dissolved solids (TDS) are the measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular suspended form, TDS may be consisting of CaNO<sub>3</sub>, MgSO<sub>4</sub>, KNO<sub>3</sub>, (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>, MnSO<sub>4</sub>, CuSO<sub>4</sub>, ZnSO<sub>4</sub>, NaCl, Na<sub>2</sub>Mo<sub>4</sub>, KH<sub>2</sub>PO<sub>4</sub>, H<sub>3</sub>BO<sub>3</sub> and Fe-Na-EDTA. The TDS were determined by TDS Prob meter, and the results obtained by water sample for each container were from 600-700 mg/L TDS, to enhance the TDS value in order to know optimized level of *E. crassipes* we used HANNA Instruments TDS Calibration Sachet 1382 mg/L TDS. 1 sachet is used for one container which resulted 900-100 mg/L TDS.

## 2.4 Impact

The benefits of phytoremediation are definitely outweighed possible drawbacks, making it a good option to solve the problem of water pollution, and at the same time improve other aspects of human life and environment.

Concerning the role in the sustainable development, this work contributes to most of the SDGs (7 out of 17), which shows that it has a high sustainability potential, and will greatly assist the region in different aspects of development.

The Impacts related to their SDGs are given below in (Table 3.2)

**Table 3.2: Impacts and their SDGs.**

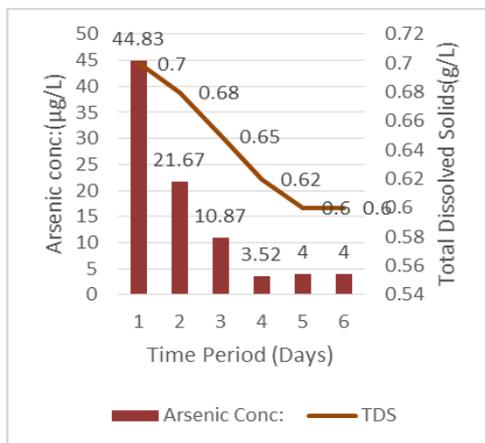
Impact	Sustainable Development Goals SDGs
Mitigating the health risk of arsenic concentration from water	Good Health and Well Being <b>SDG-3</b>
Use of the plant to uptake the metalloids from the drinking water in order to make it safe	Clean Water and Sanitation) <b>SDG-6</b>
Phytoremediation is an emerging technology for its being cost-effective, clean and environmentally eco-friendly	Affordable, reliable, sustainable and modern energy for all <b>SDG 7</b>
Using locally available and important plant, local customs and experiences in cultivation, insuring local community participation in the decision making of the work, and making them the immediate beneficiary of the phytoremediation outcome	Sustainable cities and communities <b>SDG-11</b>
Phytoremediation process of using plants which reduce the use of fossil fuels and reduce CO <sub>2</sub> , reduce warming and contributes to climate change	Climate Action <b>SDG-13</b>
By phytoremediation process reducing Arsenic concentration from water ecosystems	Life below water <b>SDG -14</b>
By phytoremediation process reducing Arsenic concentration from terrestrial ecosystems	Life on land <b>SDG-15</b>

## 3. RESULTS AND DISCUSSIONS

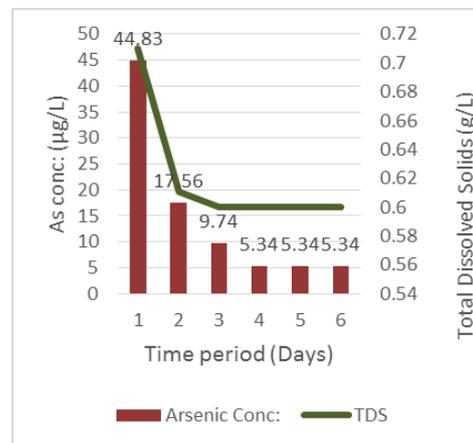
In the present work, studies on the removal of arsenic were carried out by phytoremediation technique using water floating macrophytes *Eichhornia crassipes*. The technique used in this process is called more appropriately Phyto-accumulation technique, which is a part of phytoremediation.

