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ARSENIC CONTAMINATION IN IRRIGATION WATER, SOIL AND FOOD CROPS AND THEIR REMEDIAL MEASURES

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REPORTING FORMAT FOR EACH THEME

Name of Theme: Arsenic Mitigation in crop sector

1. Abstract

Arsenic pollution can result in land degradation, which is one of the crucial factors for drastic yield reduction. Any risk to crop production is a serious concern as raising crop production is urgently needed in achieving food security. Moreover, arsenic is also entering in to the food chain through crop. Some vegetables and weeds have been reported to have higher levels of arsenic. The information regarding the presence and level of arsenic in food crops and their remedial measures are very scarce. In the recent years, Bangladesh Agricultural Research Institute (BARI) and Bangladesh Rice Research Institute (BRRI) conducted few trials and laboratory studies in this regard. The aim of this review paper is to provide the status work on presence and level of arsenic in food crops and weeds in Bangladesh. Vegetables grown with arsenic contaminated irrigation water showed highest arsenic content in stem amaranth followed by chinasak, katuadata. The moderate arsenic content was observed in Indian spinach followed by chilli, potato, bitter gourd and cabbage. The lower arsenic content was found in brinjal, okra, tomato and cauliflower. Relatively lower level of arsenic content was found when the above crops were grown with non-contaminated irrigation water even though those were much higher than the Chinese food safety standards for vegetable crops might be due to presence of higher level of arsenic in the studied soils. In general, arsenic content was higher in leafy vegetables than fruity vegetables. In another study, 34 weed species were evaluated for arsenic accumulation ability to sort out arsenic hyper accumulator for phytoremediation. The highest arsenic content was found in fern followed by wild taro and lowest in duck weed. Fern was appeared to be the most hyper accumulator followed by barn yard grass, water hyacinth, wild taro, water taro, cockle bur, duck weed and dog grass. Fern, barnyard grass, joina might be suitable to remove arsenic from soil whereas water hyacinth, duckweed, malancha and water cress from the stagnant water for phytoremediation. Research works in these contexts should be strengthened to save the environment and mankind from the deadliest arsenic poisoning.

2. Introduction

Arsenic is one of the most abundant elements in earth crust and occurs in Bangladesh geological deposits in alluvial sediments mostly at shallower depths. It is highly hazardous to human and animal health. As small as 0.1 g of arsenic trioxide (AS_2O_3) can prove lethal to human (Jarup, 1992). Arsenic is the causal factor of several physiological disorders in human namely edema, skin lesions, hyperkeratosis, skin cancer and even death (Das *et al.*, 1996; Sanyal and Naser, 2002). Arsenic poisoning in drinking water containing more than 0.05 mg As L^{-1} in STWs in 59 districts out of 64 was identified. Irrigation with arsenic contaminated ground water over the years increased its concentration in soil and eventually arsenic enters into the food chain through crop. The average arsenic content in agricultural land in Bangladesh varied from 4 to 8 mg kg^{-1} but it rose up to 83 mg kg^{-1} due to continuous use of contaminated irrigation water (Ullah, 1998). It was estimated that water extraction from the shallow aquifer for irrigation adds 1 million kg of As per year to the arable soil in Bangladesh. The most important As species are arsenate (AsV) under non-flooded conditions and arsenite (As III) under flooded condition. The solubility of arsenite (As III) is higher than AsV resulting in a higher mobility of As in flooded soils. More As in soil leads to higher concentration in plant but this depends on many factors. Uptake, accumulation and toxicity vary within and between plant species.

Arsenate (AsV) can compete with PO_4 within the plant cells distorting the energy flow in the cell. Arsenite (As III) reacts with a number of enzymes and tissue proteins that can cause inhibition of cellular functions and finally death (Meharg and Hartley- Whita Ker, 2002).

Arsenic in irrigation water can result in land degradation, adversely affecting incomes and agro-ecosystem services in terms of their ability to provide a sustainable source of sufficient and safe foods. The soil contamination can cause contamination of crops and foods, resulting in risks to food safety and thus to human health. The continuous contamination of soil is a growing threat to crop production it self, and thus to sustainable agriculture, because As in soils will become toxic to plants. This would result in reduced crop yield. Any risk to crop production is of serious concern as raising crop production is necessary to keep up with population growth. Land degradation caused by As-contamination could thus pose a threat to sustainable development. An increase in soil concentration can be reflected in concentration in crops, including the edible parts. Rice can contribute significantly to the total daily intake of inorganic As through water and foods in Bangladesh because of the high rice consumption and relatively high levels of inorganic As in rice. Some vegetables have been reported to have high levels of As, their contribution to the total daily intake is low because of their low consumption rate. However, research works regarding arsenic uptake sensitivity and translocation by the crops grown in arsenic contaminated soil irrigating with contaminated irrigation water and their effects on yield and quality of crops, toxicity limits, have not been done extensively yet. Sporadic works on rice have been done so far. Only a little information regarding the effect of arsenic contamination in vegetable crops are available. The information regarding the presence and level of arsenic in weeds is very scarce. During the recent years, BARI and BRRI conducted few trials and laboratory studies in this regard. The aim of the present review paper is to provide some information and status of work on presence and level of arsenic in food crops & weeds and their remedial measures.

