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ORIGINAL RESEARCH

Sawdust as an ameliorant to decontaminate Arsenic in potato soils

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Abstract

Purpose Bangladesh is an agriculture-based country, where about 3 million ha is covered by groundwater sources for irrigation, but a significant portion of irrigation water is Arsenic contaminated. To produce Potato under Arsenic contaminated soil, an experiment was conducted to find out the effect of sawdust as an adsorbent to decontaminate Arsenic toxicity in soil.

Method The research was conducted in pot experiment. It consisted of two factors. Factor A: Arsenic levels (4) viz., As_0: control (0 mg/kg soil), As_1: 25 mg/kg soil, As_2: 50 mg/kg soil, and As_3: 75 mg/kg soil. Factor B: Sawdust levels (4) viz., S_0: control (0 g/kg soil), S_1: 10 g/kg soil, S_2: 50 g/kg soil, and S_3: 100 g/kg soil.

Results Arsenic content in Potato tuber peel and flesh gradually increased with the increase of Arsenic levels. As_3 was found for the highest accumulation of Arsenic in tuber peel (3.867 mg/kg fresh weight) and flesh (0.6236 mg/kg fresh weight). Arsenic content in both peel and flesh of Potato tuber decreased with increasing sawdust levels. The soil treated with S_3 reduced 86.41% and 51.44% Arsenic accumulation from tuber peel and flesh, respectively, compared to control (S_0). Potato produced from the treatment As_1S_1 accumulated a lower amount of Arsenic (0.15 mg/kg fresh weight) in Potato flesh compared to those of other treatments.

Conclusion Therefore, Potato growers can produce Potato in 25 mg/kg Arsenic contaminated soil treated with 10 g sawdust/kg soil, which contains a minimum than the critical level of Arsenic for human consumption.

Keywords Arsenic, Biosorbent, Sawdust, Soil, *Solanum tuberosum*

Introduction

Arsenic (As) toxicity in groundwater is a crucial issue in Bangladesh and 30 most affected districts with more than 35 million people are exposed to drinking water contaminated with Arsenic at levels above the national standard of 50 µg L^{-1}. In Bangladesh, Arsenic concentration in groundwater ranged from <10 - >1000 µg L^{-1} (Hasanuzzaman et al. 2015). Arsenic contamination in groundwater was found in about 85% of the total area of Bangladesh (Haque et al. 2018). Irrigation with Arsenic contaminated groundwater is a vital source to enter Arsenic in the human food chain via the water-soil-crop-food system (Haque et al. 2015). Recently, it has been recognized that Arsenic contaminated groundwater used for irrigation may create the same serious health hazard to people, who consume food from the irrigated crops (Geng et al. 2006), and that Arsenic accumulating in irrigated soil creates a serious threat to sustainable agriculture in affected regions (Heikens 2006). Bangladesh is predominantly an agricultural country. The people of Bangladesh not only drink the Arsenic contaminated groundwater but also irrigate their crops. The total area under irrigation is about 4 million ha, where 75% is covered by groundwater sources (Heikens 2006). About 86% of the total groundwater withdrawn is used in the agricultural sector (Huq et al. 2004). If water is contaminated, it may be threatening for plants, animals as well as for human. Irrigation is predominantly executed in the dry season for Rabi (winter) crop cultivation. Long-term irrigation with Arsenic contaminated groundwater is likely to increase its concentration in the soil as well as in crops (Ullah 1998; Huq et al. 2003). Intensive cultivation of cereal (Boro rice, Wheat, and

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Maize), root crops (Potato, Sweet potato, Carrot, etc.), and vegetables require a high amount of irrigation water (Abedin et al. 2002). Total Arsenic concentration in soils is increasing day by day with an average concentration 35 to 40 mg kg^{-1} and a maximum of 75 mg kg^{-1} that can reach levels up to more than 1000 mg kg^{-1} (Mukhopadhyay et al. 2002). An increase of Arsenic concentrations in the cultivated medium leads to an increase in Arsenic concentration in the edible parts of vegetables (Huq et al. 2004; Shamsuddoha et al. 2005; Shaibur et al. 2009). The highest acceptable concentration of Arsenic in agricultural soil is 20 mg kg^{-1} (Kabata-Pendias and Pendias 1992; Hasanuzzaman et al. 2015). About 20% of crop (cereal) production was reduced due to a high concentration of Arsenic (20 mg kg^{-1} soil) in the plant body (Begonia et al. 1998). Arsenic accumulation in the plant parts depends on various factors, for example, plant species, soil type, soil nutrient supply, and pH (Tu and Ma 2003); among them, plant species are a significant factor. Larsen et al. (1992) observed that leafy plants accumulated Arsenic by atmospheric deposition, while tuberous plants, for example carrots and potatoes, accumulated Arsenic by both root uptake and atmospheric deposition.

Potato (*Solanum tuberosum* L.) is one of the vital tuberous food crops in the world. In Bangladesh, it ranks 2nd after rice in production. The total area under Potato crop, per hectare yield, and total production was 0.468 million hectares, 20.61 tons per ha, and 9.6 million tons, respectively (BBS 2019). Arsenic concentration in plants varied from 0.007 mg kg^{-1} to 7.50 mg kg^{-1} (Hasanuzzaman et al. 2015). Using Arsenic contaminated irrigation water, Potato accumulated a higher concentration of Arsenic (Haque et al. 2015). People of Arsenic affected areas are consuming contaminated Potatoes, which may cause a serious health issue. Very limited researches have been done on the effects of utilizing Arsenic contaminated irrigation water or soil for Potato production and induce toxicity in Potatoes and its impact on sustainable agriculture.

Arsenic cannot be destroyed easily and can only be converted into different forms or transformed into insoluble compounds in combination with other elements (Choong et al. 2007). Biosorption technology includes heavy metal removal performance for industrial wastewater, which is economical compare with others (Lee et al. 2009). It is a conventional technique for heavy metal remediation. Biosorption uses adsorbents that come from non-living biomass like sawdust, rice husk, eggshell, etc. and removes toxic metals from industrial wastewater (Lee et al. 2009). The principal uptake mechanism generally requires unspecific ion exchange reactions. For example, positively charged groups available in the biomass structure, for instance, the amino groups, are potential reactive sites to form adsorptive complexes with negatively charged ions, for example, arsenate, arsenite, chromate, sulfate, or phosphate (Veglio and Beolchini 1997). Some works have been done to eliminate arsenate by biosorption (Hansen et al. 2006). Sawdust is a good source of biosorbent (Choong et al. 2007). It consists of carbon (60.8%), oxygen (33.8%), hydrogen (5.2%), nitrogen (0.9%), lignin, cellulose, hemicelluloses, and a minor amount of extraneous materials (5-10%) (Phonphuak and Chindaprasirt 2015). However, challenges in developing biosorbents with maximum uptake and minimum cost as well as in recognizing the biosorption mechanism remain still unexploited. The objective of the study was to determine the optimum sawdust level for reducing Arsenic accumulation in Potato in Arsenic contaminated soil.