### 3.1 Arsenic Removal

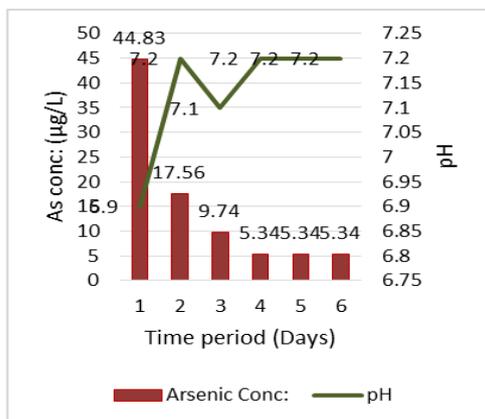
Arsenic removal rate was measured by noting but the residual arsenic concentration of the obtained water with interval of 3 days. In case of naturally occurred Total dissolved solids and pH from water sample, which was collected from Matiari district, Initially the rate at which plant removes the arsenic was higher in the first interval i-e, after three days and slowly the rate decreases in other intervals for all the three containers at obtained TDS level from water as shown in Fig 3.1. Fig 3.2 & Fig 3.3 and obtained pH level from water as shown in Fig 3.4, Fig 3.5 & Fig 3.6. The health of plant species has also been affected after 12, 9 & 9 days of container 1, 2 & 3 respectively. There have been seen a little damage and infection (anthracnose) in leaves after 12, 9 & 9 days and that was increasing by passing days. The arsenic concentration of residual water was decreasing in first three interval i-e, till 9, 9 & 12days for container 1, 2 & 3, and the concentration became approximately same after 9. 9 & 12days for container 1, 2 & 3. as all values are mentioned in Table 3.1, Table 3.2.



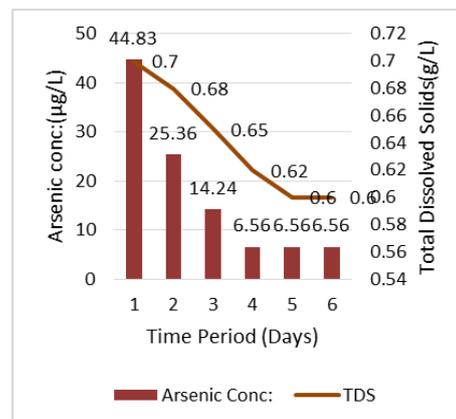
**Fig 3.1 Removal rate of arsenic with respect with respect to TDS from Container 1**



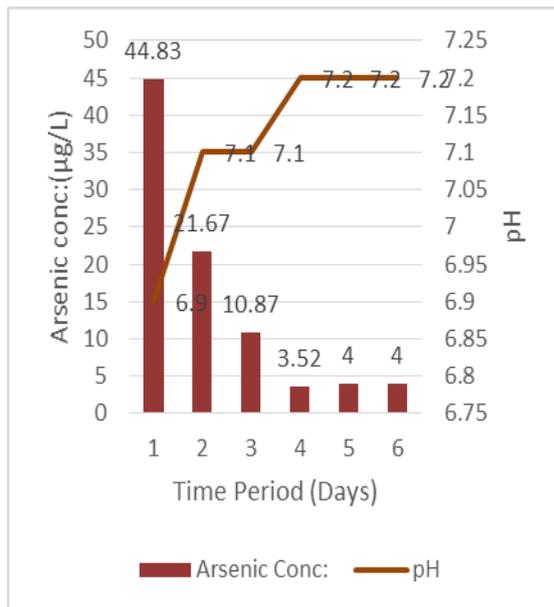
**Fig 3.2 Removal rate of arsenic to TDS from Container 2**



