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Original Research Article

Experimental Comparison of Phytoremediation and Filtration Methods in the Remediation of Water Contaminated with Arsenic

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Abstract

An experimental work was done on waters contaminated with arsenic using filtration and phytoremediation methods to determine the most appropriate remediation method. Filtration method;Measurements of arsenic solution (0.00g (de-ionized water), 0.010g, 0.020g, 0.050g, and 0.0100g)was made by a 10litre pipette into an hundred milliliter bottle (100ml) containing warm de-ionized water and each was made to pass through four different geo-materials (marble, activated charcoal, filtration carbon and clay) placed on layers of sand in glass filtration tanks ; while Phytoremediation method was done by cultivation of various ages of water hyacinth (*Eichhornia crasspipes Mart. Solms*)in arsenic acid solutionof equal concentration (100.0 mg/L); an experiment based on duration and maturitywhich was to ascertain the exact hour, (0hour, 2hours, 12hours, 24hours, 48hours, 120hours) water hyacinth will absorb a metal, and at what matured level (sprouting, flowering, matured) the plant can absorb best. Plants were harvested, dried, pulverized and analysed for metal content using inductively coupled-ion chromatography and filtrates analysed using inductively coupled plasma-optical emission spectrometry. Arsenic concentration in filtrates showed no arsenic loss, indicating poor absorption capacity of the geo-materials. Highest arsenic bio-accumulation was found at 100 mg/l in matured water hyacinth. Remediation of arsenic using water hyacinth proved to be a better method for arsenic removal compared to filtration.

Keywords: Water Hyacinth, Arsenic, Absorption, Contamination, Phytoremediation, Filtrates

Introduction

Bioaccumulation of trace elements has been a crucial problem in environmental studies (Cyle et al., 2006, GazsÓ, 2001, and Kabata-Pendias and Veter, 1984). The release of heavy metals such as Cu^{2+}, Zn^{2+}, $Fe^{2+}$and As^{2+} in biologically available forms into the environment by human activity may damage or alter both natural and man-made ecosystems (Tyler. et al., 1989, Williams, et al., 2000).Arsenic (As) a toxic metal occurs naturally in soil and minerals and may get into water and land through water run-off, wind-blown dust and leaching by man (Seth, et al., 2002). The metal has harmful effects on both humans and environment, even at low concentration (Chowhury, et al., 2000, Chwirka, et al., 2000. DeMarco, et al., 2003, Nriagu, 1994, Patlolla, et al., 2005, and Wasserman, et al., 2004).Plants absorb arsenic fairly easily and also have the ability to accumulate nonessential metals such as As, Cd and Pb. This ability allows for high amount of the metal to be present in food and could be harnessed to remove pollutant metals from the environment (Lenntech, 2006).Plantsbasedbioremediation technologies have receivedrecent attention as strategies to clean-up contaminatedsoil and water.The submerged macrophytes areparticularly useful in the abatement and monitoring ofheavy metals(Das,et al. 1997, Rogers, et al., 2000, Sadowsky,1999, Salt, et al., 1995, and Zayed, et al., 1998). Water hyacinth, (*Eichhornia crassipes)*, a floatingmacrophyte has been put to use in cleaning up municipaland agriculture wastewater because of its appetite for nutrients and explosive. Geomaterials are geologically derived materials used primarily in building construction, in both the unprocessed condition and as processed construction materialthey are hazard-resistant construction materials (Hodgson, et al., 2000)These geo-materials which are also known as geotechnical materials can be found between the ground surface and the rock and influences the structural damage examples of such are marble, clay, soil, activated charcoal/carbon, this materials can also be used as filter materials in remedial works.Considering the high rate of heavy metals such as arsenic found in the metropolis and the long term effect it could have on man, it became imperative to evaluate the best possible method of experimental remediation method between phytoremediation and filtration for possible pollution that could occur in the water sources of the study area in the future.

Materials and method

Experimental methods

Two methods were utilized in the experimental remediation study to determine the better remedial method, these were, Filtrationand Phytoremediation methods.