3. Materials and Methods

The present paper is entirely a review paper. It is written adapting and citing some notable research findings of soil science Division, BARI and soil science Division, BRRI conducted during the recent years (2002-2009). However, traditional methods for field trials and standard laboratory procedures were followed to conduct respective experiment. Interested readers are suggested to study the respective paper as mentioned in the reference list for in detail information on materials and methods followed as well as results obtained.

4. Results and Discussion

A. Nationwide Survey on Arsenic Contamination in Soil, Irrigation water and Crops

About 80% Bangladesh soil is floodplain alluvial type. Rest 12% are terrace and 8% are hill soil. Arsenic content was higher in floodplain soil compared to terrace and hill soil. Irrigated soil contained more arsenic than non irrigated soil.

Table 1. Arsenic content in Bangladesh Soil

Soil	Amount of arsenic (mg/kg)		
	Min.	Max.	Mean
Paddy soil (0-15 cm)	4.5	67	13.0
Paddy soil (15-30 cm)	4.2	51	9.8

Paddy soil (30-45 cm)	3.5	33	9.8
Paddy soil (45-60 cm)	3.6	23	7.1

Ref. : Panaullah *et al.* (2005)

Table 2. Arsenic content in Irrigation water

Source of water	Amount of arsenic (μg/L)		
	Min.	Max.	Mean
Hand tube well	5.2	311.2	43.1
Shallow tube well	6.2	280.8	37.6
Deep tube well	5.0	190.4	25.3
Pond	5.0	15.7	9.1
River	5.0	10.6	9.5
Bil	5.0	9.5	7.2

Ref. : Panaullah *et al.* (2005)

Table 3. Maximum permissible limit of Arsenic in different food crops

Food crop	**Inorganic Arsenic (**μg/kg**)**
Rice	0.15
Wheat	0.10
Other cereals	0.20
Vegetables	0.05
Fruits	0.05
Pulses	0.10

Ref. t Chinese Food Safety Standard, 2005; Alex Heikens, 2006

B. Effect of Arsenic contaminated and Arsenic free irrigation water on rice varieties

Five rice varieties were grown on Sunamgonj (Using Arsenic free surface water) and Brahmanbaria (Using Arsenic contaminated ground water). Arsenic accumulation was higher where arsenic contaminated ground water was use for irrigation. Arsenic accumulation was lower where arsenic free surface water was use for irrigation.

Table-4 t Arsenic concentration in rice varieties

Rice varities	Average Arsenic concentration (mg/kg)	
	Irrigated with Arsenic free surface water	Irrigated with Arsenic contaminated ground water
BRRI dhan-29	0.19	0.60
BRRI dhan -28	0.08	0.27
BR-3	0.11	0.36
BRRI dhan -36	0.13	0.41
BRRI dhan -32	0.17	0.46

C. Effect of Arsenic contaminated irrigation water on rice production

In a green house study it was observed that arsenic concentration in irrigation water increases, rice yield decreases.

Table-5 t Effect of Arsenic contaminated irrigation water on rice yield

Arsenic concentration in irrigation water	Straw yield (g/tob)		Grain yield (g/tob)			% yield reduction
	2002	2003	2002	2003	Average	
0 mg/L	76.3	84.0	64.5	68.8	66.7	-
0.10 mg/L	76.4	82.5	64.1	67.7	65.9	1.13
0.25 mg/L	74.9	80.2	63.2	66.9	65.1	2.40
0.50 mg/L	71.3	76.0	67.8	64.2	65.0	0.99
1.00 mg/L	67.2	71.2	58.9	60.3	59.6	10.58
2.00 mg/L	62.2	66.2	52.8	54.4	53.6	19.59
4.00 mg/L	55.2	60.3	44.4	46.0	45.2	32.18
6.00 mg/L	50.9	54.8	36.8	39.4	38.1	42.48
8.00 mg/L	44.4	49.5	28.0	32.1	30.1	54.91
10.00 mg/L	36.1	41.7	18.2	20.8	19.5	70.77

D. Effect of Arsenic contaminated irrigation water on rice varieties

An experiment was conducted at Brahmanbaria to find out the effect of Arsenic contaminated irrigation water on rice varieties. It was found that rice varieties having longer life cycle uses more irrigation water and arsenic accumulation was also higher. Short life cycled varieties uses less irrigation water and arsenic accumulation was least.