Materials and methods

The study was conducted at the Agronomy Greenhouse of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh from November 2016 to February 2017 and November 2017 to February 2018 in Rabi season (winter season) in two consecutive years. Sufficient sunshine and comparatively low temperature prevailed throughout the experimental time (BARC 2020), which is favorable for Potato growing in Bangladesh. The research consisted of two factors viz., Factor (A): Arsenic levels (As_{0-4}): As_0 - 0 mg kg^{-1} soil (control), As_1 - 25 mg kg^{-1} soil, As_2 - 50 mg kg^{-1} soil, As_3 - 75 mg kg^{-1} soil; Factor (B): Sawdust levels (S_{0-3}): S_0 - 0 g kg^{-1} soil (control), S_1 - 10 g kg^{-1} soil, S_2 - 50 g kg^{-1} soil, S_3 - 100 g kg^{-1} soil. For the Arsenic treatment of soil, Sodium meta-arsenate ($Na_2HAsO_4.7H_2O$) was used as the source of Arsenic. Sawdust was collected from a sawmill. The study was conducted in pot experiment (greenhouse condition) with a Randomized Complete Block Design (RCBD) with three replications, thus comprised of 48 baskets. The basket was set at 60 cm × 25 cm spacing, considering 66666 baskets were accommodated in 1 ha area. The collected soil was sandy loam. Soil pH and organic carbons were 5.6 and 0.45%, respectively. The experimental soil of basket was fertilized with a recommended dose of N, P, K, S, Zn, and B @ 57.5 µg, 34.5 µg, 75 µg, 10.8 µg, 1.8 µg, 0.875 µg, respectively, per kg soil

(Mondal et al. 2011). The planting materials comprised the foundation seed tubers of Cardinal (BARI Alu-8) variety of Potato. Collected seed potato tubers were kept at room temperature to facilitate sprouting. The properly sprouted, healthy, and uniform sized (60-70 g) seed potato tubers were planted according to treatment and an entire Potato planted in a basket. Seed potatoes were planted on an average 4-5 cm depth in the basket. All the intercultural operations and plant protection standards were taken as per when required. Haulm pulling was done at 90 DAP when the majority of plants showed senescence and the tops started drying. After haulm pulling, the tubers were kept under the soil for 7 days for skin hardening. The Potatoes of each basket were separately harvested, bagged, tagged, and brought to the laboratory for further analysis.

After harvesting, collected data were statistically analyzed to study the effect of sawdust and Arsenic on Potato, and evaluation of treatments for the identification of optimum sawdust level for reducing the toxicity of Arsenic from Potato tuber in Arsenic contaminated soil. The same experiment was conducted under the same treatment combination under the identical greenhouse condition in two consecutive years, and finally, the treatment means were taken from those two experiments for analysis.

Dry matter content

The samples of tubers were collected from each treatment. After peeling off the tubers from each treatment, peel and flesh were separately dried in a drying oven at 72°C for 72 hours. Dry matter content was calculated as the ratio between dry and fresh weight and expressed as a percentage (%). The dry matter percentage was calculated with the following formula.

$$\text{Dry matter content (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} X\,100$$

Total soluble solids

Total soluble solids (TSS) were measured in ^{o}brix by refractometer. Three tuber samples were taken from each treatment to determine TSS, then calculated average value from three sample data.

Specific gravity

The fresh weight of the tuber was taken first. Then the samples of tuber were sunk in a full water fill beaker. The tuber removed the equal volume of the water. The removed water weight was taken and the specific gravity of tuber was calculated with the following formula:

$$Specific\ gravity = \frac{Weight\ of\ fresh\ tuber}{\text{Weight of equal volume of water removed by tuber}}$$

Chemical analysis

Potatoes were harvested and packed with labeled net bags according to treatment. After peeling the tuber, both peel and flesh samples were separated into different labeled packets. The labeled packets were immediately sent to the Analytical Laboratory of Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka, where Arsenic was determined with an Atomic Absorption Spectrophotometer (HG-AAS) following USEPA method 1632 (USEPA 2001).

Statistical analysis

The mean data obtained for different characters were statistically calculated based on the method of analysis of variance (ANOVA) by using R & RStudio statistical software. The significant differences among the treatment means were compared by Fisher's Least Significant Difference (LSD) method at a 5% level of probability.

Results and discussion

Tuber dry matter content

For different Arsenic levels, dry matter content of tuber peel was observed non-significant (Table 1). The dry matter content of tuber peel varied significantly with different sawdust levels. The maximum dry matter content was recorded in S_3 (17.77%), which was statistically similar to S_2 (17.38%) and S_1 (17.12%), while the minimum was found in S_0 (16.32%), which was statistically similar to S_1 (17.12%) and S_2 (17.38%) (Fig. 1). Dry matter content of tuber peel was significantly influenced by the combined effects of Arsenic and sawdust levels. It was observed that the highest dry matter content of tuber peel was obtained from As_3S_2 (19.29%), which was statistically similar to As_2S_2, As_2S_3, As_1S_2, As_1S_3, As_3S_1, As_3S_0, As_0S_2, As_0S_3, As_3S_3 and As_1S_1, whereas the lowest was recorded in As_0S_0 (14.47%) (Table 2).

Dry matter content of tuber flesh was found non-significant for different Arsenic levels (Table 1). This research work showed distinct variations in tuber flesh dry matter content with different sawdust levels. The maximum dry matter content was recorded in S_3 (16.65%), which was statistically similar to S_2 (15.68%) and S_1 (15.17%), while the minimum was found from S_0 (13.71%) (Fig. 1). Dry matter content of tuber flesh was influenced by treatment combinations of Arsenic and sawdust levels. The maximum dry matter content (17.58%) was obtained from As_2S_2 which was statistically similar to As_2S_3, As_2S_1, As_1S_2, As_3S_3, As_3S_2, As_3S_1, As_0S_2, As_0S_1, As_3S_0 and As_1S_3, whereas the minimum was recorded in As_1S_0 (12.95%) (Table 2).