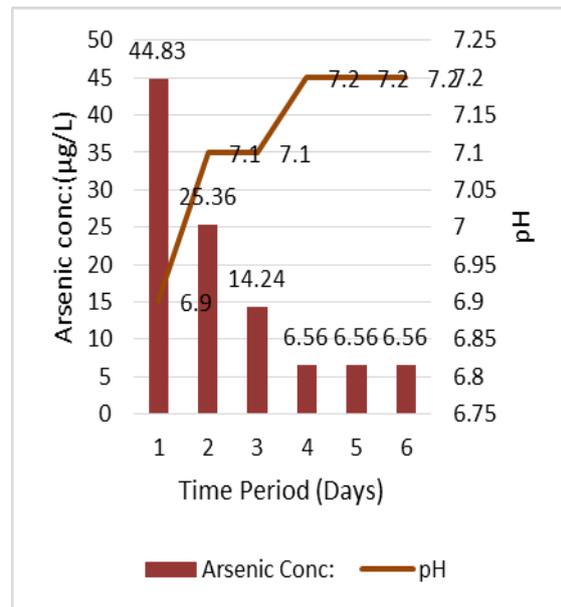
**Fig 3.3 Removal rate of arsenic with respect to TDS from Container 3**



**Fig 3.4 Removal rate of arsenic with respect to pH from Container 1**



**Fig 3.5 Removal rate of arsenic with respect to pH from Container 2**



**Fig 3.6 Removal rate of arsenic with respect to pH from Container 3**

**Table 3.1: Values of residual arsenic concentration of water with respect to Time and TDS.**

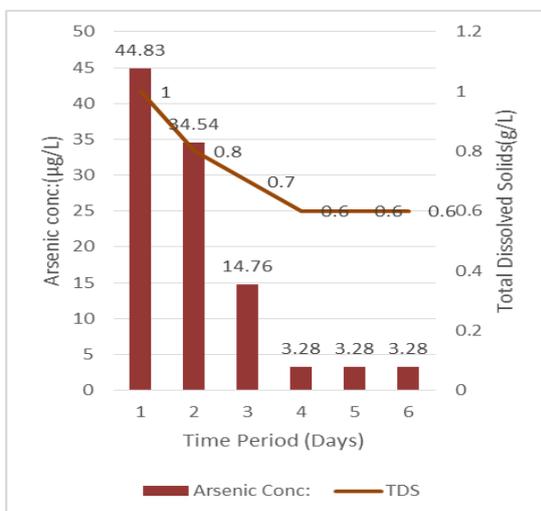
	Time period (Days)	Arsenic conc: (ug/L)	Total Dissolved Solids (g/L)
<b>Container 1</b>	0	44.83	0.71
	3	17.56	0.611
	6	9.74	0.6
	9	5.34	0.6
	12	5.34	0.6
<b>Container 2</b>	0	44.83	0.7
	3	21.67	0.68
	6	10.87	0.65
	9	3.52	0.62
	12	4	0.6
<b>Container 3</b>	0	44.83	0.7
	3	25.36	0.68
	6	14.24	0.65
	9	6.56	0.62
	12	6.56	0.6

**Table 3.2 Values of residual arsenic concentration of water with respect to Time and pH.**

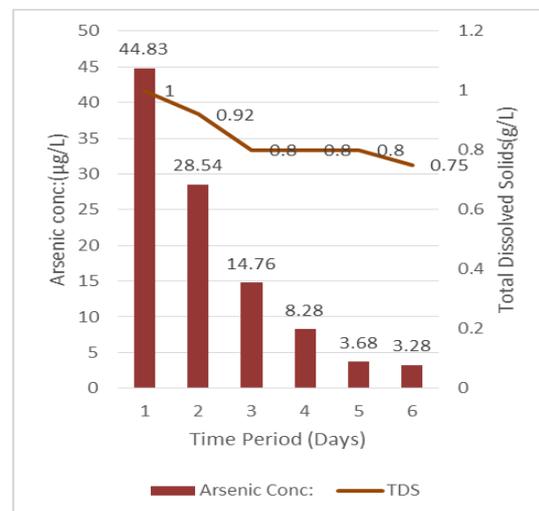
	Time period (Days)	Arsenic conc: (ug/L)	pH
<b>Container 1</b>	0	44.83	6.9
	3	17.56	7.2
	6	9.74	7.1
	9	5.34	7.2
	12	5.34	7.2
<b>Container 2</b>	0	44.83	6.9
	3	21.67	7.1
	6	10.87	7.1
	9	3.52	7.2
	12	4	7.2
<b>Container 3</b>	0	44.83	6.9
	3	25.36	7.1
	6	14.24	7.1
	9	6.56	7.2
	12	6.56	7.2