Table-6 t Effect of Arsenic contaminated irrigation water on rice varieties

Rice varities*	Life duration (days)	Amount of irrigation water (cm)	Yield (t/ha)		Arsenic content (mg/kg)	
			Grain	Straw	Grain	Straw
BRRI dhan-28	137	77	4.00	4.82	0.40	2.17
BRRI dhan-29	154	92	4.92	6.19	0.61	3.79
BRRI dhan-36	140	81	3.84	4.65	0.44	2.56
BINA-6	159	96	5.02	6.56	0.69	4.56

E. Arsenic concentration in rice

Meharg and Rahaman (2003) collected rice samples from different places. Collected rice samples were analysed. Analytical result were given below :

Table -7 t Amount of Arsenic in rice varieties

Collection Area	Arsenic concentration (mg/kg)		Variety
	Grain	Soil	
Gaipur	0.092	10.9	Average of 11 varieties
Bogra	0.058-0.104	4.9-15.5	Average of 4 varieties
Dinajpur	0.203	11.7	BR-11
Noagaon	1.84	26.7	BR-11
Chapai Nawabgonj	1.75	20.9	BR-11
Mymensingh	0.078	6.0-25.4	BR-8
Rangpur	0.185	6.5-11.5	BR-11
Rajshahi	0.075-0.117	7.8	Average of 3 varieties

Ref. t Meharg and Rahaman, 2003

F. Survey on Arsenic Contamination in water, soil & crops in North-Center of Bangladesh

A total of 38 union of 19 thana of 9 districts were randomly selected from the North-Centre part of Bangladesh during boro season of 2004. Analytical report has been presented below :

i) Arsenic content in irrigation water Samples :

Among the 5 water sources, Arsenic content was higher in HTW. In 19 % samples of HTW and 29% samples of STW was found > 50 µg/l.

Arsenic in (µg/L)	HTW	STW	Pond	River	Canal
Min.	0.52	0.52	0.52	0.52	0.52
Max.	311.17	220.25	15.68	10.63	19.47
Mean	42.95	41.85	3.09	3.96	4.31
SD	73.86	57.51	4.11	3.75	7.58
CV (%)	171.96	137.42	133.01	94.7	175.87

ii) Arsenic content in Soil Samples :

In each soil depth, arsenic content is higher in irrigated soil and lower in non irrigated soil

Arsenic in	Irrigated soil	Non irrigated soil

(mg/kg)	0-15 cm	15-30 cm	30-60 cm	0-15 cm	15-30 cm	30-60 cm
Min.	0.22	0.17	0.19	0.24	0.21	0.23
Max.	9.00	20.00	22.80	10.80	12.8	17.50
Mean	2.67	3.24	3.38	2.44	2.52	2.82
SD	2.25	3.80	4.04	2.05	2.20	2.87
CV (%)	84.27	117.28	119.53	84.02	90.16	101.78

iii) Arsenic content in Rice grain and straw samples :

Arsenic content is higher in rice straw and lower in rice grain

Arsenic content in (mg/kg)	Rice grain	Rice straw
Min.	0.08	0.33
Max.	0.44	8.44
Mean	0.22	2.27
SD	0.10	2.20
CV (%)	45.45	96.92

iv) Arsenic status of Non rice Samples :

Arsenic content is higher in amaranth, red amaranth, bottle gourd, sesame and onion

Name of Non rice crop	Arsenic in µg/L
Tomato	222
Bean	182
Potato	222
Coriander	222
Lentil	222
Chilli	250
Onion	556
Mustard	278
Garlic	500
Wheat	118
Sesame	667
Amaranth	389
Brinjal	111
Red Amaranth	778
Bottle gourd	333

G. Survey on Arsenic Contamination in water, soil & crops in Dhaka, Manikgonj and Greater Faridpur

A survey work on arsenic contamination were conducted in Dhaka, Manikgonj and Greater Faridpur during winter season of 2006.