Preparation of As solution for the experiments

Arsenic acid was prepared by treating arsenic trioxide with concentrated nitric acid:

$$As_2O_3 + 2HNO_3 + 3H_2O \longrightarrow 2H_3AsO_4 + 2HNO_3$$

Arsenic acid was formed from arsenous acid and water (H_3AsO_4) under oxygen pressure with catalytic amounts of nitric and a halide. Arsenic acid formed was then dissolved in a five liter white plastic keg with warm de-ionized water,to allow for proper dissolution of the acid.

Measurements of arsenic solution (0.00g (de-ionized water), 0.010g, 0.020g, 0.050g, and 0.0100g)(Fig 1) was made by a 10litre pipette into an hundred milliliter bottle (100ml) containing warm de-ionized water and each was made to pass through the geo-materials (Fig 2) on layers of different grain sizes of sand (very coarse sand are in the bottom, while finer sizes of sand were placed on top) in a glass filtration tanks for the filtration method, while phytoremediation method which was the experiment based on duration and maturity was to ascertain the exact hour, (0hour, 2hours, 12hours, 24hours, 48hours, 120hours) water hyacinth will absorb a metal, and at what matured level (sprouting, flowering, matured) the plant can absorb best. The same concentration of arsenic solution 100 mg/L was measured into the potsby a 10litre pipette (Figure 3).

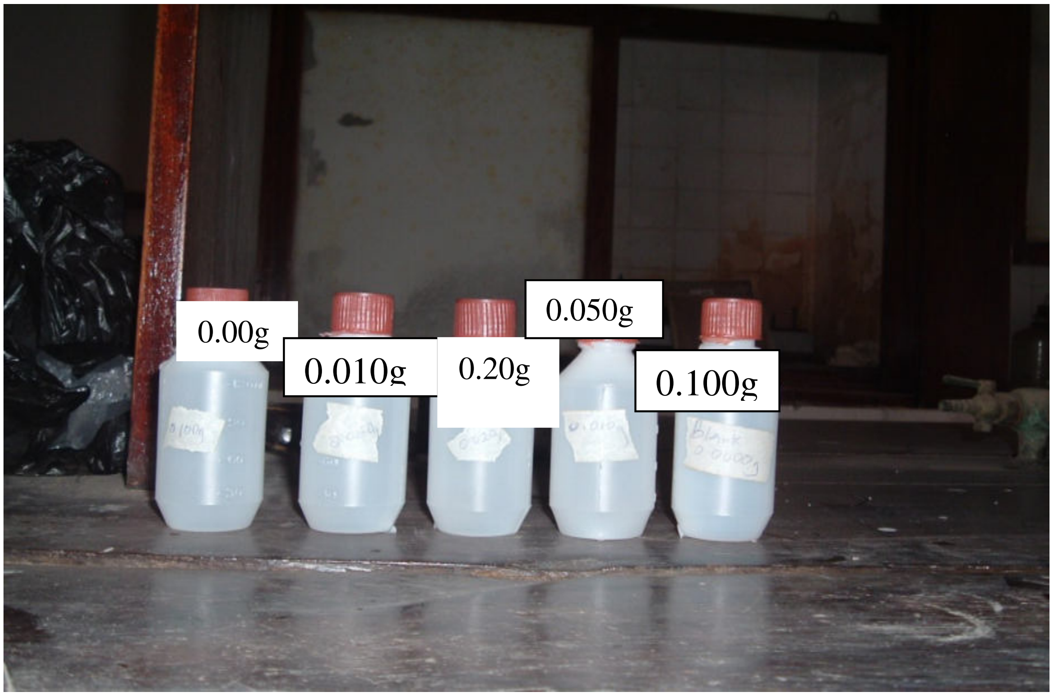
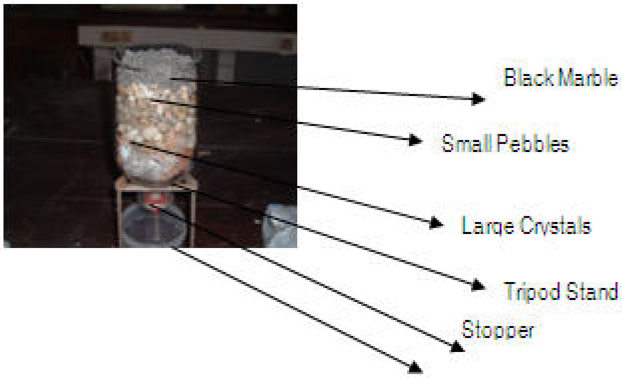