Application of different levels of Arsenic had no effect on both tuber peel and flesh dry matter content but with the increasing of sawdust levels up to 100 g sawdust kg^{-1} soil gradually increased both tuber peel and flesh dry matter content. A higher concentration of Arsenic is toxic to plant, it influences the metabolic process, induces phytotoxicity (Haque et al. 2015) and affects different types of plant nutrients especially the phosphate through disrupting of phosphate metabolism, which ultimately reduces the uptake of P in a plant (Farnese et al. 2014). But P is essential to increase the percentage of dry matter of Potato (Fernandes et al. 2015). As a result, when sawdust levels were increased, the accumulation of Arsenic was decreased in plant and increased tuber dry matter content by uptaking more P in a plant.

Specific gravity of tuber

Specific gravity of tuber varied significantly with dif-

Table 1 Effect of Arsenic levels on percentage of dry matter content

Treatments	Tuber peel dry matter content (%)	Tuber flesh dry matter content (%)
As_0	15.02	15.94
As_1	14.72	16.56
As_2	16.14	17.37
As_3	15.82	17.72
CV (%)	9.76	12.04
Level of significance	NS	NS

As_0: Control, As_1: 25 mg As/kg soil, As_2: 50 mg As/kg soil, As_3: 75 mg As/kg soil. NS- Non-significance.

Table 2 Combined effect of sawdust and Arsenic levels on percentage of dry matter content

Treatments	Tuber peel dry matter content (%)	Tuber flesh dry matter content (%)
As_0S_0	14.47 d	13.92 cd
As_0S_1	16.22 bd	15.53 a-d
As_0S_2	17.35 a-c	16.35 a-c
As_0S_3	17.24 a-d	14.29 bd
As_1S_0	16.09 bd	12.95 d
As_1S_1	16.95 a-d	14.41 bd
As_1S_2	17.76 a-c	16.70 a-c
As_1S_3	17.68 a-c	14.81 a-d
As_2S_0	15.87 cd	13.10 d
As_2S_1	15.68 cd	16.82 a-c
As_2S_2	19.08 a	17.58 a
As_2S_3	18.87 ab	17.07 ab
As_3S_0	17.35 a-c	14.88 a-d
As_3S_1	17.37 a-c	15.9 a-d
As_3S_2	19.29 a	15.98 a-d
As_3S_3	17.09 a-d	16.53 a-c
LSD Value	3.089	2.782
CV (%)	12.04	9.76
Level of significance	*	*

As_0: Control, As_1: 25 mg As/kg soil, As_2: 50 mg As/kg soil, As_3: 75 mg As/kg soil, and S_0: Control, S_1: 10 g sawdust/kg soil, S_2: 50 g sawdust/kg soil, S_3: 100 g sawdust/kg soil. * indicates 5% level of significance.

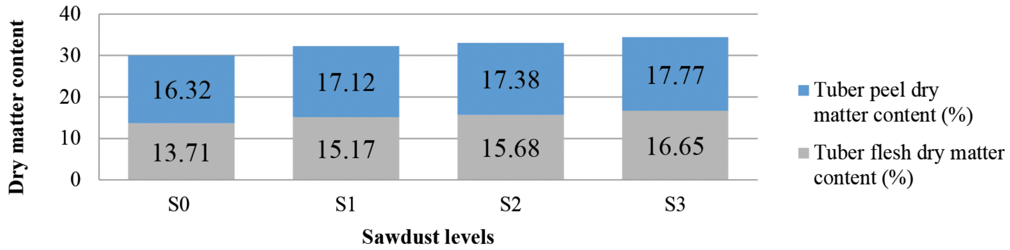

Fig. 1 Effect of sawdust levels on percentage of dry matter content

S_0: Control, S_1: 10 g sawdust/kg soil, S_2: 50 g sawdust/kg soil, S_3: 100 g sawdust/kg soil. (LSD value: 1.544 and 1.391 in tuber peel and flesh dry matter content, respectively).

ferent Arsenic levels. The study showed that specific gravity gradually increased with the increase of Arsenic levels. The maximum Specific gravity of tuber recorded from As_2 (1.036 g cm^{-3}), which was statistically similar to As_3 (1.033 g cm^{-3}), while the minimum was in As_0 (1.014 g cm^{-3}) (Table 3). Due to the application of different levels of sawdust, the specific gravity of the tuber varied significantly. The experiment indicated that treated with S_1 (10 g sawdust kg^{-1} soil) produced the maximum specific gravity of tuber compared to those of other treatments and a higher dose of sawdust reduced specific gravity of tuber. The highest specific gravity (1.039 g cm^{-3}) of tuber was recorded in S_1, while the minimum (1.013 g cm^{-3}) was found from S_2 (Table 4). Specific gravity of tuber was significantly influenced by the treatment combinations of Arsenic and sawdust levels. The maximum specific gravity of the tuber was observed in As_0S_2 (1.063 g cm^{-3}), while the minimum was found in As_0S_1 (1.005 g cm^{-3}) (Table 5).

With the increase of Arsenic levels, the specific gravity of the tuber was increased. In the case of the application of sawdust, the specific gravity of the tuber slightly increased then decreased with the increase of sawdust. A high concentration of P may decrease specific gravity (Freeman et al. 1998). So, when sawdust levels were increased, the accumulation of Arsenic was decreased and the Potato plant was able to uptake more P, which decreased specific gravity in the tuber.

Total soluble solids of tuber

Total soluble solids (TSS) of tuber varied significantly with different Arsenic levels. Table 3 showed that the total soluble solids of tuber decreased with increasing Arsenic levels. The maximum total soluble solid of tuber was recorded from As_0 (6.375° Brix) while the minimum from As_1 (5.708° Brix). Total soluble solids of tuber varied significantly with different sawdust levels. The experiment indicated that sawdust had an antagonistic relationship with the total soluble solids of the tuber. Table 4 showed that total soluble solid decreased with increasing sawdust levels. The maximum value of TSS of tuber was recorded in S_0 (6.33° Brix), which was statistically similar to S_1; while the minimum was found from S_2 (5.5° Brix). Treatment combinations of different Arsenic and sawdust levels significantly influenced the total soluble solid of the tuber. The maximum total soluble solid of tuber was observed in As_0S_0 (7.0° Brix), which was statistically similar to As_3S_0, As_1S_1, and As_0S_3; while the minimum was found from As_1S_2 (5.0), which was also statistically similar to As_1S_0, As_3S_1, As_3S_2, and As_2S_3 (Table 5).

