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Removal of Arsenic by Phytoremediation - A Study of Two Plant Spices

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Abstract:

Arsenic is a naturally occurring element widely distributed in the earth's crust. Arsenic is very toxic when found in large quantities of drinking water. In countries around the world, particularly some part of India and Bangladesh, arsenic contaminates the groundwater supply. Removal of arsenic by conventional method is very costly, this paper focuses the method of phytoremediation to remove arsenic from soil. This method is being aesthetically pleasing and is on average tenfold cheaper than other physical, chemical or thermal remediation methods. Pteris Vittata and Vettiver Grass were chosen for the laboratory study, growth of these plants were observed in different concentration of arsenic contained soil by using sodium arsenate at different concentrations of 10 - 50 mg As/kg soil. The accumulation of arsenic in leaves, steam and root were analyzed at time interval of 15, 30, 45 and 60 days. It was observed that all the plants were survived in the varied concentration of arsenic and the results of the study were encouraging. When they were harvested and tested, results showed that these plants can accumulate significant amount of Arsenic in soil.

Key word: pteris vittata, vetiver grass, arsenic removal, phytoremediation.

Introduction:

Arsenic is widely distributed in the biosphere. It occurs in sea water at a level of about 2 µg / kg [1,2]. It is present in more than 200 different minerals, the most common of which is called arsenopyrite. About one-third of the arsenic in the earth's atmosphere is of natural origin. Volcanic action is the most important natural source. The next most important source is arsenic-containing vapor that is generated from solid or liquid forms of arsenic salts at low temperatures. Inorganic arsenic of geological origin is found in groundwater used as drinking water in several parts of the world, for example Bangladesh, India and Taiwan. Elemental arsenic is produced commercially from arsenic trioxide. Arsenic trioxide is a by-product of metal smelting operations. Compounds of arsenic are notorious as poisons but at the same time there are indications that arsenic is an essential element [3]. Arsenic toxicity is dependent on its chemical form. Of the inorganic forms of arsenic, arsine is highly toxic, and arsenite is accepted as being more toxic than arsenate [4]. About 70% of the world production of arsenic is used in timber treatment, 22% in agricultural chemicals, and the remainder in glass, pharmaceuticals and metallic alloys. Mining, metal smelting and burning of fossil fuels are the major industrial processes that contribute to arsenic contamination of air, water and soil. In recent years, arsenic contamination of water has become a major concern on a global scale [5].The use of arsenic-containing pesticides in the past has left large areas of agricultural land contaminated. The use of

arsenic in the preservation of timber has also led to contamination of the environment

Arsenic and its compounds are naturally present in low concentration at places with high geothermal activities (6). The current drinking water quality guideline by WHO for arsenic is 0.01 ppm (7). The permissible limit of arsenic concentration in potable water is fixed at 50µg/l in India, Bangladesh and many other countries, however WHO (1993) recommends lowering this limit provisionally to 10µg/l, which has been endorsed by Bureau of Indian standards (2003). According to the Union Ministry of Water Resources, eight districts of West Bengal and one district of Bihar are arsenic contaminated. The fact is that arsenic is increasingly found in the districts of Bihar, Uttar Pradesh, Madhya Pradesh, Assam and some parts of Raichur district, Karnataka state (8,9,10,11). Scientists report that arsenic is natural and is found in this region because it came with the silt deposited by the mighty rivers centuries ago. This silt was deposited when the rivers meandered and slowed down, so it is widespread in the deltas of West Bengal and Bangladesh.