Figure. 1.Laboratory photography showing arsenic solution prepared in a 100ml bottles arranged at ascending order

Black Marble White Marble Filtration Carbon Activated Charcoal/Carbon

Clay

Geomaterials (a)



A typical glass filtration tank (b)

Figure 2: Different geo-materials (a) and Glass filtration tank (b)

The Green House

The Water Hyacinth

Transfer Function (TF)

This is a measure of bioaccumulation or uptake of metals by plants from the soil or water-based substrate. It is expressed as:

Eq. (2):TF = $\underline{C_{mplant}}$

$CM_{substrate}$

Where C_{mplant} is the measured concentration of metal, m in plant and

$CM_{substrate}$ is the measured concentration of the soil or water substrate (Uchida and Tagami;

2005) that the plant was taken from. If the Transfer uptake is greater than 1 (TF > 1) it implies that bioaccumulation or uptake of the specified metal has occurred in the plants.

Normal Metal Concentration

The Normal metal concentration (NMC) and Phyto-toxic metal (TMC) concentration in leaves (Alloway and Ayres, 1993) is used to ascertain the toxicity of leaves (Table 1.0).

Table 1.0. Normal Metal Concentration and Phytotoxic Metal Concentration

Plant concentrate	Pb mg/l	As mg/l	Zn mg/l	Cu mg/l
NMC	5.0-10	0.02-5	1.0-40	1.0-40
TMC	3.0-10	5.0-20	100-400	20-200

Translocation factor (TF) / Accumulation factor (AF)

This is a measure of the rate of accumulation in plant shoots; it is expressed as (Brooks, 1998):

Accumulation Factor = Total elemental concentration in shoot tissue

Total elemental concentration in soil/water

If the accumulation factor is greater than one (AF>1) this means the shoot is not capable of accumulating metals, while, Translocation Factor was used to affirm results of the Accumulation Factor. Translocation Factor (TF) measures the rate at which the shoot is capable of accumulating metals; (Brooks, 1998).

Translocation Factor = Total elemental concentration in shoot tissue

Total elemental concentration in the root tissue

If translocation factor is greater than 1 (TF>1) this means that the plant is useful for phyto-extraction (that is, shoot capable of accumulating metals).

Filtration Method

Geo-materials used for the experiment are black and white marble; filtration carbon; activated charcoal and clay. Clay, an important product of weathering of rocks, is yellowish in color and highly plastic and was sampled from an abandoned well in the study area. Two types of marbles (white and black) were used for the experiment; Marble is a rock resulting from metamorphism of sedimentary carbonate rocks, most commonly limestone or dolomite rock.Marbles can be found easily from Igbeti, Ewekoro and Sagamu of Oyo and Ogun State respectively of Southwestern Nigeria. Pure white marble is the result of metamorphism of a very pure (silicate-poor) limestone or dolomite protolith. The characteristic swirls and veins of many colored marble varieties are usually due to various mineral impurities such as clay,silt, sand, sand, iron oxide, or chert. Activated Charcoal/Carbon is a form of carbon that has been processed to make it extremely porous thus having a very large surface area and it is available for adsorption. Activated carbon is usually derived from charcoal. Charcoal is widely used as a substitute for kerosene in the study area and thus easy to access.Filtering Carbon is a black granule that is used most often in making batteries and this was easily found around the study area (Fig 2).

To begin the project, each geo-materialwere washed with de-ionized water to remove impurities. Thesewashedgeo-materialswere then placed to cap layers of pebbles and coarse sand materials stacked to about 0.5cm thickness in the constructed glass filtration bottle (Figure 2). Generally each washed geo-material was left to drain for 15 minutes in order to reduce the dilution effect it may have on the acid solution prior to the experiment.Arsenicacid solution prepared was then poured into the filtration bottle, andallowed to drain for 30minutes. The stopper was then removed from the filtration bottle for the filtrates to drain into a conical (collection) flask. The process was allowed to continue for 30 minutes before the filtrate was poured into a clean 100mL plastic bottle for analysis.The geo-materialand different layers of grain sizes of sand (coarse sand and pebbles) used were removed from the filtrationbottle and thrown away at the end of each process.