Table 3 Effect of Arsenic levels on specific gravity of tuber and total soluble solids

Treatments	Specific gravity of tuber (g/cm^3)	Total soluble solid of tuber (°Brix)
As_0	1.0135 c	6.375 a
As_1	1.0196 b	5.708 b
As_2	1.0359 a	5.792 b
As_3	1.0328 a	5.792 b
LSD Value	0.0037	0.428
CV (%)	3.59	8.69
Level of significance	*	*

As_0: Control, As_1: 25 mg As/kg soil, As_2: 50 mg As/kg soil, As_3: 75 mg As/kg soil. * Indicates 5% level of significance.

Table 4 Effect of sawdust on specific gravity of tuber and total soluble solids

Treatments	Specific gravity of tuber (g/cm^3)	Total soluble solid of tuber (ºBrix)
S_0	1.029 b	6.333 a
S_1	1.039 a	5.958 ab
S_2	1.013 d	5.500 c
S_3	1.019 c	5.875 bc
LSD Value	0.0037	0.428
CV (%)	3.599	8.690
Level of significance	**	*

S_0: Control, S_1: 10 g sawdust/kg soil, S_2: 50 g sawdust/kg soil, S_3: 100 g sawdust/kg soil. ** and * Indicate 1% and 5% level of significance, respectively.

Table 5 Combined effect of sawdust and Arsenic levels on specific gravity of tuber and total soluble solids

Treatments	Specific gravity of tuber (g/cm^3)	Total soluble solid of tuber (ºBrix)
As_0S_0	1.057 ij	7.00 a
As_0S_1	1.005 j	6.00 bd
As_0S_2	1.063 a	6.00 bd
As_0S_3	1.042 cd	6.50 a-c
As_1S_0	1.015 f-h	5.50 de
As_1S_1	1.040 d	6.50 a-c
As_1S_2	1.053 b	5.00 e
As_1S_3	1.049 bc	5.83 c-e
As_2S_0	1.013 g-i	6.00 bd
As_2S_1	1.007 ij	6.00 bd
As_2S_2	1.016 f-h	6.00 bd
As_2S_3	1.018 e-g	5.16 de
As_3S_0	1.020 e-g	6.83 ab
As_3S_1	1.026 e	5.33 de
As_3S_2	1.010 h-j	5.00 e
As_3S_3	1.021 ef	6.00 bd
LSD Value	0.007	0.8562
CV (%)	3.59	8.69
Level of significance	*	*

As_0: Control, As_1: 25 mg As/kg soil, As_2: 50 mg As/kg soil, As_3: 75 mg As/kg soil, and S_0: Control, S_1: 10 g sawdust/kg soil, S_2: 50 g sawdust/kg soil, S_3: 100 g sawdust/kg soil. * Indicates 5% level of significance.

The application of Arsenic reduced the total soluble solids of tuber (Paul et al. 2014). The application of sawdust also decreased the total soluble solids of the tuber.

Arsenic content of tuber peel

Arsenic content of tuber peel varied significantly ($P \leq 0.01$) with different Arsenic levels. Fig. 2 showed that the Arsenic content of the tuber peel gradually increased with increasing Arsenic levels. The highest arsenic content of tuber peel was recorded from As_3 (3.867 mg/kg) while the minimum was in As_0 (0.00 mg/kg). Fig. 2 also showed that a high positive correlation was observed between the Arsenic level in the soil and Arsenic accumulation in tuber peel ($R^2 = 0.937$**). Comparison of Arsenic accumulation of different plant parts of Potato clearly showed that the translocation of Arsenic in edible parts was relatively lower than any other plant parts. Arsenic accumulation of different plant parts was in the following sequence: root > stem > leaf > tuber, irrespective of all cultivars (Kundu et al. 2012). Arsenic concentration in Potato peel was higher than Arsenic concentration in Potato flesh (Norton et al. 2013). A higher concentration of Arsenic in soils also creates higher absorption of this element by roots, which are damaged and plants are restricted in growth (Onken and Hossner 1995).

Arsenic content of tuber peel varied significantly ($P \leq 0.01$) with different sawdust levels. Fig. 3 showed that the Arsenic content of tuber peel (mg/kg) decreased gradually with increasing sawdust levels. The highest Arsenic content of tuber peel was recorded in S_0 (4.164 mg/kg), while the minimum was found from S_3 (0.5658 mg/kg). The concentration of Arsenic in tuber peel drastically decreased with increasing sawdust levels (Fig. 3). Fig. 3 showed that a high negative correlation was observed between sawdust levels and Arsenic accumulation in tuber ($R^2 = 0.902^{**}$) and there was a close negative affinity between sawdust and Arsenic accumulation in tuber peel. A plant can only uptake Arsenic as As (III) and As (V). However, it is possible when Arsenic complex hydrolysis in soil solution and make As (III) and As (V) but when sawdust or bioadsorbent was present in the soil, the As (III) and As (V) made a bond with different cellulosic organic complex with soil colloid and produced intermediate complex among Arsenic, cellulosic compound and soil colloid. In this regard, the plant could not accumulate Arsenic. Sawdust has a close affinity for heavy metal remediation from the aqueous solutions (Sud et al. 2008). The sorption of heavy metals towards biomaterials is attributed to their constituents, which are mostly carbohydrates, proteins, and phenolic compounds because they carry functional groups, for example, amines, carboxyls, and hydroxyls, which can bind to the metal ions (Choi and Yun 2006). Arsenite adsorption by the bioadsorbent (maize cob) changed with phosphoric acid/ammonia was 11 $\mu g\ g^{-1}$, which corresponds to 98% removal from a 550 μg As L^{-1} solution for an adsorbent dose of 50 mg ml^{-1} where the maize cob changed by phosphoric acid/urea removed 0.4 $\mu g\ g^{-1}$ arsenate from a 300 μg As L^{-1} solution (Elizalde-González et al. 2008). Arsenate and arsenite uptake by plants depends on various environmental conditions but biosorption techniques, Arsenic is removed by a biological substrate, as a sorbent, bacteria, fungi, algae, or vascular plants surfaces based on passive binding of Arsenic or other contaminants on cell wall surfaces containing special active functional groups. Hence, more works are required on addressing the molecular-level behavior of Arsenic in plants, kinetics of uptake, and transfer of Arsenic in plants with flowing waters, remobilization through decay, possible methylation, and volatilization (Vithanage et al. 2012).