Phytoremediation involves the use of plants to remove toxic substances from the environment [12]. Phytoremediation takes advantage of the unique, selective and naturally occurring uptake capabilities of plant root systems, together with the translocation, bioaccumulation and pollutant storage/degradation abilities of the entire plant body. A wide range of plant species has been identified as being arsenic resistant. Many researchers reported that ferns can highly absorb toxic and carcinogenic substances, heavy metals, from contaminated soils, that opened up the possibility for its use for remediation of soils. Successful application of phytoremediation to arsenic contaminated soils depends on many factors, among which plant biomass and arsenic concentration are the most important. Plant species used to extract arsenic should be responsive to agricultural practices designed to enhance arsenic accumulation and to allow repeated planting and harvesting of arsenic-rich biomass [13]. In India, Pteris Vittata L. is very common and widely distributed, and It can be found in Brazil from the northern to the southern region [14]. It is found on almost any calcareous substrate, such as old masonry, sidewalks, building crevices, with exposed limestone, among the known arsenic hyperaccumulators, Pteris vittata (brake fern) is one of the most efficient and most studied plants. Brake fern effects, reported that the Pteris vittata is extremely efficient in extracting arsenic from soils [15]. It accumulates up to 22,630 mg per kg of soil of its above ground biomass, indicating its high tolerance to arsenic efficient mechanisms of arsenic detoxification [15]. Although it is reported that this plant species is endemic in the sub tropical region, there are a few reports on its availability and elucidation of conformity for arsenic accumulation. In addition to this, it has also been reported that different genotypes of Pteris vittata exhibit variation in their capability for arsenic tolerance and hyper accumulation, that can take up and concentrate in excess of 0.1% of a given element in their tissue [16]. Keeping these aspects in mind, efforts have been made to spot Pteris vittata endemic to the Indian sub-continent and, ascertain its capability for arsenic tolerance and accumulation.

Figure 1: Pteris Vittata

Figure 2: Vetiver Grass

All species of vetiveria were originally distributed in the Old World tropics. Vetiveria zizanioides is believed to be native to northern India, where it has usually been found growing wildly or traditionally cultivated in low, damp wetlands [17]. It gets its name from the Tamil word 'vetriver', meaning root. From India it travelled to the West Indies, Fiji and Africa, where a new use was found for it as a sponge to hold the soil in place and prevent erosion, according to a report by the Academy for Mountain Environics, an NGO based in Dehra Dun, in north India. With the support of the World Bank, Vetiveria zizanioides has been used for soil and water conservation in India[18], due to its unique morphological and physiological characteristics, which has been widely known for its effectiveness in erosion and sediment control[19,20] has also been found to be highly tolerant to extreme soil conditions including heavy metal toxicities [21], but it can also protect fields against pests and weeds. Vetiver has favorable qualities for animal feed. From the roots, oil is extracted and used for cosmetics and aromatherapy. Can tolerate and grow in high metal contaminated soil, the Vetive different concentrations of up to 150 mg arsenic per kilogram of soil and significantly decreased with the arsenic accumulating more in the roots than in the leaves.

Materials and methods

The species of plants that absorb arsenic are collected from fern garden at Bontanical garden at R.L.Science college, Belgaum and University of Agricultural Science, Dharwad, Karnataka State. Selected Pteris Vittata and Vetiver grass among the identified plant species that grow under tolerable environmental conditions.

The soil sample was collected in college campus these samples were tested for the parameters like moisture, pH, soil type at the laboratory conditions. These soil samples are treated with various concentration of sodium arsenate. The two plants were grown in five different pots with concentrations of 10, 20, 30, 40 and 50 mg/liter. The growths of the plants were observed at different time intervals of 15, 30, 45 and 60 days. The leaves, roots and steam of the plants were collected and oven dried and the individual plant parts were analyzed for the accumulation of arsenic.

Growth of the Plant

Pteris Vittata and Vettiver grass were grown in 5 different pots containing 2 kilogram of soil with different arsenic concentrations ranging from 10 to 50 ppm and 2 grams of Di-ammonium phosphate to provide nutrition's to these plant species and kept it under partial sunlight conditions with sufficient water supply for the plant species to grow.

The species were collected and planted in soil samples without arsenic contamination. Mean while known quantity of soil samples were collected, and analysed for pH, moisture content of the soil was checked for both the soil samples with and without arsenic contaminations. Growth is observed for every 15 days

Collection of Plant Parts

After every 15 days plant species were cut into roots, stems and leaves and kept for drying in the oven at 70^{o}C, the dried samples are crushed and further volumetric analysis is carried out.

Volumetric Analysis for The Determination of Arsenic Content

About 0.1 gm of the sample is first mixed with about 8 g of a fusion mixture of 4 gm of Na_2CO_3 and 4 gm of KNO_3 in a porcelain crucible, and is heated for about 30 min. After cooling of the crucible, distilled water is added, left it for 12-16 hours, and filtered with a filter paper. The filtrate is acidified with 40 ml nitric acid and boiled to release the CO_2. Excess NaOH is then added to make the solution alkaline to phenolphthalein and the red color just discharged with acetic acid. The arsenate formed is then precipitated with excess silver nitrate and filtered. After washing the precipitate with cold distilled water it is re-dissolved in 40 ml HNO_3 and titrated against 0.09 N potassium thiocyanate, ferric alum is used as indicator to get end point.

