Using Asclite to Reduce Arsenic Concentration in Vegetables Grown on Arsenic Contaminated Soil

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Authors' contributions

This work was carried out in collaboration among all the authors. Authors JCJ and SK designed the study, wrote the protocol, performed the statistical analysis and wrote the first draft of the manuscript. Authors TY and HW were involved in the preparation of asclite. Author MI supervised the work when the third experiment was conducted in Bangladesh. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Three pot experiments were conducted to assess the capacity of asclite in reducing arsenic (As) contents in vegetable plants from arsenic contaminated soil. Asclite is an artificially made granular amorphous iron (Fe)-hydroxide material having high ability in adsorbing As(III) as well as As(V). In the first experiment, Japanese mustard spinach (JMS) (*Brassica rapa* var. *perviridis*) was grown in a 242 mg As kg^{-1} soil with 10 and 20% of asclite application. The second and third experiments were conducted in Japan and Bangladesh, respectively, with JMS and Bangladesh spinach (BS) (*Spinacia oleracea*) grown in a 50 mg As kg^{-1} soil where 1 and 2% asclite were applied. Application of asclite to arsenic contaminated soil significantly reduced the arsenic concentration in the edible part of the plants as compared to the control plants. The arsenic concentration in JMS reduced by 43 and 60% at 10 and 20% asclite application when grown in a 242 mg As kg^{-1} soil. The arsenic concentration was reduced by 29 and 37% in JMS, whereas it was 52 and 74% in BS, at 1 and 2% asclite application, respectively, when grown in a 50 mg As kg^{-1} soil. There was no significant change in the growth and the nutrient elements concentration in

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the plants. Our findings suggested that asclite could be used to reduce arsenic concentration in vegetables grown on arsenic contaminated soil. Considering the soil type, soil pH, soil arsenic concentration and plant species, further study is required to examine the desirable conditions for reducing the arsenic concentration in vegetable plants with asclite application.

1. INTRODUCTION

Arsenic is a common metalloid usually present in a small amount in all rocks, soils, waters, air and biological tissues [1, 2]. Arsenic is one of the most toxic elements of the environment [3–5]. Arsenic can enter into the terrestrial and aquatic environments through natural geologic processes and anthropogenic activities as well. So, arsenic can be present in groundwater and soil. Groundwater contamination by arsenic has been discussed as the worst calamity of the century in Asia particularly in Bangladesh and West Bengal, India. It is widely accepted that ingestion of arsenic contaminated groundwater is the major cause of arsenic poisoning in arsenic affected areas. Now, it is also established that ingestion of arsenic contaminated groundwater is not the only exposure pathway to humans. Another pathway might be the arsenic contamination in food materials through arsenic contaminated irrigation water and the subsequent transfer of arsenic via water/soil to crops [6–10].

Low levels of arsenic (about 5 mg kg^{-1}) occur naturally in soils all over the world with a variation depending on the origin of the soil [1, 11]. Generally, in non-contaminated soil, arsenic concentration ranges from 0.1 to 10 mg kg^{-1} [12]. Usually, crops grown in non-contaminated soil do not accumulate enough arsenic to be toxic to man. However, in arsenic contaminated soil, the uptake of arsenic by the plant tissue is significantly elevated, particularly in vegetables and edible crops [7, 9, 10, 13]. It is reported by many researchers that in Bangladesh, extensive application of arsenic contaminated underground water for irrigating crop fields has resulted in elevated concentrations of arsenic in surface soils [9, 14-18].

There are various types of mitigation techniques to remove arsenic from drinking water. It is possible to remove arsenic from the drinking water in a small scale. But it is difficult to clean up for a large scale irrigation water as well as arsenic contaminated soil. There are also a number of technologies to reduce arsenic contamination in soils [19]. One of the methods is through excavation followed by land filling with clean soil. But it is a very expensive and difficult task for remediation of arsenic contaminated soil [20]. Other techniques present are phytoremediation [21, 22]; soil washing [23]; inorganic solidification/stabilization using inorganic binders such as cement, lime and pozzolanic materials [24]; electro-kinetic remediation [25, 26] and in situ chemical immobilization. The last technique, in situ chemical immobilization, implies the application of inorganic amendments, which are incorporated and mixed with the contaminated soil. Soil amendments can adsorb, bind, or co-precipitate the contaminating elements [27]. The binding of arsenic to the amendment material reduces its mobility and bioavailability in the soil, making the long-term stability of the new compounds formed [28]. The long-term stability of the arsenic compounds depends on many factors including the disposal site characteristics, particle crystallinity, grain size distribution and others [29].