With 5% eggshell addition, the increase in soil pH may contribute to heavy rapeseed residue, metal immobilization by altering heavy metals into more stable in soils. Concentrations of - Cd and Pb were reduced by up to 67.9 and 93.2% by the addition of 5% eggshell compared to control (Lee et al. 2013). The adsorption specificity of sawdust is Pb > Cu > Cd > Zn, where the adsorption capacity of Cu and Pb onto NaOH-treated sawdust is improved 2~3 times compare to the untreated sawdust (Lee et al. 2009). The highest biosorption capacity of the sawdust modified with ferric oxyhydroxides, evaluated by the Langmuir adsorption model, was 9.259 mg g^{-1} and the adsorption capacity recommending that the prepared chemically modified biosorbent has a prospect in the remediation of Arsenic from the contaminated soil water (Urik et al. 2009).

The treatment combination of sawdust level and different Arsenic levels influenced the Arsenic content of tuber peel significantly ($P \leq 0.01$). Arsenic content of tuber peel was observed maximum in As_3S_0 (6.820 mg/kg) while no accumulation (0.000 mg/kg) was found from As_0S_0 (0.000 mg/kg), As_0S_1(0.000 mg/kg), As_0S_2 (0.000 mg/kg) and As_0S_3 (0.000 mg/kg) treatment combinations (Fig. 4). Treatment combinations of As_0S_0, As_0S_1, As_0S_2 and As_0S_3 showed that there was no Arsenic accumulation by tuber peel because Arsenic levels were controlled. Arsenic level As_1 (25 mg/kg soil) was same four treatments As_1S_0, As_1S_1, As_1S_2 and As_1S_3 where As accumulation by tuber peel was (3.523, 2.1, 1.102 and 0.3967 mg/kg) where sawdust level was S_0 (control), S_1 (10 g sawdust/kg soil), S_2 (50 g Sawdust/kg soil) and S_3 (100 g Sawdust/kg soil) (Fig. 4). Fig. 4 showed that only by increasing of sawdust level, the accumulation of Arsenic decreased in tuber peel. Sawdust acted as a bioadsorbent in soil and breakdown by microorganism with the presence of soil water and produced cellulosic waste materials viz., acetamido, amido, amino, alcoholic, carbonyl, phenolic, sulphydryl groups, etc. by microorganism with the presence of soil water adsorb Arsenic by sawdust from the Soil solution and make an intermediate complex between soil colloid and Arsenic. Sawdust has a close affinity for heavy metal remediation from the aqueous solutions (Sud et al. 2008). High bioadsorbent in soil occurred more as a bisoroption process, that's why by increasing different sawdust levels in a particular concentration of Arsenic, Arsenic content in tuber peel decreased (Fig. 4). Result showed same trends in case of As_2 and As_3 Arsenic levels with S_0, S_1, S_2 and S_3 sawdust level As_2S_0 (6.313 mg/

kg), As_2S_1 (4.43 mg/kg), As_2S_2 (2.277 mg/kg) and As_2S_3 (1.023 mg/kg), and As_3S_0 (6.82 mg/kg), As_3S_1 (4.78 mg/kg), As_3S_2 (3.023 mg/kg) and As_3S_3 (0.843 mg/kg).

Arsenic content of tuber flesh

Arsenic content of tuber flesh varied significantly ($P \leq 0.01$) with different Arsenic levels. Fig. 2 showed that the Arsenic content of tuber flesh increased gradually with increasing Arsenic levels. The highest arsenic content of tuber flesh was recorded from As_3 (0.6236 mg/kg), while the minimum was in As_0 (0.00 mg/kg). High positive correlation was observed between Arsenic level in the soil and Arsenic accumulation in tuber flesh ($R^2 = 0.924^{**}$). Fig. 2 indicated that Arsenic accumulation in tuber flesh increased with the increasing Arsenic levels in the soil. Arsenic accumulation of different plant parts was in the following sequence: root > stem > leaf > tuber, irrespective of all cultivars (Kundu et al. 2012). A higher concentration of Arsenic in soils also creates higher absorption of this element by roots, which are damaged and plants are restricted in growth (Onken and Hossner 1995).

Arsenic content of tuber flesh was strongly significant ($P \leq 0.01$) with different sawdust levels. Fig. 3 showed that the Arsenic content of tuber flesh (mg/kg) decreased gradually with increasing sawdust levels. The highest Arsenic content of tuber flesh was found in S_0 (0.415 mg/kg), which is while the minimum was found from S_3 (0.2015mg/kg). Fig. 3 showed that a high negative correlation was observed between sawdust levels in soil and As accumulation in tuber flesh ($R^2 = 0.902^{**}$). Arsenic

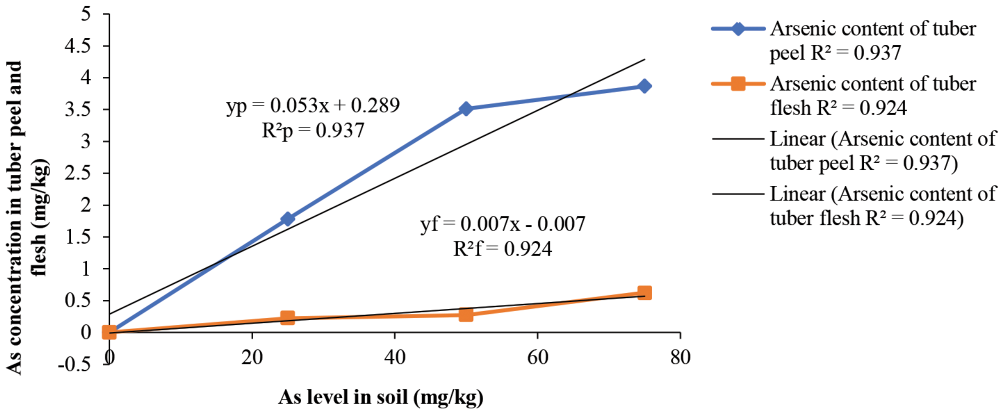

Fig. 2 Linear relationship between Arsenic level in soil and Arsenic content of tuber peel and flesh