Table 8. Information of sampling location and Arsenic concentration of samples

Sl. No.	Sampling location			Crop Name	Arsenic concentration	
	Village	**Union**	**Thana**		**Soil (mg/kg)**	**Crop ($\mu g\ g^{-1}$)**
01	Khatra	Kalia	Dhamrai	Amaranth	13.31	0.42
02	”	”	”	Bottle gourd	13.90	0.30
03	”	”	”	Chilli	14.60	0.23
04	Sreerampur	Sutipara	Dhamrai	Chilli	10.80	0.27
05	”	”	”	Cabbage	8.16	0.23
06	Pucoria	Baliakhora	Ghior	Cabbage	**31.62**	0.45
07	Pucoria	Baliakhora	Ghior	Cabbage	**23.54**	0.11
08	Doulatdia (South)	Goalond	Rajbari	Cabbage	15.83	0.30
09	”	”	”	Sweet gourd	**31.16**	0.57
10	Doulatdia (South)	Goalond	Rajbari	Country bean	9.15	0.22
11	”	”	”	Radish	13.80	0.56
12	Nimtoli	Nimtoli	Rajbari	Coriander leaf	10.81	1.93
13	”	”	”	Tomato	17.24	0.76
14	”	”	”	Cauliflower	13.36	0.24
15	”	”	”	Radish	12.74	0.42
16	”	”	”	Country bean	11.42	0.26
17	Moharajpur	Bosantapur	Rajbari	Potato	5.83	0.27
18	Mojlishpur	Bosantapur	Rajbari	Potato	16.66	0.19
19	Keshobnagar	Gherda	Faridpur	Potato	9.16	0.64
20	”	”	”	Brinjal	11.33	0.49
21	”	”	”	Red Amaranth	7.26	0.45
22	Shonkor Pasha	Talma	Nogorkanda	Red Amaranth	9.16	1.17
23	”	”	”	Potato	11.88	0.34
24	Naopara	Vanga Pourashaba	Vanga	Country bean	14.98	0.15
25	Pulse Research Sub Centre, Madaripur	Ghotmaghi	Madaripur	Country bean	16.64	0.18
26	Noya Khandi	Kendua	Madaripur	Country bean	17.49	0.34
27	”	”	”	Red Amaranth	14.60	1.85
28	”	”	”	Indian Spinach	11.44	1.54
29	Chagoldia	Ragdhi	Madaripur	Sponge gourd	14.99	0.64
30	”	”	”	Indian Spinach	10.66	1.13
31	Choudhuri Kanda	Vanga Pourashaba	Vanga	Kachu	14.14	1.66
32	”	”	”	Indian Spinach	12.18	2.03
33	”	”	”	Bottle gourd	16.32	1.06
34	BRRI station, Vanga	Vanga Pourashaba	Vanga	Radish	**22.13**	1.74
Minimum					5.83	0.11
Maximum					31.62	2.03
Mean					14.41	0.70
SD					5.91	0.60
CV %					41.01	85.71

Table 9. Arsenic status in collected soil samples

	Arsenic concentration in mg/kg		
	0-10 mg/kg	10-20 mg/kg	> 20 mg/kg
Sample Number	6	24	4

H. Survey on Arsenic Contamination in Vegetables

Farid *et al.* (2003) conducted an experiment to reveal the effect of arsenic contaminated and non-contaminated irrigation water on different vegetables grown under varying levels of arsenic contaminated soils in different areas of Bangladesh. Arsenic concentration in soil varied from 0.2 to 40.1 mg kg^{-1} while the level of As in irrigation water ranged from 0.059 to 0.80 mgL^{-1}. Results showed that arsenic content in different vegetables grown with arsenic contaminated irrigation water were much higher than those grown with non contaminated irrigation water (Table 10).

Table 10. Arsenic content in different vegetables grown under varied locations

Crop	Location	Arsenic content (mg kg^{-1})			
		Contaminated		Non-contaminated	
		Range	Mean	Range	Mean
Tomato	Nawabgonj	0.016-0.049	0.030	0.001-0.025	0.011
Potato	Monirampur	0.013-0.021	0.017	0.001-0.014	0.007
	Gopalgonj Sadar	0.211-0.390	0.301	0.083-0.0284	0.184
	Pirgachha	0.042-0.107	0.068	0.024-0.068	0.041
	Rajarhat	0.000-0.080	0.024	0.000-0.055	0.021
Brinjal	Nawabgonj	0.042-0.063	0.049	0.028-0.063	0.045
Red amaranth	Monirampur	0.132-0.606	0.321	0.072-0.240	0.163
Bitter gourd	Gopalgonj	-	0.091	-	0.039
Stem Amaranth	Nawabgonj	0.093-0.201	0.161	0.099-0.109	0.103
	Pirgachha	0.182-2.791	0.935	0.060-0.370	0.241
	Monirampur	-	0.620	-	0.074
Katua data	Charghat	0.060-0.333	0.168	0.092-0.163	0.125
	Monirampur	-	0.400	-	0.103
China shak	Pirgachha	-	0.539	-	0.278
Cabbage	Muksedpur	0.031-0.042	0.037	0.000-0.059	0.030
	Monirampur	-	0.106	-	0.080
Indian spinach	Monirampur	0.134-0.387	0.267	0.092-0.228	0.154
	Muksedpur	0.096-0.126	0.111	0.000-0.091	0.046

Crop	Location	Arsenic content (mg kg^{-1})			
		Contaminated		Non-contaminated	
		Range	Mean	Range	Mean
Cauliflower	Muksedpur	-	0.011	-	0.001
Chilli	Gopalgonj	-	0.112	-	0.103
Okra	Charghat	0.034-0.046	0.040	0.016-0.046	0.031