Phytoremediation Method

The Green House

Green house was designed to contain the cultivated plants, (Figure3). The length, breadth, and height of the house were 170 cm by 245.5 cm by 245.5cm respectively, and a green roof was placed on the house to reduce the rate at which sunlight penetrates the plants.

Water Hyacinth (*Eichhornia crasspipes Mart. Solms*)

Water Hyacinth (*Eichhornia crasspipes Mart. Solms*)(Figure 3) was rinsed with de-ionized water toremove any epiphytes and insect larvae grown on plants, and then it was cultivated in the green house.The uptake of metals is greater in plants grown in pots of water in the greenhouse than from the same water in the field (De Vries and Tiller, 1978. Page and Chang, 1978)

Experimental Procedures

In this experiment,100mg/L of arsenic acid was measured into all the five 10litre plastic buckets that Water Hyacinth(*Eichhornia crasspipes Mart. Solms*)was cultivated within twenty- four hours. The plants were harvested, dried, pulverized and then sent for analysisusing the ICP-OES methods; while, the water samples in each bucket were analyzed for to determine the rate of arsenic removal by the plants.

Results and discussion

Filtration method

Geochemical results of the geo-materials (Table 2) revealed that geo-materials were unable to absorb the metals but rather increase the arsenic level in the water (Figure 4). The geo-materials raw metal content was then evaluated and it was observed that all the geo-materials have arsenic as a by-product.High arsenic content found in clay could be associated to arsenic adsorption which is significantly positively correlated with clay content of soils apart from being a by-product of clay mineral. Elkhatib, et al., (1984a, b).(Table 2).

Phytoremediation method

The experiment based on duration and maturitythat was to ascertain the exact hour, (0hour, 2hours, 12hours, 24hours, 48hours, 120hours) water hyacinth will absorb a metal, and at what matured level (sprouting, flowering, matured) the plant can absorb best. The same concentration of arsenic solution 100 mg/L was measured into the pots. Geochemical results of the water that the water hyacinth was cultivated showed no evidence of arsenic but some trace metals like K, Ca, Na, Ba, and Zn were found this could be as a result of weathering of rocks in the study area. The water that water hyacinth was cultivated that has the same measurement of arsenic (100mg/L) but was taken at different hour revealed no evidence of arsenic in the water (Table 3), which depicts that all the arsenic content has being absorbed by the water hyacinth plant, and it also shows faster absorption by plants at shorter periods.

Table 1: Geochemical results of water from the Geo-materials in the Filtration Method

Physical materials	Concentrates(g)	Pbmg/l	Cumg/l	Znmg/l	Femg/l	Kmg/l	Camg/l	Namg/l	Bamg/l	**Asmg/l**
A	0.00	0.06	0.238	2.89	1.92	3.5	103	625	0.02	**1.02**
A	0.01	0.05	0.176	1.06	2.79	3.6	49.3	589	0.02	**27.2**
A	0.02	0.02	0.02	0.396	1.34	1.5	7.4	75.4	0.02	**58.8**
A	0.05	0.01	0.01	0.207	0.36	0.9	9.4	23	0.02	**183**
A	0.1	0.01	0.002	0.113	0.38	0.7	8.6	11	0.02	**381**
B	0.00	0.01	0.002	0.673	0.01	3.4	578	7.8	0.07	**1.37**
B	0.01	0.01	0.013	0.428	0.01	3.2	603	6.4	0.08	**14.9**
B	0.02	0.01	0.02	0.353	0.01	2.4	609	0.7	0.06	**27.9**
B	0.05	0.01	0.023	0.072	0.01	1.7	635	0.7	0.05	**77.7**
B	0.1	0.01	0.006	0.749	0.01	1.6	609	0.1	0.06	**168**
C	0.00	0.01	0.005	0.052	0.05	12.1	12.9	2.3	0.1	**1.44**
C	0.01	0.01	0.005	0.158	0.02	9.4	10.7	1.3	0.13	**37.2**
C	0.02	0.01	0.004	0.136	0.04	4	4.2	1	0.05	**38.7**
C	0.05	0.01	0.004	0.124	0.03	3.6	4.5	0.9	0.04	**131**
C	0.1	0.01	0.004	0.142	0.02	3.2	4.1	0.6	0.04	**269**
D	0.00	0.01	0.005	0.015	0.01	76.3	28.7	7	0.08	**7.94**
D	0.01	0.01	0.002	0.06	0.01	49.5	38.2	6.3	0.08	**59.3**
D	0.02	0.01	0.002	0.07	0.01	18.3	13.2	1.6	0.05	**40.2**
D	0.05	0.01	0.003	0.082	0.01	11.1	8.9	1.1	0.03	**186**
D	0.1	0.01	0.002	0.096	0.01	8.6	8.5	0.6	0.03	**398**
E	0.00	0.01	0.002	0.019	0.01	3.5	10.3	32.3	0.06	**0.15**
E	0.01	0.01	0.004	0.022	0.01	3.1	8.3	26.4	0.08	**31.4**
E	0.02	0.01	0.002	0.078	0.01	3.8	13.9	18.5	0.27	**135**
E	0.05	0.01	0.003	0.034	0.01	2.3	5.9	17	0.08	**500**
E	0.1	0.01	0.004	0.026	0.01	3.9	6.4	22	0.07	**998**