As_0: Control, As_1: 25 mg As/kg soil, As_2: 50 mg As/kg soil, As_3: 75 mg As/kg soil. (LSD value: 0.1099 and 0.008426 in As content in tuber peel and flesh, respectively).

accumulation in tuber flesh decreased significantly with the increase of sawdust levels as compared to control treatment (Fig. 3). Comparison of Arsenic accumulation in different levels of sawdust treatments, plant parts of Potato clearly showed that translocation of As in tuber flesh edible parts were gradually lower to S_0 (0.4150 mg/kg), S_1 (0.390 mg/kg), S_2 (0.2569 mg/kg) and S_3 (0.2015 mg/kg) when sawdust levels were gradually higher.

Treatment combination of different sawdust and Arsenic levels influenced the Arsenic content of tuber flesh significantly ($P \leq 0.01$). Arsenic content of tuber flesh was observed maximum (1.083) in As_3S_0 while no As was found from As_0S_0 (0.000), As_0S_1 (0.000), As_0S_2 (0.000) and As_0S_3 (0.000) treatment combination (Fig. 4). The result showed similar trends in regards to As content in tuber peel. The result concluded that high bioadsorbent in soil that occurred as a more bisoroption process, that's why by increasing different sawdust levels in a particular concentration of Arsenic, Arsenic content in tuber flesh drastically decreased by only increasing of sawdust level. Sawdust acted as a bioadsorbent in soil and breakdown by microorganism with the presence of soil water and produced cellulosic waste materials viz. acetamido, amido, amino, alcoholic, carbonyl, phenolic, sulphydryl groups, etc., by microorganism with the presence of soil water adsorb As by sawdust from the soil solution and make an intermediate complex between soil colloid and As. Sawdust has a close affinity for heavy metal remediation from the aqueous solutions (Sud et al. 2008). As a result, when different sawdust (bioadsorbent) levels increased in soil more biosorption process occurred, then the concentration of Arsenic decreased in tuber flesh (Fig. 4).

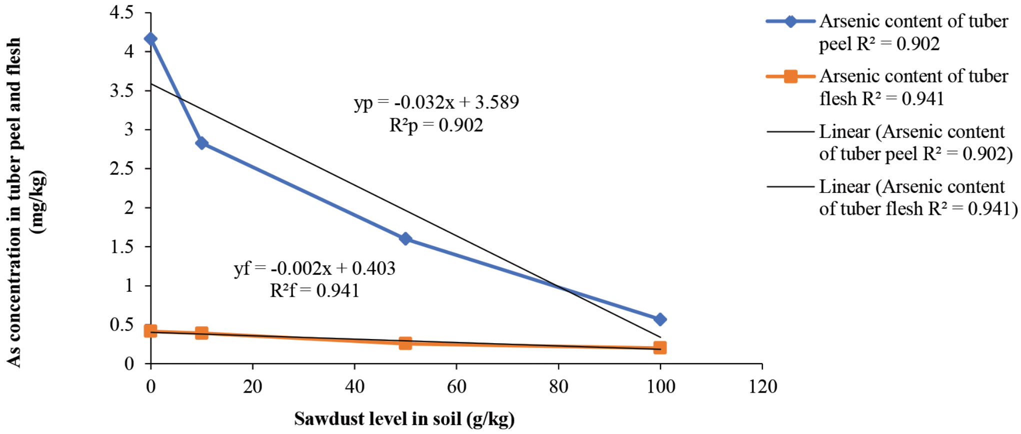

Fig. 3 Linear relationship between sawdust level in soil and Arsenic content of tuber peel and flesh

S_0: Control, S_1: 10 g sawdust/kg soil, S_2: 50 g sawdust/kg soil, S_3: 100 g sawdust/kg soil. (LSD value: 0.09970 and 0.008426 in As content in tuber peel and flesh, respectively).

According to the above discussion based on biosorption by bioadsorbent (sawdust), a tentative layout of minimizing the toxicity of Arsenic by biosorption technology is given below (Fig. 5).

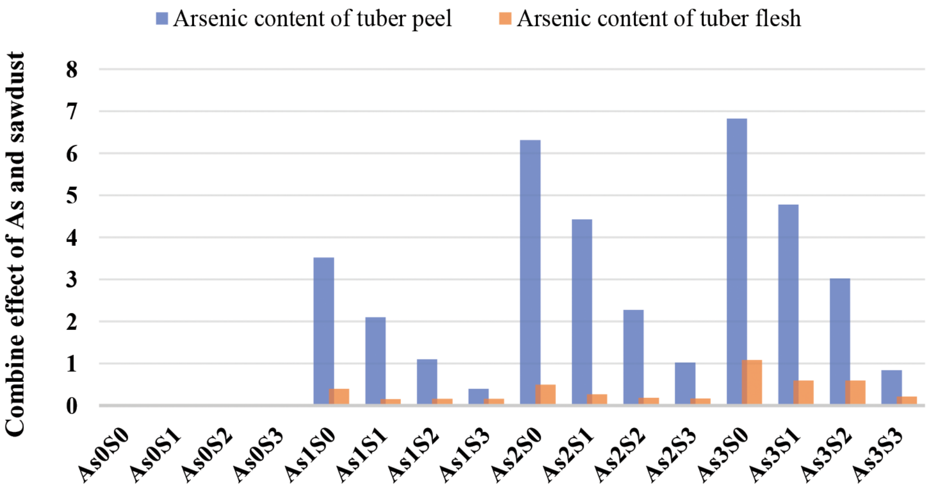

Fig. 4 Combined effect of sawdust and Arsenic levels on Arsenic content in Potato tuber peel and flesh

As_0: Control, As_1: 25 mg As/kg soil, As_2: 50mg As/kg soil, As_3: 75 mg As/kg soil, and S_0: Control, S_1: 10 g sawdust/kg soil, S_2: 50 g sawdust/kg soil, S_3: 100 g sawdust/kg soil. (LSD value: 0.1994 and 0.01685 in As content in tuber peel and flesh, respectively).