### 3.2 Changing the Factors (TDS & pH)

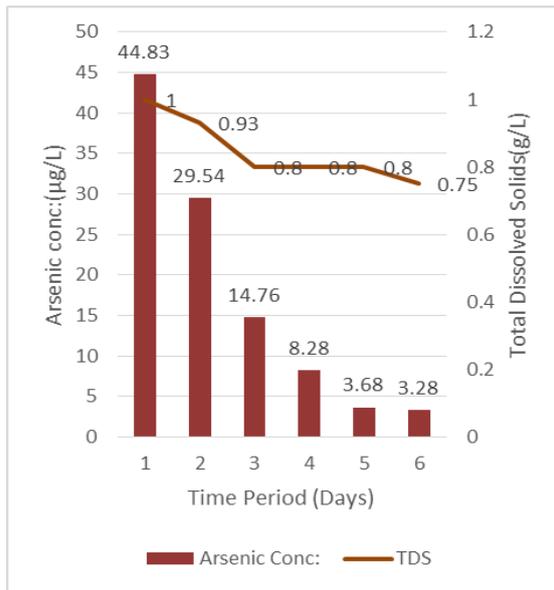
In case of artificially increasing total dissolved solids of water the rate at which plant removes the arsenic was increasing from interval to interval i-e, from day 3 to 15, as shown in **Fig 3.7, Fig 3.8, Fig 3.9 & Table 3.3**. Each plant of every container remains undamaged and un-infectious through the experiment. While increasing pH the rate of arsenic accumulation was decreased as shown in **Fig 3.10, Fig 3.11, Fig 3.12 & Table 3.4**. The health of plant species has also been affected after 12 days. There have been seen a little damage and infection (anthracnose) in leaves after 12 days in case of increased pH.



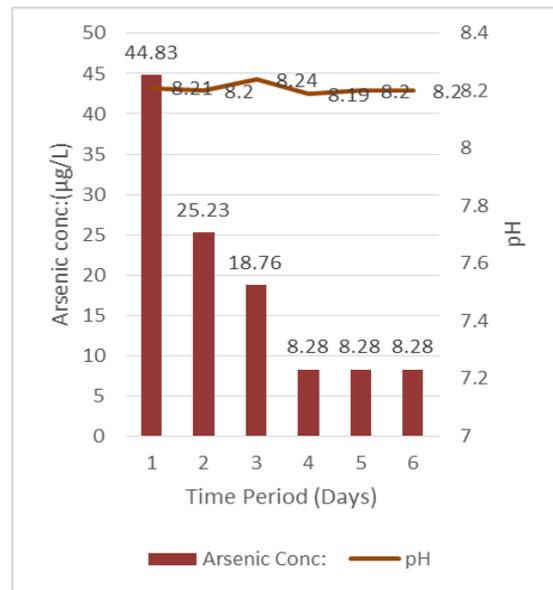
**Fig 3.7 Removal rate of arsenic with respect to TDS from Container 1**



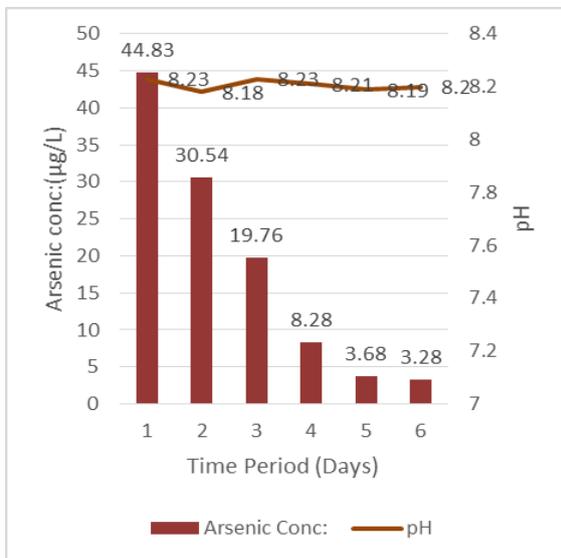
**Fig 3.8 Removal rate of arsenic with respect to TDS from Container 2**