Various inorganic amendments had been used previously to reduce arsenic contamination in soils, such as silica, phyllosilicates, clays, zeolites, amorphous Al and Mn oxides and nanocrystalline titanium dioxide [30–37]. The sequential extraction of arsenic-contaminated soils had indicated that arsenic was primarily associated with crystalline and amorphous Fe oxides [38–40]. So, arsenic sorption on amorphous and crystalline Fe hydroxides had shown great potential to remediate contaminated soils [28, 33, 34, 41–47]. Arsenic may also co-precipitate with Fe oxides [48, 49]. The efficiency of the remediation treatments depends on the soil characteristics, the sorption capacity of the Fe source used as amendment and the environmental conditions to which the treated soil is exposed [50]. Among the numerous inorganic amendments in reducing arsenic availability, Fe minerals and Fe industrial byproducts are considered to be the great potential for in situ remediation [51] of arsenic.

The present study was conducted with an artificially made granular amorphous iron (Fe)-hydroxide material viz. asclite having high ability to adsorb As(III) as well as As(V). The aim of the present study was to evaluate the effectiveness of asclite in reducing arsenic concentration in vegetable plants from arsenic contaminated soils.

2. MATERIALS AND METHODS

2.1 Experimental Design

Three pot experiments were conducted to evaluate the efficiency of the adsorbent material asclite in reducing arsenic concentration of vegetables grown on arsenic-contaminated soil.

2.1.1 First experiment

In the 1st experiment, Japanese mustard spinach (JMS) was grown in highly arsenic contaminated soil (242 mg kg^{-1}) with the application of the adsorbent asclite. Arsenic-contaminated soil was collected from Gunma Prefecture in Japan by composite soil sampling method [52]. In our information, the source of the arsenic in the soil was the chemical factory which produced pesticides. The factory was already closed and the soil of the land of the factory remained contaminated with arsenic. The soil was collected with the help of spade from the surface of the arsenic contaminated field and was stored in the shade of the green house of Iwate University, Japan. Asclite was applied at two rates (10 and 20%) along with a control (no asclite) in four replications. For better plant growth, 1 g of chemical fertilizer [10:10:10, N:P$_2$O$_5$:K$_2$O (Taki Chemicals Co. Ltd, Kakogawa)] was added to each pot (1-L). Soil, asclite and fertilizer were mixed thoroughly. About 250-ml of water was added in each pot to keep the mixture moist. After seven days, the contents of the pots were mixed thoroughly again and 6-8 seeds of JMS were sown. Seven days after sowing, the plants were thinned to three plants per pot. The plants were harvested 30 days after seed sowing.

2.1.2 Second experiment

In the 2nd experiment, JMS was also grown in artificially arsenic spiked soil contaminated up to 50 mg kg^{-1} with the application of the adsorbent asclite. The soil was spiked by arsenic mixing Na$_2$HAsO$_4$.7H$_2$O (di-sodium hydrogen arsenate heptahydrate) as solution. The soil used in the experiment was commercially obtained (Trust, Tochigi). In this experiment, asclite was applied at two rates (1 and 2%) along with a control (no asclite) in four replications. Fertilizer application and other processes were done similarly to the 1st experiment.

2.1.3 Third experiment

In the 3rd experiment, the procedure was similar to that of the 2nd experiment but in different climatic condition (in Bangladesh) where Bangladesh spinach (BS) was grown in alluvial soil. This soil arsenic content was also artificially raised to 50 mg kg^{-1} by spiking with arsenic salt, $Na_2HAsO_4.7H_2O$ (di-sodium hydrogen arsenate heptahydrate), calculating the inherent arsenic concentration of the soil. The soil was collected from the field of Khulna University, Bangladesh by composite soil sampling method [52].

2.2 Soils Characteristics

The chemical characteristics of the soils are shown in the Table 1.