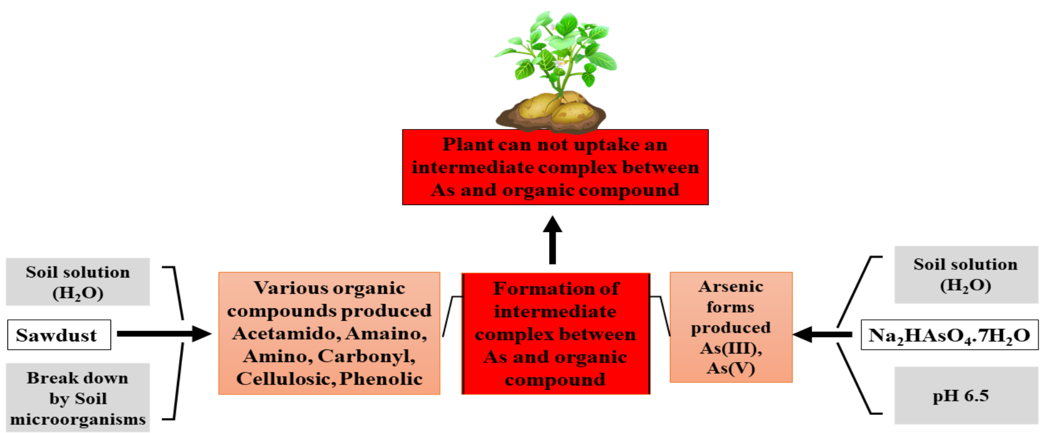

Fig. 5 Tentative layout of minimizing toxicity of Arsenic by biosorption technology

Conclusion

Sawdust had significant effects on quality contributing parameters of Potato. Sawdust improved the quality characters of Potato tuber, like slightly increased dry matter content, removed Arsenic content from tuber peel and flesh. The soil treated with S_3 (100 g sawdust kg^{-1} soil) decreased 86.41% and 51.44% Arsenic accumulation through tuber peel and flesh, respectively, compared to the control (S_0). Among the treatment combinations (As_1S_1) was suitable because, in this combination, tuber flesh accumulated 0.15 mg kg^{-1} Arsenic, which was lower than the critical level of Arsenic contamination, but S_3 (100 gm sawdust kg^{-1} soil) was the best treatment for remediation of Arsenic toxicity from Potato tuber. So, Potato growers can cultivate Potato up to 25 mg kg^{-1} Arsenic contaminated soil using 10 g sawdust kg^{-1} soil. Potato production in this condition is safe for human consumption. Since Arsenic content in tuber reduced with increasing the sawdust levels, the experiment opens the door for further research to find out the exact sawdust level to minimize 100% of Arsenic from Potato tuber.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

References

Abedin MJ, Feldmann J, Meharg AA (2002) Uptake kinetics of Arsenic species in rice plants. Plant Physiol 128: 1120-1128. https://doi.org/10.1104/pp.010733

BARC (Bangladesh Agricultural Research Council) (2020) Climate Information Management System Dhaka, Bangladesh. http://climate.barcapps.gov.bd/ (Accessed 30 April 2020)

BBS (Bangladesh Bureau of Statistics) (2019) Handbook of agricultural statistics. Bangladesh Bureau of Statistics, Ministry of Planning, Govt. of the Peoples' Republic of Bangladesh, Dhaka, pp 510. http://www.bbs.gov.bd/. (Accessed 25 April 2020)

Begonia GB, Davis CD, Begonia MFT, Gray CN (1998) Growth responses of indian mustard (*Brassica juncea* L. Czern.) and its phytoextraction of lead from a contaminated soil. Bull Environ Contam Toxicol 61: 38-43. https://doi.org/10.1007/s001289900726

Choi S, Yun Y (2006) Biosorption of cadmium by various types of dried sludge: An equilibrium study and investigation of mechanisms. J Hazard Mater 138: 378-383. https://doi.org/10.1016/j.jhazmat.2006.05.059

Choong TSY, Chuah TG, Robiah Y, Gregory Koay FL, Azni I (2007) Arsenic toxicity, health hazards and removal techniques from water: an overview. Desalination 217: 139-166. https://doi.org/10.1016/j.desal.2007.01.015

Elizalde-González MP, Mattusch J, Wennrich R (2008) Chemically modified maize cobs waste with enhanced adsorption properties upon methyl orange and Arsenic. Bioresour Technol 99: 5134–5139. https://doi.org/10.1016/j.biortech.2007.09.023

Farnese FS, Oliveira JA, Farnese MS, Gusman GS, Silveira NM, Siman LI (2014) Uptake Arsenic by plants: Effects on mineral nutrition, growth and antioxidant capacity. Idesia (Arica) 32: 99-106. https://doi.org/10.4067/s0718-34292014000100012

Fernandes AM, Soratto RP, de Aguila Moreno L, Evangelista RM (2015) Effect of phosphorus nutrition on quality of fresh tuber of potato cultivars. Bragantia 74: 102-109. https://doi.org/10.1590/1678-4499.0330

Freeman KL, Franz PR, Jong RW (1998) Effect of phosphorus on the yield, quality and petiolar phosphorus concentrations of potatoes (cv. Russet Burbank and Kennebec) grown in the krasnozem and duplex soils of Victoria. Aust J Exp Agricu 38: 83-93. http://dx.doi.org/10.1071/EA96045

Geng CN, Zhu YG, Hu Y, Williams P, Meharg AA (2006) Arsenate causes differential acute toxicity to two p-deprived genotypes of rice seedlings (*Oryza sativa* L.). Plant Soil 279: 297-306. https://doi.org/10.1007/s11104-005-1813-7

Hansen HK, Ribeiro A, Mateus E (2006) Biosorption of Arsenic(V) with *Lessonia nigrescens*. Miner Eng 19: 486-490. https://doi.org/10.1016/j.mineng.2005.08.018

Haque MN, Ali MH, Roy TS, Masum SM, Hossain MN (2015) Growth performance of fourteen potato varieties as affected by Arsenic contamination. J Plant Sci 3: 31-44. https://doi.org/10.11648/j.jps.20150301.16

Haque MN, Ali MH, Roy TS (2018) Specific gravity, dry matter and starch concentration of different potato cultivars as affected by Arsenic contamination. Potato Res 61: 51-64. https://doi.org/10.1007/s11540-017-9351-2