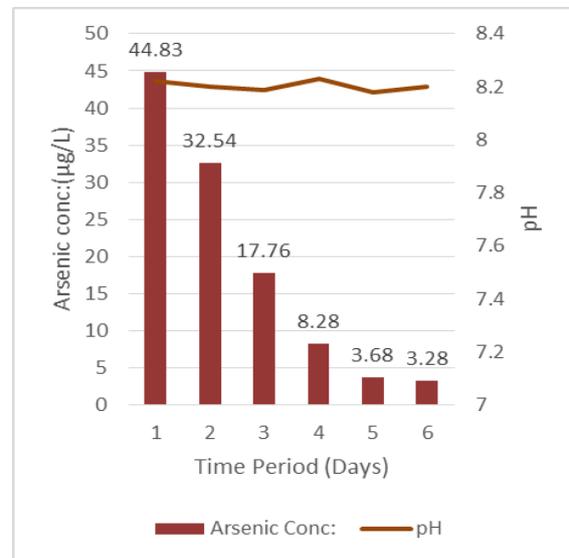
**Fig 3.9 Removal rate of arsenic with respect to TDS from Container 3**



**Fig 3.10 Removal rate of arsenic with respect to pH from Container 1**



**Fig 3.11 Removal rate of arsenic with respect to pH from Container 2**



**Fig 3.12 Removal rate of arsenic with respect to pH from Container 3**

**Table 3.3: Values of residual arsenic concentration of water with respect to Time and TDS.**

	Time period (Days)	Arsenic conc: (ug/L)	Total Dissolved Solids (g/L)
<b>Container 1</b>	0	44.83	1
	3	34.54	0.8
	6	14.76	0.7
	9	3.28	0.6
	12	3.28	0.6

<b>Container 2</b>	0	44.83	1
	3	28.54	0.92
	6	14.76	0.8
	9	8.28	0.8
	12	3.68	0.8
<b>Container 3</b>	0	44.83	1
	3	29.54	0.93
	6	14.76	0.8
	9	8.28	0.8
	12	3.68	0.8

**Table 3.2: Values of residual arsenic concentration of water with respect to Time and pH.**

	<b>Time period (Days)</b>	<b>Arsenic conc: (ug/L)</b>	<b>pH</b>
<b>Container 1</b>	0	44.83	8.22
	3	25.23	8.20
	6	18.76	8.19
	9	8.28	8.23
	12	8.28	8.18
<b>Container 2</b>	0	44.83	8.21
	3	30.54	8.20
	6	19.76	8.24
	9	8.28	8.19
	12	3.68	8.23
<b>Container 3</b>	0	44.83	8.18
	3	32.54	8.23
	6	17.76	8.21
	9	8.28	8.19
	12	3.68	8.20

#### 4. CONCLUSION

Phytoremediation technique is good and inexpensive tool for removing and/or stabilizing arsenic and to clean up of water systems. However, its success depends on both plant and water factors such as pH and Total Dissolved Solids, level of contamination. The process is best step for achieving Sustainable Development Goals. The higher removal rate of arsenic concentration from water was at lower level of TDS and pH between 6.8-7.8, but the plant specie could not survive for maximum days, where as in case of increasing total dissolved solids, plant species survived till the end of experimentation, but the removal efficiency decreased till the TDS reached to 600-700 mg/L, then uptake of arsenic started with higher rate, hence the plant priorities the minerals uptake comparing with the arsenic. In case of pH when increased from 7.2-8.2 approximately, the rate of removal concentration of arsenic was decreased, and plant species seen unhealthy after some days.

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