Table 1. Chemical analysis of the soils used in the three experiments

Parameters	1st experiment soil	2nd experiment soil	3rd experiment soil
pH	8.15	5.17	7.43
EC (dS m^{-1})	2.74	0.17	1.25
As (mg kg^{-1})	242	11.40	6.90
1N HCl Extractable As (mg kg^{-1})	14.60	0.12	0.29
P (%)	0.62	0.26	0.32
Fe (%)	1.97	2.38	3.44
Na (%)	0.16	0.84	1.12
K (%)	0.53	0.36	0.20
Ca (%)	6.24	0.45	0.65
Mg (%)	1.51	0.31	1.01

2.3 Composition of Asclite

Asclite is an artificially made Fe based material produced by Createrra Inc. Tokyo, Japan. It is a granular (100～300 µm) amorphous Fe-hydroxide having high ability in strongly and quickly adsorbing As(III) as well as As(V). Many active -OH groups are present on surface of outer and inner surfaces of the granules. The composition of asclite is shown in the Table 2. The elements were measured by X-ray fluorescence analysis by using "Wavelength Dispersive X-ray Flourescence Spectrometer, Supermini 200, Rigaku Corporation, Tokyo". Phosphorus in asclite was measured by colorimetric method after being digested by alkaline (Na_2CO_3) resolution method.

Table 2. Physico-chemical characteristics of asclite

Parameters	Contents
Fe_2O_3 (%)	19.4
-OH (%)	44.0
SiO_2 (%)	28.9
Al_2O_3 (%)	24.2
TiO_2 (%)	1.13
MnO (%)	0.21
CaO (%)	1.47
MgO (%)	2.18
K_2O (%)	0.45
Na_2O (%)	0.41
P_2O_5 (%)	0.26
SO_3 (%)	6.33
Arsenic (mg kg^{-1})	Not detected
pH	5.0
Electric conductivity (dS m^{-1})	0.18
Bulk density (g cm^{-3})	0.45
Particle size (μm)	100-300

2.4 Measurement of the Elements

Both the soils and plant samples were digested with concentrated nitric acid and perchloric acid mixture (V/V, 2:1) for the determination of arsenic and other elements. The concentration of arsenic and the other nutrient elements in the digest were determined on an hydride generation atomic absorption spectrophotometer (AA-6200, Shimadzu, Kyoto) by following the prescribed laboratory methods [53, 54]. Reagent blanks were used to ensure the accuracy and precision in the analysis. The arsenic concentration was expressed as mg kg^{-1} DW whereas the total arsenic uptake was expressed as μg $plant^{-1}$. Total arsenic uptake was calculated by multiplying the arsenic concentration with the DW of the edible part of the respective plant.

2.5 Statistical Analyses

The results were expressed as the averages of four replications. The data were subjected to ANOVA. Differences between means were statistically analyzed using a Ryan-Einot-Gabriel-Welsch multiple range test (P=.05) run on the SAS software program [55] at Iwate University, Japan.

3. RESULTS

3.1 First Experiment

Visually there was no distinct change in the growth of the plant due to the application of asclite. The arsenic concentration (mg kg^{-1} DW) in the edible part of the plant (JMS) as well as the total arsenic uptake (μg $plant^{-1}$) decreased significantly with the application of asclite as compared to the control plant (Fig. 1a, b). Due to the application of 10% asclite, the arsenic concentration of edible part of the plant reduced by 43% and it was 60% at 20% asclite applied soil (Fig. 1a). Reduction of arsenic concentration in plant part was significantly different from the control in individual rate of asclite application. The average reduction of arsenic concentration was higher in 20% asclite application than that of 10%