Source: Farid *et al*. (2003)

In case of contaminated water, the mean (over the location) arsenic content was found highest (0.572 mg kg^{-1}) in stem amaranth followed by Chinashak (0.539 mg kg^{-1}), red amaranth (0.321 mg kg^{-1}) and katua data (0.281 mg kg^{-1}). The moderate arsenic content was observed in Indian spinach (0.189 mg kg^{-1}) followed by chilli (0.112 mg kg^{-1}), potato (0.103 mg kg^{-1}), bitter ground and cabbage (0.072 mg kg^{-1}). Relatively lower arsenic content was found in brinjal (0.049 mg kg^{-1}) followed by okra (0.040 mg kg^{-1}) and tomato (0.030 mg kg^{-1}). The lowest arsenic content (0.011 mg kg^{-1}) was food in cauliflower (Fig.1).

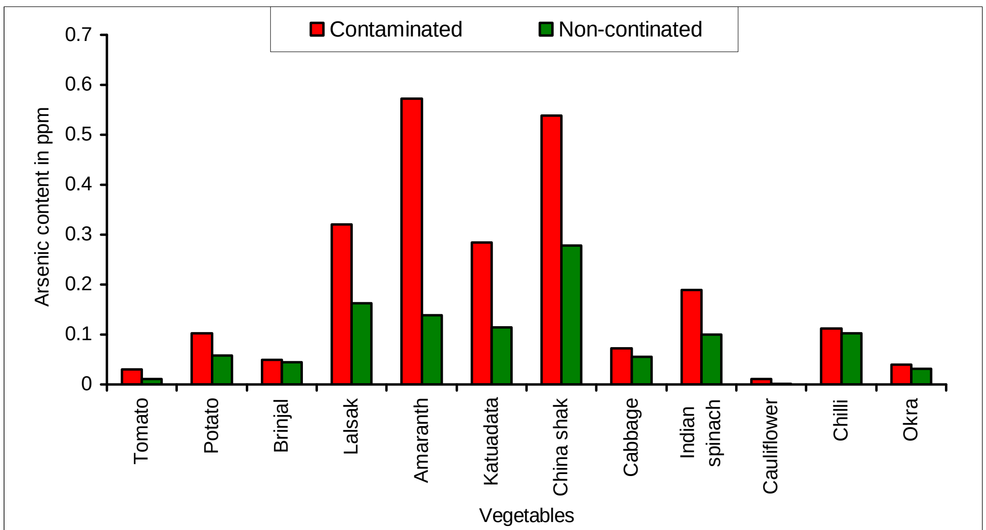

Fig. 1. Relative Arsenic content of different vegetables irrigated with arsenic contaminated and non-contimanted water

Source: Farid *et al*, (2003)

Incase of non-contaminated irrigation water, the highest arsenic content (0.278 mg kg^{-1}) was reordered in chinashak followed by red amaranth (0.163 mg kg^{-1}), amaranth (0.139 mg kg^{-1}) and katua data (0.114 mg kg^{-1}). The moderate arsenic content was observed in chilli (0.103 mg kg^{-1}), Indian spinach (0.100 mg kg^{-1}) and potato (0.058 mg kg^{-1}). The lower level of arsenic content was found in cabbage (0.059 mg kg^{-1}), brinjal (0.045 mg kg^{-1}) and okra (0.031 mg kg^{-1}). The lowest arsenic content (0.001 mg kg^{-1}) was recorded in cauliflower. The arsenic accumulation of the studied vegetables exceeds the Chinese food safety standards of inorganic arsenic for vegetables (0.05 mg kg^{-1}). However, these mean results may not be the absolute value of contents of arsenic in the studied vegetable because of limitations of growing all types of vegetables in all studied locations but it shows the uptake pattern of the studied vegetables. The trend of arsenic accumulation was found higher in leafy vegetables and lower in fruity vegetables. Accumulation of arsenic varied from place to place and crop to crop, the reason may be due to variation in soil properties and crop physiology. The relationship between arsenic availability with arsenic accumulation was followed the order: tomato>potato>red amaranth>katua data (Table 11). These results signified that tomato is more susceptible to As availability in irrigation water followed by potato, red amaranth and katua data.