Result and Discussions:
Ph of soil sample

The pH of the soil is tested at the laboratory condition and the pH of the soil is tested with different concentrations of sodium arsenate by using gravimetric method. It is observed that the pH of the soil is decreased with number of day.

Table 1 : Standard Soil Sample

Characteristic	Value	Analyzed Method
Moisture	10%	Gravimetric Method
pH	6.2	pH Meter

Table 2: change in soil pH with varying concentrations of arsenic

Arsenic Concentration, ppm	0	10	20	30	40	50
Soil pH	6.2	6.5	6.7	6.75	6.85	7.00

Growth observation

Pteris Vittata and Vettiver Grass both the plants were grown very well in different concentration of arsenic. The growth of the plant were observed and measured at different interval of time 15, 30, 45 and 60 days

Table 3: growth of Pteris Vittata in different concentrations of arsenic in Soil Sample

Different concentrations of As in Soil Sample (mg As/kg of soil)	Initial Height	15th Day	30th Day	45th Day	60th Day
10	12.5 cm	20.0 cm	26.0 cm	35.0 cm	39.0 cm
20	15.0 cm	16.0 cm	17.0 cm	25.0 cm	31.0 cm
30	11.0 cm	12.0 cm	15.5 cm	16.5 cm	18.0 cm
40	12.5 cm	14.0 cm	16.6 cm	18.0 cm	21.0 cm
50	10.0 cm	13.0 cm	14.5 cm	17.0 cm	19.0 cm

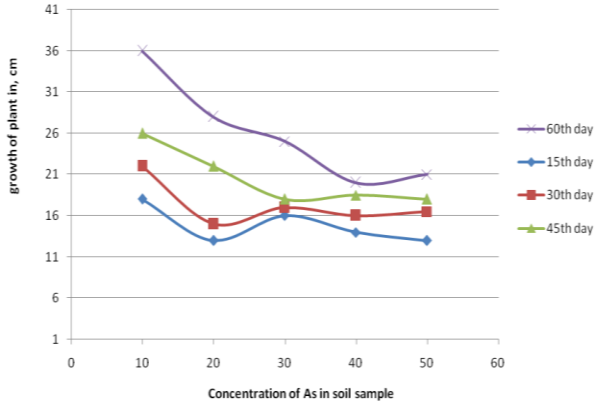

Figure 3- Growth of plant Pteris Vittata versus concentration of arsenic in soil

Table 4: growth of Vettiver Grass in different concentrations of arsenic in Soil Sample

different concentrations of As in Soil Sample (mg As/kg of soil)	Initial Height, cm	15th Day	30th Day	45th Day	60th Day
10	10.5 cm	18.0 cm	22.0 cm	26.0 cm	36.0 cm
20	09.0 cm	13.0 cm	15.0 cm	22.0 cm	28.0 cm
30	15.0 cm	16.0 cm	17.0 cm	18.0 cm	25.0 cm
40	12.5 cm	14.0 cm	16.0 cm	18.5 cm	20.0 cm
50	12.0 cm	13.0 cm	16.5 cm	18.0 cm	21.0 cm

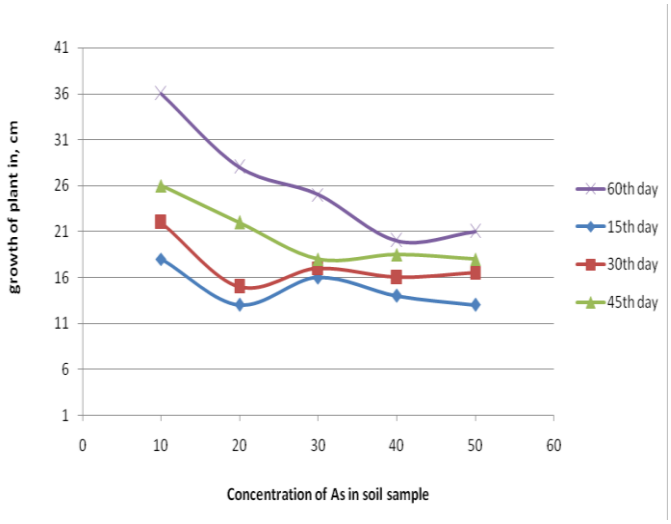

Figure 4: Growth of plant Vettiver Grass versus concentration of arsenic in soil

Estimation of accumulation of arsenic in plant

Amount of arsenic accumulated in the plat were analyzed in the laboratory by using volumetric method, is compared with analytical method and it has been observed that the accumulation of arsenic is increasing with number of days.