Notes: A-black marble; B – white marble; C – filtration carbon; D – activated charcoal; E – clay

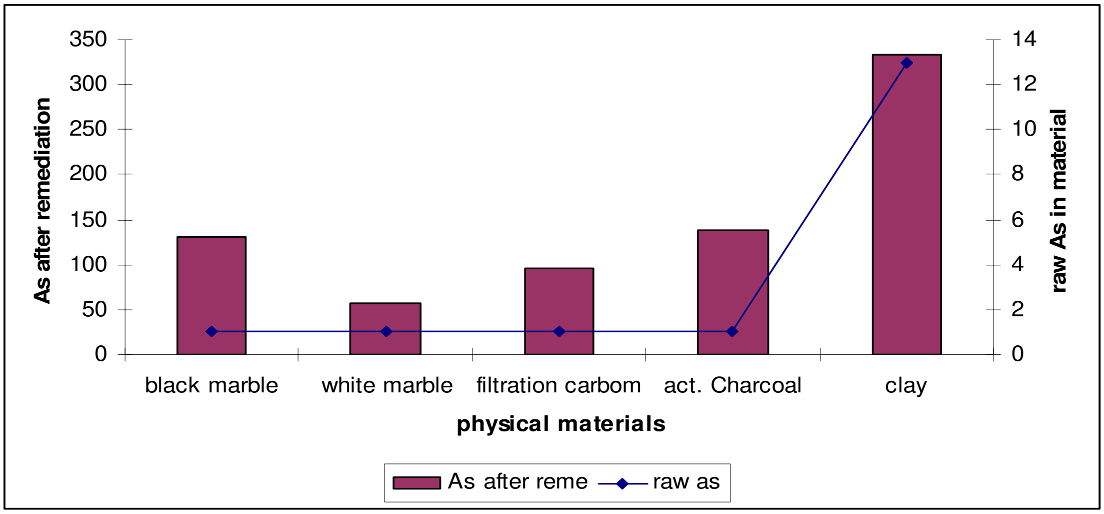


Figure 4. Statistical plot of bar chat ofAs mg/L concentrations in the water of geo-materials after experiment in the filtration method

Table 2. Comparison of the Geo-materials with the by-component

Geo-materials	As content of the raw geo-materials (µg/g)	As content after remediation (mg/l)
Black Marble	1	130.204
White Marble	1	57.974
Clay	13	332.91
Activated charcoal	1	138.288
Filtration carbon	1	95.468