asclite application. But there was no significant difference between the applications of 10 and 20% of asclite. The total arsenic uptake (μg plant^{-1}) was also reduced by 36 and 55% for 10 and 20% asclite applications, respectively (Fig. 1b). This reduced amount of arsenic in asclite applied plant was significantly different from the control plant. The mixing of asclite in arsenic contaminated soil could reduce the arsenic concentration as well as total arsenic uptake in plant. There were no significant changes on the nutrient element concentrations in the plant part (Table 3).
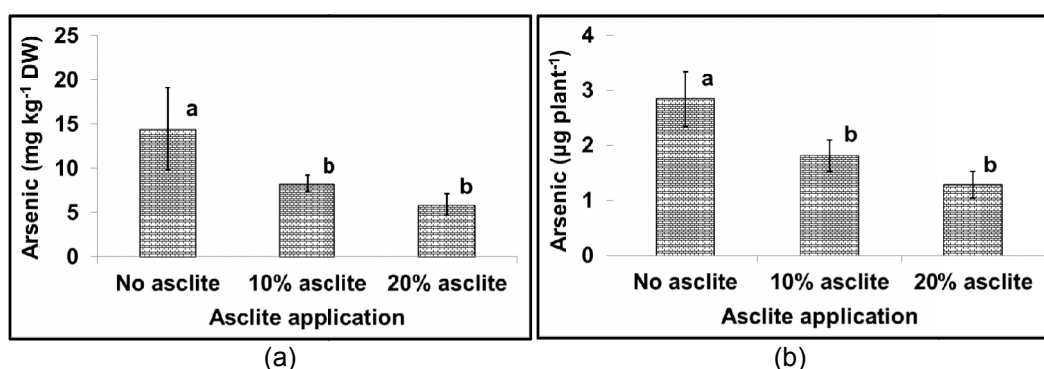

(a)   (b)

Fig. 1. (a) Arsenic concentration (mg kg^{-1} DW), and (b) Total arsenic uptake (μg plant^{-1}) in the edible part of Japanese mustard spinach grown in 242 mgAskg^{-1} soil
Bars with different letters are significantly different (P=.05) according to a Ryan–Einot–Gabriel–Welsch multiple range test. Error bars are the standard deviations (SDs)

Table 3. Changes in dry weight (DW) and nutrient element concentrations in the edible part of Japanese mustard spinach grown in 242 mgAskg^{-1} soil

Treatment	DW (g)	P (mg kg^{-1})	Fe (%)	Na (%)	K (%)	Ca (%)	Mg (%)
No asclite	0.18^{ab}	146.4^a	0.12^a	0.21^b	3.46^{ab}	1.99^b	0.17^a
	(±0.03)	(±1.2)	(±0.05)	(±0.01)	(±0.29)	(±0.28)	(±0.03)
10% asclite	0.22^a	126.8^a	0.08^a	0.39^a	3.05^b	2.68^a	0.22^a
	(±0.02)	(±7.6)	(±0.03)	(±0.02)	(±0.22)	(±0.23)	(±0.01)
20% asclite	0.16^b	143.9^a	0.06^a	0.23^b	3.73^a	2.17^b	0.19^a
	(±0.02)	(±25.4)	(±0.01)	(±0.07)	(±0.44)	(±0.24)	(±0.03)

Different letters after the values in the table are significantly different (P=.05). Numbers in the parenthesises are the standard deviations (SDs)

3.2 Second Experiment

In the 2nd experiment, with the application of asclite the arsenic concentration (mg kg^{-1} DW) and the total arsenic uptake (μg plant^{-1}) in the edible part of the plant (JMS) were also reduced as compared to the control. The arsenic concentration in the edible part of the plant reduced by 29 and 37% at 1 and 2% asclite application, respectively (Fig. 2a). But this reduced arsenic concentration in the plant part was not significantly different from the arsenic concentration of the control plant. The total arsenic uptake (μg plant^{-1}) was also reduced but it was statistically similar (Fig. 2b). The total arsenic uptake (μg plant^{-1}) was reduced by 40 and 42% for 1 and 2% asclite applications, respectively (Fig. 2b). Similarly to the result of the 1st experiment, there was no significant change in the growth or visual symptoms and nutrient element concentrations in the plant part due to the application of asclite (Table 4).
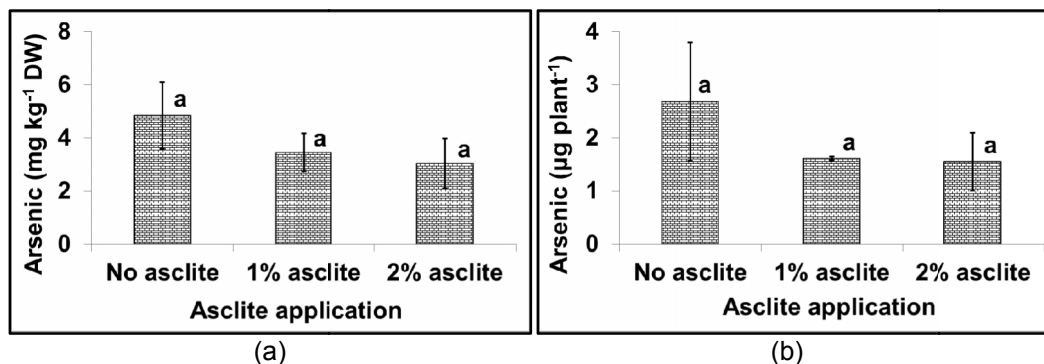
(a)