Table 11. Relationship between arsenic in irrigation water and arsenic accumulation by vegetables

Crop	Location	Particular	Equation	R^2
Tomato	Chapai Nawabgonj	Water vs Fruit	y = 0.0004x + 0.012	0.9862
Potato	Monirampur	Water vs Tuber	y = 0.0001x + 0.0084	0.8897
Red amaranth	Charghat	Water vs Leaf	y = 0.1170x + 0.1928	0.8875
Katua data	Charghat	Water vs Stem	y = 0.0402x + 0.025	0.6817

Source: Farid *et al*, (2003)

On a dry weight basis, some vegetables contained higher As concentration than rice. This does not necessarily mean that As in vegetables poses a higher risk to human health than As in rice. From a food safety perspective, water contents and food consumption data need to be taken into account. Usually, food consumption data are on a raw weight basis, i.e. fresh vegetables (contains more the 70 to 90 percent water) and uncooked rice (contains approximately 13 percent water). Comparing As concentrations in rice and vegetables on a raw weight basis showing that As contents in rice are usually higher than the vegetables (Heikens, 2006). Das *et al*. (2004) observed higher arsenic content in taro leaves (0.09-3.99 mg kg^{-1}), potato (0.07-1.36 mg kg^{-1}) and kalmi shak (0.10 - 1.53 mg kg-^{1}), which collected from different parts of Bangladesh.

I. Arsenic in Weeds

Akter *et al* (2007) collected 34 samples of naturally grown weed samples from highly arsenic contaminated Faridpur and arsenic non-contaminated Gazipur regions. The collected samples were divided into different plant parts like root, shoot and leaf. Plant samples were collected from the vicinity of rice fields, then dried and ground. Along with plant samples, soil samples of the surveyed areas were also collected. Arsenic content of the collected samples were analyzed using hydride generation technique. The arsenic content in irrigation water was 0.22 mg L^{-1} at Faridpur while it was 0.006 mg L^{-1} at Gazipur. The arsenic content in soil varied from 18.7 to 50.4 mg kg^{-1} and 1.7 to 4.1 mg kg^{-1} at Faridpur and Gazipur, respectably. The highest arsenic content was found in roots of fern (117.1 mg kg^{-1}) followed by leaves of wild taro (106.8 mg kg^{-1}) and lowest in the roots of duck weed (44.1 mg kg^{-1}) (Table 12). Out of 34 plant species, 11 plants were detected as of arsenic hyper accumulating nature. The pattern of arsenic accumulation by water taro, water cress wild taro, duckweed and water hyacinth was leaf>short>root. The mesophytes like barnyard grass, cockle bur, dog grass and fern accumulated arsenic in the order of root>shoot>leaf. The rest of the plant species accumulated higher arsenic in shoot than leaves and roots. Similar type of arsenic accumulation pattern was reported by Mollah (2002). The relationships between soil As vs root As, soil As vs stem As, soil As vs leaf As & stem As vs leaf As, stem As vs root As and leaf As vs root As were significant at 1% level at Faridpur. But at Gazipur, relationships between soil As vs root As, soil As vs stem As, soil As vs leaf As were statistically non- significant (Table 13). The hyper accumulating plants were ranked on the basis of higher AS tolerance, higher bio-concentration factor, shorter life cycle, higher propagation rate, wide distribution and longer shoot biomass. Considering the above criteria, fern was found to be the most hyper accumulator followed by barnyard grass, water hyacinth, wild taro, water taro, cockle bur, duck weed and dog grass. The lower graded hyper accumulator was topapana, water cress and malancha. Again, fern, barnyard grass might be suitable to remove arsenic from soil whereas water hyacinth and topapana from stagnant water and can be used for phytoremediation.

Table 12. Arsenic content in soil, water and corresponding weed samples collected from Arsenic contaminated area