Table 3. Geochemical Results of Water Based on Time and Maturity

Immersion Time(hours)	Plant Maturity	Zn mg/l	K mg/l	Ca mg/l	Na mg/l	Ba mg/l	**As mg/l**
0	No Plant	1.56	16.9	16.0	8.10	0,40	**0.01**
0	Sprouting	0.007	0.0137	0.0125	0.0151	0.31	**0.00001**
2	Sprouting	0.005	0.0138	0.0141	0.0155	0.17	**0.00001**
12	Sprouting	0.016	0.0141	0.0129	0.0159	0.2	**0.00001**
24	Sprouting	0.014	0.0154	0.0153	0.0165	0.12	**0.00001**
48	Sprouting	0.005	0.0135	0.0131	0.0163	0.13	**0.00001**
120	Sprouting	0.005	0.0203	0.0129	0.017	0.07	**0.00001**
0	Flowering	0.01	0.0139	0.0121	0.0157	0.31	**0.00001**
2	Flowering	0.005	0.0138	0.0143	0.0153	0.17	**0.00001**
12	Flowering	0.025	0.0144	0.0126	0.0164	0.2	**0.00001**
24	Flowering	0.007	0.0154	0.015	0.0162	0.12	**0.00001**
48	Flowering	0.005	0.015	0.0134	0.0167	0.13	**0.00001**
120	Flowering	0.005	0.0202	0.0139	0.0181	0.08	**0.00001**
0	Matured	0.009	0.0135	0.013	0.0162	0.33	**0.00001**
2	Matured	0.005	0.0136	0.0144	0.0157	0.18	**0.00001**
12	Matured	0.006	0.0143	0.0133	0.0156	0.21	**0.00001**
24	Matured	0.01	0.0157	0.0146	0.0157	0.12	**0.00001**
48	Matured	0.005	0.0135	0.0128	0.0165	0.13	**0.00001**
120	Matured	0.005	0.0164	0.0173	0.0191	0.145	**0.00001**

Transfer Function (TF)(Uchida and Tagami, 2005)

Transfer factor (Table 4) used to evaluate the rate of uptake of metals by the leaf, stem and root for the plants revealed that the uptake of metal is from the root, to leaf and stem. The highest uptake for arsenicwas observed in the leaves of sprouting by twelve hours (12th) and the roots between 12th and 48th hour. The uptake for flowering leaves and roots are between the 48th and 120th hour respectively, while that of the matured leaves and roots are between the 120th and 48th hour respectively. The transfer factor therefore, shows highest rate of absorption between the hours of twelve and one hundred and twenty.

Table 4: Transfer Function/ Uptake value for the leaf, stem and roots of Water hyacinth in concentrates

Plant Segment	Immersion time (hours)	As	Plant Segment	Immersion time (hours)	As	Plant Segment	Immersion time (hours)	As
Leaf	0sprouting	100.00	stem	0sprouting	100.00	root	0sprouting	200.00
Leaf	2sprouting	100.00	stem	2sprouting	100.00	root	2sprouting	800.00
Leaf	12sprouting	200.00	stem	12sprouting	100.00	root	12sprouting	1600.00
Leaf	24sprouting	100.00	stem	24sprouting	100.00	root	24sprouting	900.00
Leaf	48sprouting	100.00	stem	48sprouting	100.00	root	48sprouting	3100.00
Leaf	120sprouting	100.00	stem	120sprouting	100.00	root	120sprouting	800.00
Leaf	0flowering	100.00	stem	0flowering	100.00	root	0flowering	500.00
Leaf	2flowering	100.00	stem	2flowering	100.00	root	2flowering	800.00
Leaf	12flowering	100.00	stem	12flowering	100.00	root	12flowering	800.00
Leaf	24flowering	100.00	stem	24flowering	100.00	root	24flowering	500.00
Leaf	48flowering	100.00	stem	48flowering	200.00	root	48flowering	5400.00
Leaf	120flowering	200.00	stem	120flowering	100.00	root	120flowering	1400.00
Leaf	0matured	100.00	stem	0matured	100.00	root	0matured	200.00
Leaf	2matured	100.00	stem	2matured	100.00	root	2matured	1000.00
Leaf	12matured	100.00	stem	12matured	100.00	root	12matured	600.00
Leaf	24matured	100.00	stem	24matured	100.00	root	24matured	1900.00
Leaf	48matured	100.00	stem	48matured	100.00	root	48matured	6500.00
Leaf	120matured	100.00	stem	120matured	100.00	root	120matured	1300.00

Normal Metal Concentration (NMC) and Phytotoxic Metal Concentration (TMC)

Normal metal concentration in plants and phytotoxic metal concentration (TMC) in plants- leaves (Alloway and Ayres, 1993),NMC and TMC were used to check the rate of toxicity of metal in the leaves of the water hyacinth, the result showed that leaves of water hyacinth used in the concentrationshave an anomalously high value of arsenic (157.89-1302.63mg/l) while all the leaves showed an evidence of bioaccumulation. The highest rate of bioaccumulation was found in the leaves with highest spiced arsenic (100mg/l) this confirms an evidence of bioaccumulation of metals by the leaves as the arsenic solution increases. (Table 5)