(b)

Fig. 2. (a) Arsenic concentration (mg kg^{-1} DW), and (b) Total arsenic uptake (µg plant^{-1}) in the edible part of Japanese mustard spinach grown in 50 mgAskg^{-1} soil
Bars with different letters are significantly different (P=.05) according to a Ryan–Einot–Gabriel–Welsch multiple range test. Error bars are the standard deviations (SDs)

Table 4. Changes in dry weight (DW) and nutrient element concentrations in the edible part of Japanese mustard spinach grown in 50 mgAskg^{-1} soil

Treatment	DW (g)	P (mg kg^{-1})	Fe (mg kg^{-1})	Na (mg kg^{-1})	K (%)	Ca (%)	Mg (%)
No asclite	0.54[a]	70.8[a]	59.6[a]	968[a]	2.87[a]	2.15[a]	0.15[a]
	(±0.08)	(±14.9)	(±11.9)	(±30)	(±0.47)	(±0.42)	(±0.06)
1% asclite	0.52[a]	83.1[a]	88.6[a]	990[a]	3.32[a]	2.62[a]	0.20[a]
	(±0.12)	(±10.4)	(±9.4)	(±9)	(±0.80)	(±0.79)	(±0.06)
2% asclite	0.51[a]	64.3[a]	131.9[a]	958[a]	3.72[a]	2.02[a]	0.20[a]
	(±0.09)	(±25.6)	(±53.7)	(±91)	(±0.20)	(±0.32)	(±0.05)

Different letters after the values in the table are significantly different (P=.05). Numbers in the parenthesises are the standard deviations (SDs)

3.3 Third Experiment

There was no distinct change in plant growth and visual symptoms. The arsenic concentration (mg kg^{-1} DW) and total arsenic uptake (µg plant^{-1}) in the edible part of the plant (BS) are shown in figures 3a and 3b. In this experiment, the arsenic concentration in the edible part of the plant reduced by 52 and 74% at 1 and 2% asclite application, respectively (Fig. 3a). The reduced arsenic concentration in plant part was significantly different from the arsenic concentration in control plant in each rate of asclite application and between the application rates of asclite also (Fig. 3b). The total arsenic uptake (µg plant^{-1}) was also reduced significantly and different from the arsenic uptake in the control plant. The total arsenic uptake (µg plant^{-1}) was reduced by 50 and 66% for 1 and 2% asclite applications, respectively (Fig. 3b). Similarly to the 1st and 2nd experiments, there were no significant differences in the growth and nutrient element concentrations in the edible part of the plant (Table 5).

A summary of the reduced amount of both arsenic concentration (mg kg^{-1} DW) and total arsenic uptake (µg plant^{-1}) in the edible part of the plants among the asclite application doses in all three experiments are shown in Table 6.

Table 5. Changes in dry weight (DW) and nutrient element concentrations in the edible part of Bangladesh spinach grown in 50 mgAskg^{-1} soil

	DW (g)	P (%)	Fe (%)	Na (%)	K (%)	Ca (%)	Mg (%)
No asclite	0.54^b (±0.05)	0.77^a (±0.09)	0.24^a (±0.03)	4.03^a (±0.42)	0.55^b (±0.01)	1.30^a (±0.24)	0.80^a (±0.03)
1% asclite	0.57^b (±0.10)	0.82^a (±0.12)	0.12^b (±0.03)	3.85^a (±0.30)	0.95^a (±0.09)	1.33^a (±0.21)	0.89^a (±0.13)
2% asclite	0.70^a (±0.07)	0.78^a (±0.13)	0.10^b (±0.02)	4.19^a (±0.41)	1.21^a (±0.32)	1.11^a (±0.11)	1.02^a (±0.22)

Different letters after the values in the table are significantly different (P = .05). Numbers in the parenthesises are the standard deviations (SDs)

Table 6. Reduction of arsenic concentration and total uptake in edible plant part as affected by asclite application rates