Sam No.	English name	Soils As (mg kg^{-1})		Plant As (mg kg^{-1}) Root		Stem		Leaf		Bio concentration factor (BCF)	
		Faridpur	Gazipur	Faridpur	Gazipur	Faridpur	Gazipur	Faridpur	Gazipur	Faridpur	Gazipur
1.	Green nutsedge	34.1	2.2	30.9	1.8	25.8	1.4	18.9	1.1	0.74	0.65
2.	Water taro	38.3	2.4	44.5	4.0	54.9	6.4	67.8	8.9	1.46	2.68
3.	Water cress	40.5	2.0	46.1	4.2	52.8	5.8	63.9	6.9	1.34	2.82
4.	Sushnisak	29.0	1.8	25.4	1.5	20.9	1.2	17.2	1.0	0.73	0.69
5.	Barn yard grass	37.1	2.5	90.4	8.2	71.3	7.4	54.6	4.8	1.94	2.72
6.	Keshuti	26.8	1.7	20.4	1.5	16.3	1.2	13.2	0.8	0.62	0.69
7.	Kesordam	18.7	2.3	9.4	1.7	11.5	2.1	18.8	2.4	0.71	0.89
8.	Foska begun	20.9	2.1	17.2	1.8	13.8	1.4	11.6	1.0	0.68	0.67
9.	White verticilla	26.9	2.4	18.7	2.0	16.4	1.5	12.6	1.0	0.59	0.63
10.	Yellow nutsedge	22.6	2.2	16.3	1.8	12.8	1.4	8.9	1.2	0.56	0.67
11.	Cockle bur	33.7	2.8	58.3	11.6	50.5	10.4	47.2	7.6	1.54	3.52
12.	Lambs quarter	27.6	2.6	22.4	2.7	20.7	2.2	17.2	1.4	0.73	0.81
13.	Angta	22.3	2.9	17.1	2.0	13.6	1.5	12.2	1.2	0.64	0.54
14.	Dog grass	44.4	3.5	59.8	8.7	51.6	7.8	46.3	6.3	1.18	2.17
15.	Azolla	40.3	2.4	-	-	-	-	52.1	5.2	0.43	0.72
16.	Topapana	41.6	3.0	57.8	5.2	63.2	6.7	46.1	4.0	1.33	1.77
17.	Wild taro	50.4	3.4	59.1	9.6	77.4	11.3	106.8	13.2	1.61	3.34
18.	Crab grass	22.3	3.8	15.1	3.2	12.9	2.9	10.3	2.3	0.57	0.74
19.	Algae	26.1	3.4	-	-	-	-	12.0	2.7	0.15	0.26
20.	Duck weed	33.5	4.1	44.1	6.8	58.1	10.2	66.3	14.1	1.68	2.52
21.	Fern	40.8	3.2	117.1	11.8	94.2	9.4	70.4	7.4	2.30	2.98
22.	Common sedge	19.4	3.4	13.8	3.1	10.6	2.7	9.2	2.4	0.58	0.80
23.	Water hyacinth	42.6	3.2	54.8	6.8	71.5	7.6	80.3	8.3	1.62	2.36
24.	Malancha	37.8	2.8	51.9	4.8	65.8	6.6	58.8	6.2	1.56	2.10
25.	Chanchi	22.7	3.4	17.1	2.6	13.1	2.4	10.4	2.1	0.70	0.70
26.	Kanai bashi	28.8	3.3	19.4	2.4	20.8	2.7	22.4	2.8	0.72	0.80
27.	Panilong	40.8	3.6	24.6	2.7	31.5	2.9	33.6	3.4	0.73	0.83
28.	Marsh pepper weed	32.5	3.1	28.9	3.1	24.6	2.7	21.8	2.4	0.77	0.88
29.	Creeping wood sorrel	26.1	3.5	12.7	2.8	16.1	3.1	20.3	3.8	0.63	0.92
30.	Chota dudhia	37.1	3.1	28.5	3.0	22.4	2.6	17.1	2.4	0.61	0.86
31.	Joyna	22.6	3.3	17.1	3.2	14.6	2.5	20.9	2.1	0.78	0.79
32.	Wild mustard	31.2	3.7	23.5	3.2	16.8	2.8	13.2	2.2	0.57	0.74
33.	Arailya	28.1	3.5	24.1	3.1	20.1	3.0	16.4	2.6	0.72	0.83
34.	Wild helitrop	33.7	3.8	26.8	2.9	21.8	2.6	16.6	2.8	0.64	0.72
Minimum		18.7	1.7	9.4	1.5	10.6	1.2	8.9	0.80	0.15	0.26
Maximum		50.4	4.1	117.1	11.8	94.2	11.3	106.8	14.10	2.30	3.52
Mean		31.80	2.95	32.74	3.94	32.01	4.01	32.81	4.06	0.94	1.35
SD		8.20	0.63	24.89	2.99	24.79	3.17	25.44	3.36	0.50	0.96

Source: Akter *et al.* (2007)

Table 13. Relationships among arsenic in soil and different parts of weeds at Faridpur and Gazipur

Location	Parameter	Root		Stem		Leaf	
		2006	2007	2006	2007	2006	2007
Faridpur	Stem	0.931**	0.938**				
	Leaf	0.674**	0.705**	0.832**	0.863**		
	Soil	0.575**	0.654**	0.684**	0.750**	0.843**	0.821**
Gazipur	Stem	0.914**	0.937**				
	Leaf	0.703**	0.602**	0.902**	0.869**		
	Soil	0.219	0.257	0.294	0.274	0.219	0.296

Source: Akter *et al.* (2007)

Shaheen *et al* (2006) conducted a pot trial at the Bangladesh Agricultural University for studying the effect of different levels of added arsenic on growth of and arsenic accumulation by nine naturally grown weeds for the possible development of phytoremediation technology. The experiment comprised seven arsenic doses viz. 0, 10, 20, 30, 50, 70 and 100 mg kg^{-1} as added as $NaAsO_2$ in solution. Out of nine selected weed species. Water cress absorbed highest amount (42.76 μg pot^{-1} of arsenic followed by Join (36.73 μg pot^{-1}), Barnyard grass (36.04μg pot^{-1}) and Malancha (29.80 μg pot^{-1}) (Table 12). Arsenic absorption was in the order of root > shoot. Water cress was the best arsenic accumulator. But considering the intensity of infestation rate in rice field, Joina and Barn yard grass are more appropriate for mitigating arsenic contamination from the affected rice field. On the other hand, Water cress and Malancha may be proposed for the remediation of arsenic from contaminated stagnant water.