Table 5: Comparison of the Water Hyacinth leaves with Normal Metal Concentration and Phytotoxic Metal Concentration

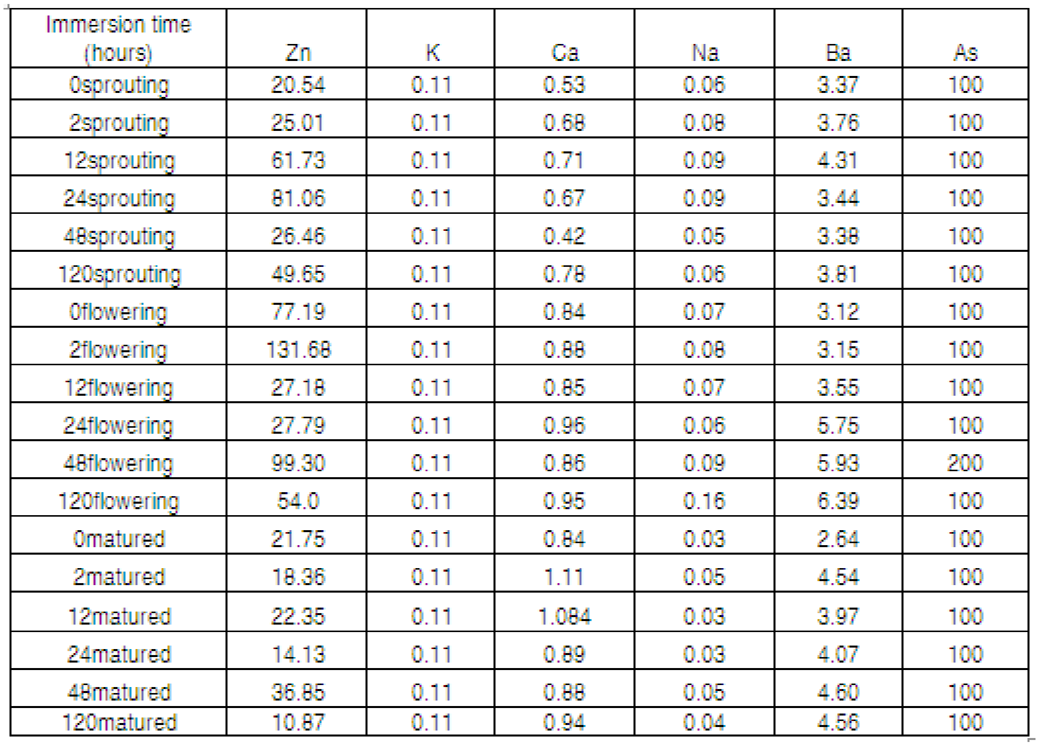
Young	Pb mg/L	As mg/L	Zn mg/L	Cu mg/L
Water hyacinth (leaves)	0.50-3.28	100-200	33.22-46.39	6.29-10.00
NMC	5.0-10	0.02-5	1.0-40	1.0-40
TMC	3.0-10	5.0-20	100-400	20-200
Medium	Pb mg/L	As mg/L	Zn mg/L	Cu mg/L
Water hyacinth (leaves)	0.77-2.82	100-200	17.76-40.47	3.63-10.48
NMC	5.0-10	0.02-5	1.0-40	1.0-40
TMC	3.0-10	5.0-20	100-400	20-200
Old	Pb mg/L	As mg/L	Zn mg/L	Cu mg/L
Water hyacinth (leaves)	0.46-1.08	100	14.26-32.01	4.10-7.91
NMC	5.0-10	0.02-5	1.0-40	1.0-40
TMC	3.0-10	5.0-20	100-400	20-200

Notes:
NMC- Normal metal concentration
TMC-Phytotoxic metal concentration.