Experiment	Arsenic concentration (mg kg^{-1} DW)			Total arsenic uptake (µg plant^{-1})		
Dose (d) comparison	No asclite vs 10 or 1%	No asclite vs 20 or 2%	10 or 1% vs 20 or 2%	No asclite vs 10 or 1%	No asclite vs 20 or 2%	10 or 1% vs 20 or 2%
1st experiment (reduction)	$d_{no}>d_{10}$ (43%)*	$d_{no}>d_{20}$ (60%)*	$d_{10}>d_{20}$ (29%)^{ns}	$d_{no}>d_{10}$ (36%)*	$d_{no}>d_{20}$ (55%)*	$d_{10}>d_{20}$ (29%)^{ns}
2nd experiment (reduction)	$d_{no}>d_1$ (29%)^{ns}	$d_{no}>d_2$ (37%)^{ns}	$d_1>d_2$ (12%)^{ns}	$d_{no}>d_1$ (40%)^{ns}	$d_{no}>d_2$ (42%)^{ns}	$d_1>d_2$ (4%)^{ns}
3rd experiment (reduction)	$d_{no}>d_1$ (52%)*	$d_{no}>d_2$ (74%)*	$d_1>d_2$ (47%)*	$d_{no}>d_1$ (50%)*	$d_{no}>d_2$ (66%)*	$d_1>d_2$ (33%)^{ns}

*d-indicates asclite application dose; * Indicates statistically significant; ^{ns} indicates statistically not significant*
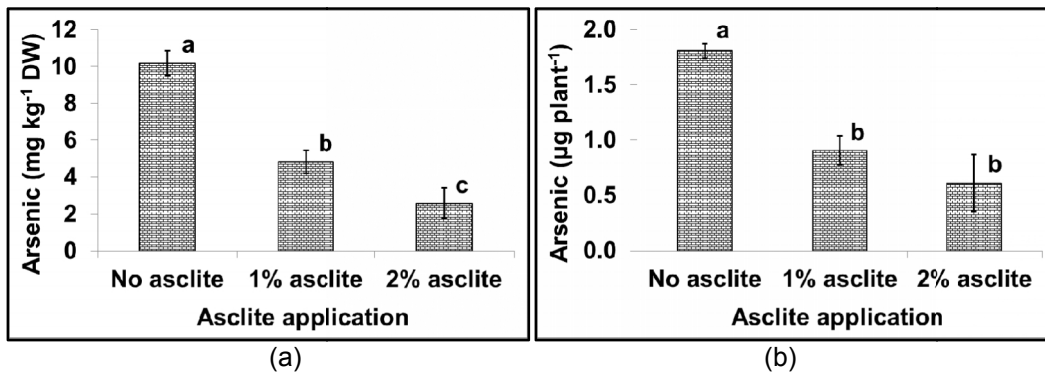
Fig. 3. (a) Arsenic concentration (mg kg^{-1} DW), and (b) Total arsenic uptake (μg plant^{-1}) in the edible part of Bangladesh spinach grown in 50 mgAskg^{-1} soil
Bars with different letters are significantly different (P = .05) according to a Ryan–Einot–Gabriel–Welsch multiple range test. Error bars are the standard deviations (SDs)

4. DISCUSSIONS

In the 1st experiment, both the arsenic concentration (mg kg^{-1} DW) and total arsenic uptake (μg plant^{-1}) in the edible part of the plant (JMS) reduced significantly as compared to the arsenic contents in control plant. In this experiment, we used a highly arsenic contaminated soil which contained 242 mgAskg^{-1} soil and higher rate of asclite was applied (10 and 20%). Actually, such a type of highly arsenic contaminated soil is unusual in agricultural field. The soil arsenic concentrations were selected up to 50 mg kg^{-1} of soil based on the information of arsenic concentrations in Bangladesh soils [9, 10, 14, 15, 17, 18]. Besides, the rate of asclite application (10 and 20%) might be practically too high. That's why, we again conducted the 2nd and 3rd experiment by reducing the asclite application rate and soil arsenic concentration. These two experiments were conducted in two different climatic conditions growing two vegetables in two types of soils. Similarly, the 2nd experiment was conducted in Japan whereas the 3rd experiment was conducted in Bangladesh. In both of the experiments, the soil arsenic content was artificially raised to 50 mg kg^{-1} by spiking arsenic and the asclite application rate was 1 and 2%. In all the three experiments, it was shown that the arsenic concentration in the edible part of the plants decreased significantly. The decreased arsenic concentration in the plant part was not due to the dilution effect by the enhancement of the plant growth. Because, the overall growth of the plants was not affected by the application of asclite in the arsenic contaminated soils. Besides, the total arsenic uptake in the plant part was also reduced. Asclite did not have any fertilizer effect. Therefore, the decreased arsenic concentrations in the plant part might be induced by the adsorption of arsenic by amorphous Fe hydroxide in asclite.