Table 14. Arsenic concentration (ppm) in different naturally grown weeds

Treatments	Barnyare grass	Joina	Mutha	Water cress	Malancha	Pani Kachu	Panilong	Chisra	Topapana
T_0	10.52d	1.88e	2.40d	13.26f	3.61f	4.71e	0.46c	4.25e	0.17e
T_{10}	23.35b	10.69d	5.95c	23.33e	13.08e	5.89d	0.41c	10.17d	0.72d
T_{20}	16.71c	11.59d	10.11b	27.68d	16.13d	4.97e	1.26b	15.05c	1.08c
T_{30}	25.76b	36.18a	12.60a	32.01c	21.63c	7.72c	1.72a	14.48c	2.73b
T_{50}	24.96b	31.41b	11.53a	42.76a	23.47c	13.00b	1.65a	13.68c	3.01a
T_{70}	36.04a	19.75c	9.70b	36.21b	29.80a	16.94a	1.12b	21.57a	-
T_{100}	24.51b	36.73a	9.03b	38.11b	26.47b	17.74a	0.61c	19.98b	-
Level of significance	**	**	**	**	**	**	**	**	**
CV (%)	5.90	3.64	7.67	4.47	6.02	4.55	12.89	5.67	11.96

Source : Riffat Shaheen *et al* (2006)

6. Recommendations (Remedial measures of Arsenic mitigation in Agriculture)

1. Arsenic free water (surface water) should be used for irrigation.
2. Arsenic tolerant crop varieties/species should be find out and cultivated in arsenic prone area.
3. Arsenic hyper accumulating weeds should be used for phyto remediation.
4. Alternate wetting and drying method for irrigation should be practiced in rice field. It will reduce water requirement of rice. As a result less arsenic is accumulated in paddy.
5. Bed planting method should be practice instead of traditional flat planting method. It will reduce water consumption of crop and thereby arsenic accumuluation in food crop.
6. Suitable crop cultivation technique should be find out to mitigate arsenic contamination.

7. Conclusions

About 90% water is used for irrigation purpose. Soil and crop is the ultimate sink of groundwater Arsenic. The accumulation of arsenic in food crops, its threshold and toxicity and safe limits have not been done extensively yet. Again, the levels of arsenic in weeds and their capability in removing arsenic from the contaminated soil is still needs due attention.

To evaluate current and future soil concentration, representative toxicity data for crops are needed especially under non-flooded and flooded conditions. The soil parameters which correlate with uptake and toxicity by different crops needs to be developed to set standards for arsenic in different soil situations. Suitable arsenic removal technique from soil crop should be developed in future.

8. Future research sugessted in Agriculture

1. Arsenic tolerant crop varieties/species should be find out.
2. Arsenic hyper accumulating weeds should be used for phyto remediation.
3. Non food crop should be cultivated in sevearly arsenic affected area.
4. Suitable water management technique should be find out to mitigate arsenic.
5. Suitable crop cultivation technique should be find out to mitigate arsenic contamination.

9. Implementation plan :

- Conduct research & development activities by National Agrcicultural Research Institutes (BARI, BRRI & BINA) to mitigate arsenic in food chain.

-Evaluation of Arsenic status in Irrigation water by Bangladesh Agricultural Development Corporation.

-Dissemination of Arsenic mitigating technology among the farmers by Department of Agricultural Extension (DAE)

11. COST ESTIMATE FOR IMPLEMENTING THE RECOMMANDATION AND MITIGATION MEASURES OF ARSENIC

Sl. No.	Description	Quantity	Unit Rate	Tatal Amount (Lakh taka)
1.	Water quality test at different depth of a well (maximum 5 samples in each well). Cost including wages of technical manpower, kits, chemicals, transport etc.	5,00,000 nos.	Tk. 500	Tk. 2500.00 Lakh
2.	Replacement of Arsenic contaminated Shallow Tube Well (STW) to Deep Tube Well (DTW). Cost includes material, installation, overhead tank etc. complete in all respect.	1,000 nos.	Tk. 25 Lakh	Tk. 25000.00 Lakh
3.	Research and development work for detecting the presence and level of arsenic in food crops.	LS		Tk. 1500.00 Lakh
4.	Technology dissemination to the user/ farmers by modern extension processes. Cost includes printing, publication, report returns etc. all complete.	LS		Tk. 1000.00 Lakh
	TOTAL			Tk. 30000.00 Lakh

N.B. Total 15,53,514 number of equipment used for irrigation in the country during the last Rabi season of 2008-09

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