Hasanuzzaman M, Nahar K, Hakeem KR, Öztürk M, Fujita M (2015) Arsenic toxicity in plants and possible remediation. Soil Remediation Plant 433-501. https://doi.org/10.1016/b978-0-12-799937-1.00016-4

Heikens A (2006) Arsenic contamination of irrigation water, soil and crops in Bangladesh: Risk implications for sustainable agriculture and food safety in Asia. RAP Publication (FAO). http://www.fao.org/3/ag105e/AG105E05.htm (Accessed 30 April 2020)

Huq SI, Rahman A, Sultana N, Naidu R (2003) Extent and severity of Arsenic contamination in soils of Bangladesh. In: F. Ahmed, M. A. and Ali, Z. A. (Eds.). BUET-UNU Int. Symp. Dhaka, Bangladesh. pp. 69-84

Huq SI, Bulbul A, Choudhury MS, Alam S, Kawai S (2004) Arsenic bioaccumulation in a green algae and its subsequent recycling in soil of Bangladesh. In: Bundschuh, Bhattacharya and Chandrashkharam (eds). Natural Arsenic in Groundwater: Occurrence, Remediation and Management. Taylor and Francis Group London. pp. 119-124

Kabata-Pendias A, Pendias H (1992) Trace element in soil and plants. CRC, 2nd Edition. London, UK

Kundu R, Majumder A, Pal S (2012) Evaluation of potato cultivars against Arsenic accumulation under an Arsenic contaminated zone of Eastern India. Potato J 39: 62-68

Larsen E, Moseholm L, Nielsen M (1992) Atmospheric deposition of trace elements around point sources and human health risk assessment. II: Uptake of Arsenic and chromium by vegetables grown near a wood preservation factory. Sci Total Environ 126: 263-275. https://doi.org/10.1016/0048-9697(92)90201-3

Lee HY, Jeon C, Lim KJ, Hong KC, Lim JE, Choi BS, Kim NW, Yang JE, Ok YS (2009) Adsorption characteristics of heavy metal ions onto chemically modified rice husk and sawdust from aqueous solutions. Korean J Environ Agric 28: 158-164. https://doi.org/10.5338/kjea.2009.28.2.158

Lee SS, Lim JE, El-Azeem SAMA, Choi B, Oh SE, Moon DH, Ok YS (2013) Heavy metal immobilization in soil near abandoned mines using eggshell waste and rapeseed residue. Environ Sci Pollut Res 20: 1719-1726. https://doi.org/10.1007/s11356-012-1104-9

Mondal MRI, Islam MS, Jalil MAB, Rahman MM, Alam MS, Rahman MHH (2011) KRISHI PROJUKTI HATBOI (Handbook of Agro-technology), 5th edition. Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh. pp: 307

Mukhopadhyay R, Rosen BP, Phung LT, Silver S (2002) Microbial Arsenic: From geocycles to genes and enzymes. FEMS Microbiol Rev 26: 311-325. https://doi.org/10.1111/j.1574-6976.2002.tb00617.x

Norton G, Deacon C, Mestrot A, Feldmann J, Jenkins P, Baskaran C, Meharg AA (2013) Arsenic speciation and localization in horticultural produce grown in a historically impacted mining region. Environ Sci Technol 47: 6164-6172. https://doi.org/10.1021/es400720r

Onken BM, Hossner LR (1995) Plant uptake and determination of Arsenic species in soil solution under flooded conditions. J Environ Qual 24: 373–381. https://doi.org/10.2134/jeq1995.00472425002400020022x

Paul S, Upadhyay SK, Lal EP (2014) Accumulation of Arsenic in radish (*Raphanus sativus* L.), and their effects on growth and antioxidant activities. Int J Pharm Sci Res 5: 3536-3543. http://dx.doi.org/10.13040/IJPSR.0975-8232.5(8).3536-43

Phonphuak N, Chindaprasirt P (2015) Types of waste, properties, and durability of pore-forming waste-based fired masonry bricks. Eco-Efficient Masonry Bricks and Blocks 103-127. https://doi.org/10.1016/B978-1-78242-305-8.00006-1

Shaibur MR, Islam T, Kawai S (2009) Response of leafy vegetable kalmi (Water Spinach; *Ipomoea aquatica* L.) at elevated concentrations of Arsenic in hydroponic culture. Water Air Soil Pollut 202: 289-300. https://doi.org/10.1007/s11270-009-9976-0

Shamsuddoha ASM, Bulbul A, Imamul Huq SM (2005) Accumulation of Arsenic in green Algae and its subsequent transfer to soil-plant system. Bangladesh J Microbiol 22: 148-151

Sud D, Mahajan G, Kaur M (2008) Agricultural waste material as potential adsorbent for sequestering heavy metal ions from aqueous solutions – A review. Bioresour Technol 99: 6017-6027. https://doi.org/10.1016/j.biortech.2007.11.064

Tu S, Ma LQ (2003) Interactive effects of pH, Arsenic and phosphorus on uptake of As and P and growth of the Arsenic hyperaccumulator *Pteris vittata* L. under hydroponic conditions. Environ Exp Bot 50: 243-251. https://doi.org/10.1016/s0098-8472(03)00040-6

Ullah SM (1998) Arsenic contamination of groundwater and irrigated soils of Bangladesh. In International conference on Arsenic pollution of groundwater in Bangladesh: Causes, effects and remedies, 1998. Dhaka Community Hospital, Dhaka, Bangladesh. p. 133

Urik M, Littera P, Sevc J, Kolencik M, Cernansky S (2009) Removal of Arsenic (V) from aqueous solutions using chemically modified sawdust of spruce (*Picea abies*): Kinetics and isotherm studies. International J Environ Sci Technol 6: 451-456. https://doi.org/10.1007/bf03326084

USEPA (US Environmental Protection Agency) (2001) Method 1632, revision A: Chemical speciation of Arsenic in water and tissue by hydride generation quartz furnace atomic absorption spectrometry

Veglio F, Beolchini F (1997) Removal of metals by biosorption: A review. Hydrometallurgy 44: 301–316. https://doi.org/10.1016/s0304-386x(96)00059-x

Vithanage M, Dabrowska BB, Mukherjee AB, Sandhi A, Bhattacharya P (2012) Arsenic uptake by plants and possible phytoremediation applications: A brief overview. Environ Chem Lett 10: 217–224. https://doi.org/10.1007/s10311-011-0349-8