Accumulation Factor (AF) and Translocation Factor (TF)

The accumulation and translocation factor are used to deduce the rate of accumulation and absorption of the metals. Accumulation Factor (AF) Brooks, (1998) of the stem which is greater than one showed that the stem cannot accumulatearsenic or any other metals (Table 6). The result was confirmed by the results of the Translocation Factor (TF) (Brooks, 1998) that was less than one in most of the metals which shows that the stem is not capable of absorbing the metals. However, the results of TF revealed that the stem is capable of absorbing metals such asCa, Na, Ba and K at certain levels but it cannot accumulate the metal at any concentration (Table 7).

Table 6: Accumulation Factor (AF) for the Stem of water hyacinth plant in water concentrates



Immersion time (hours)	Zn	K	Ca	Na	Ba	As
0sprouting	20.54	0.11	0.53	0.06	3.37	100
2sprouting	25.01	0.11	0.68	0.08	3.76	100
12sprouting	61.73	0.11	0.71	0.09	4.31	100
24sprouting	81.06	0.11	0.67	0.09	3.44	100
48sprouting	26.46	0.11	0.42	0.05	3.38	100
120sprouting	49.65	0.11	0.78	0.06	3.81	100
0flowering	77.19	0.11	0.84	0.07	3.12	100
2flowering	131.68	0.11	0.88	0.08	3.15	100
12flowering	27.18	0.11	0.85	0.07	3.55	100
24flowering	27.79	0.11	0.96	0.06	5.75	100
48flowering	99.30	0.11	0.86	0.09	5.93	200
120flowering	54.0	0.11	0.95	0.16	6.39	100
0matured	21.75	0.11	0.84	0.03	2.64	100
2matured	18.36	0.11	1.11	0.05	4.54	100
12matured	22.35	0.11	1.084	0.03	3.97	100
24matured	14.13	0.11	0.89	0.03	4.07	100
48matured	36.85	0.11	0.88	0.05	4.60	100
120matured	10.87	0.11	0.94	0.04	4.56	100

Table 7: Translocation Factor (TF) for the Stem of water hyacinth plant in water concentrates

Immersion time (hours)	Zn	K	Ca	Na	Ba	As
0sprouting	0.47	1.00	1.35	0.63	0.59	0.50
2sprouting	0.34	1.00	1.74	1.30	4.03	0.13
12sprouting	0.72	1.00	2.62	1.89	1.69	0.06
24sprouting	1.96	1.00	1.92	3.13	23.88	0.11
48sprouting	0.45	1.00	1.71	1.80	0.97	0.03
120sprouting	1.02	1.00	2.89	3.64	3.80	0.13
0flowering	1.63	1.00	1.42	1.67	5.83	0.20
2flowering	3.41	1.00	5.04	8.19	1.34	0.13
12flowering	0.42	1.00	2.44	2.08	5.41	0.13
24flowering	0.35	1.00	2.81	1.76	3.56	0.20
48flowering	2.06	1.00	2.62	3.02	4.90	0.04
120flowering	0.85	1.00	3.61	9.03	8.47	0.07
0matured	0.70	1.00	0.96	0.30	0.44	0.50
2matured	0.64	1.00	2.22	1.01	7.23	0.10
12matured	0.38	1.00	1.39	0.49	5.38	0.17
24matured	0.46	1.00	2.90	1.52	4.10	0.05
48matured	0.69	1.00	2.24	1.55	7.69	0.02
120matured	0.43	1.00	3.31	1.30	3.38	0.08

Conclusions

Filtration method involves the use of different geo-materials (marble (white and black), carbide, charcoal, and clay) the geo-materials were of no effect since the materials were not able to remediate arsenic, since they contain arsenic as part of its product.
Phytoremediation method involves cultivation of Water Hyacinth (Eichhornia crassipes) in a greenhouse, the experiment which was based on As level concentration, showed a progressive increase asAs concentration increases. Transfer factor showed highest uptake in the root, then leaves and then stem. Low absorption by stem was also confirmed by bioaccumulation factor (AF) and translocation factor (TF), the plant was also found to be able to absorb other metals like Ca, Na, Ba and K. Normal metal concentration in plants (NMC) and phytotoxic metal concentration (TMC) in plants- leaves, revealed the leaves to be toxic, which show absorption of acid by the leaves.
In conclusion, the study provides the best method (Phytoremediation) that can be used to remediate in case of pollution and also analysed reasons why the other method (Filtration) is inadequate, Water-hyacinth was also shown from the experiment to be a good remediation material for metals like arsenic.

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