Asclite is an amorphous Fe hydroxide material, therefore, arsenic might form complexes with Fe or arsenic might be un-available to plants due to Fe sorption mechanism. Fe-oxide surfaces are known to be involved in arsenic adsorption in soils [56, 57]. Arsenic is strongly adsorbed on the surface sites of Fe hydroxides through the formation of inner-sphere complexes [58]. Carbonell-Barrachina et al. [59] also reported that water soluble Fe concentrations were highly correlated with dissolved total arsenic, suggesting that hydrous Fe oxides play an important part in controlling arsenic adsorption-desorption reactions in sewage sludge. Iron oxides applied to garden soils had shown decreases of up to 50% in water extractable arsenic concentrations, together with lower accumulation levels in plant

tissues [51]. The results of our experiments employing arsenic adsorption on asclite, an amorphous Fe hydroxide material, was in good agreement with the findings of many other researchers [27, 28, 33, 42, 43, 46, 47, 60, 61] to remediate contaminated soils applied with amorphous and crystalline Fe hydroxides.

In the 2nd experiment, the reduced arsenic concentration in the edible part of the plant (JMS) applied with asclite was not significantly different from that of control plant. One of the reasons might be the effect of soil pH. The pH values of the soils of 1st and 3rd experiments were higher than 7, while the pH value of the soil of 2nd experiment was 5.2. It is considered that intensity of the effect of asclite might be affected by pH of the soil because of the solubility of Fe hydroxide in asclite. Arsenic concentrations in the edible part of the plant depend on the availability of soil arsenic and the ability of a plant to take up arsenic and to translocate it to the organs in the shoot [62]. There are many factors that influence arsenic uptake by plants, including species differences [63], the presence of competing ions [64], concentration of arsenic in the soil [65], soil type and soil properties such as pH, clay content [66], redox potential and the presence of Fe oxides.

Besides, there were no significant differences in nutrient element concentration (P, Fe, Na, K, Ca and Mg) in the edible part of the plants (Tables 3–5). So, the application of asclite, in reducing arsenic concentrations of the vegetable plant on arsenic contaminated soil had no harmful effect on the growth and the mineral concentrations of the plants.

Both organic and inorganic forms of arsenic are present in terrestrial plants [67] but arsenic in terrestrial food plants is dominated by inorganic arsenic [68] and in case of peas and spinach only inorganic arsenic was present [68]. Douglas et al. [69] reported that the inorganic arsenic and DMA in rice (n=6) were 43.8% and 56.2%, respectively. In our experiments, we measured the total arsenic contents in the plant by digesting the plant samples with a mixture of HNO_3 and $HClO_4$. In this experiment, organic and inorganic arsenic could not be separately measured. It is also reported that in the Bengal Delta region, where arsenic-contaminated water has been used for irrigation, some vegetables and spices contained relatively high concentration of arsenic [70, 71] and most of the arsenic are present only in inorganic forms [69–74]. Inorganic arsenic (arsenite and arsenate) in rice grain and vegetables contributed 89.9% and 89.2%, respectively [71]; 95% and 96%, respectively, in West Bengal [73]; 87% and 96%, respectively, in Bangladesh [74] of the total content of arsenic.

5. CONCLUSION

The application of asclite in arsenic contaminated soil significantly reduced the arsenic concentration and uptake in the edible part of the vegetable plants in different scales depending on the soil arsenic concentration, plant species and soil characteristics, thus reduced the food chain transfer potential of arsenic. The application of asclite also did not show any adverse effect on the growth and elemental composition of the plants. We think that asclite could be used in reducing arsenic contents in vegetables when it is grown in arsenic contaminated soil. A large scale investigation should be conducted to find out the desirable conditions to increase the effectiveness of the application of asclite to produce arsenic-safe-food considering the characteristics of soils or plant species.

ACKNOWLEDGEMENT

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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