Table 5: Percentage Recovery of arsenic in Pteris Vittata

Standard Arsenic concentration in ppm	Burette Reading of soil (ml)	Burette Reading of Pteris Vittata (ml)	% Removal
10	1.1	0.7	63.63
20	2.6	2.4	92.31
30	2.7	2.5	92.60
40	4.4	2.8	63.63
50	4.55	4.4	96.70

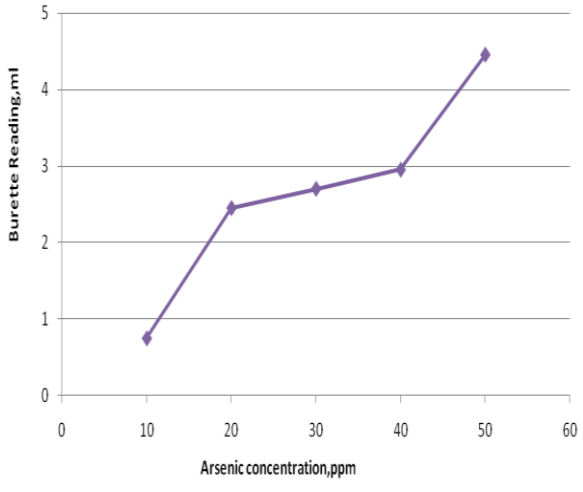

Figure 5: Concentration of arsenic in soil (Pteris Vittata)

Table 6: Percentage Recovery of arsenic in Vettiver Grass

Standard Arsenic concentration, ppm	Burette Reading of soil, ml	Burette Reading of Vettiver Grass, ml	% Recovery
10	1.1	0.7	63.63
20	2.6	1.2	46.15
30	2.7	2.3	85.18
40	4.4	2.7	61.36
50	4.55	3.6	79.12

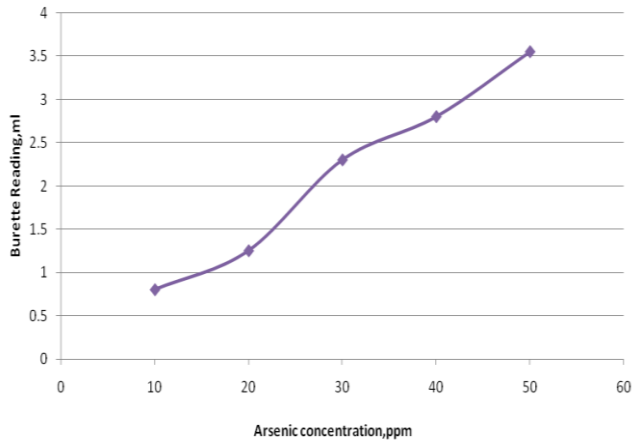

Figure 6: Concentration of arsenic in soil (Vettiver Grass)

During the experimental period, the above mentioned plants and ferns survived under all conditions of soil arsenic concentration and grew well in the control group. This finding has confirmed that plants and ferns are highly tolerable and thus could grow in high arsenic contaminated soil. Percentage recovery of arsenic by Pteris Vittata Fern is more than Vettiver Grass.

Conclusion

When the contaminated wastes cannot be practically or economically treated or removed, offsite pollution caused by the spreading of the pollutants must be prevented. Wind and water erosion and leaching are often the causes of off-site contamination. Literature shows that phytoremediation is the most practical and economical means of attenuating the problem on large scale. Vetiver grasses could grow well in arsenic contaminated soil, up to 180 mg As/kg soil. Vetiver grass and Pteris Vittata posses the ability to grow well in every soil arsenic concentration. It is recommended that Vetiver grass could be used to remove arsenic contaminated soil.

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