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Arsenic Concentrations of Groundwater and Rice Grains in Bangladesh and Phytoremediation

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방글라데시의 지하수와 쌀의 비소오염 및 식물정화법

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Abstract

While groundwater is the major source for drinking and irrigation purposes, arsenic (As) contamination of groundwater is a serious issue in Bangladesh. With a view to reduce As contamination in drinking water the guideline value recommended for Bangladesh is 0.05 mg/L. We assessed groundwater As in an As-affected Sadar Upazilla (small administrative unit) in the District (administrative unit) of Chapai Nabwabganj during 2006, where 50% hand tube well water were above the recommended limit (0.05 mg/L) during dry season. Almost 20% tube well waters were above the recommended limit during rainy season, perhaps due to the dilution of water table. The groundwater in Bangladesh contaminates surface soils and plants thereby As entering the food chain. In 2005, we examined the As levels in different rice varieties grown in different Districts of Bangladesh and the As concentrations in rice grain ranged from 0.07~1.12 mg/kg while the concentrations in 3 rice varieties were above the recommended limit (1 mg/kg rice grain) and the maximum concentration was 1.12 mg/kg rice grain in the rice variety BR 11. With few exceptions, the As content of rice grain in Bangladesh is not considered to be concentration of greater health concern as yet. We also observed enhanced root uptake, efficient root-to shoot translocation, and a much elevated tolerance through internal detoxification all contribute to As hyperaccumulation in a plant, ladder brake fern (*Pteris vittata* L.*)*. But the phytoremediation technique might not be an appropriate tool to reduce the As calamity in the vast areas of Bangladesh. To mitigate the As problem of Bangladesh, better coordination among governmental agencies and many other organizations will be required to combat the disaster.

keywords : Arsenic, Bangladesh, Groundwater, Phytoremediation, Rice grains

1. Introduction

Arsenic (As) is ubiquitous in the environment, usually being present in small amounts in all soils, rocks, waters, air and biological tissues (Nriagu and Pacyna, 1988). In Bangladesh, As contamination is now the most important environmental concern. Contamination of groundwater with As in Bangladesh is the largest poisoning of a population in history, with millions of people exposed. An estimated 57 million people drink water with As levels exceeding the limits set by the WHO (2000). It has also been reported that about 0.2 million Bangladeshi people are suffering from arsenicosis, ranging from melanosis to skin cancer (Das, 2000). An estimated 100,000 cases of skin lesions caused by As have already occurred and 200,000~270,000 additional cancer cases are expected (Smith et al., 2000). However, the extent of contamination level varies from area to area and actual cause of the contamination is yet to be confirmed.

Some studies have shown that groundwater in 60 out of 64 Districts in Bangladesh are contaminated by As. High concentrations of As are found in water from thousands of wells across the country and more areas are being identified as contaminated with As. The use of As contaminated groundwater for irrigation of crops has resulted in elevated concentrations of As in agricultural soils and plants. Arse-

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nic concentration in plants varies among species and among various areas of Bangladesh.

Bangladesh occupies a territory in the north-western part of the Indian subcontinent north of the Bay of Bengal. Bangladesh has an area of 147,570 km^2 and a population of 150 million with 75 to 80% living in the rural areas. Currently 97% of the population of Bangladesh use tube well water for drinking, cooking and irrigation purposes, although surface water, to a smaller extent, is also being used for some domestic and agricultural purposes. Groundwater is widely used for irrigation during dry season (December to April), particularly for growing dry-season rice called *boro* which requires about 1 m of irrigation water each year (Hossain et al., 2003). Groundwater is considered as free from pathogenic microorganisms and available in adequate quantity in shallow aquifers for low-cost water supply system in rural areas of Bangladesh. But some shallow groundwater in Bangladesh is contaminated with As from geogenic sources (DPHE-BGS, 2000). Groundwater As contamination causes serious health hazards as reported from many countries of the world, but especially in Bangladesh and neighboring India. Over a period of 20~25 years about 4 million wells have been installed to utilize groundwater from deeper aquifer layers, typically less than 200 m depth (UNICEF, 1999). Exploitation of groundwater from these wells has resulted in mobilizing the As and led to mass poisoning in the region.

Surveys have shown that As concentration in contaminated Bangladesh soils varied from 7.21 to 27.58 mg/kg gradually absorbed by different crop species (Das et al., 2000). A strong positive correlation between the amount of As in rice (the roots, straw, husk, and, to a lesser extent, the grain) and As concentrations in soil solution has been found in greenhouse research (Abedin et al., 2002a). In addition, irrigation with As contaminated water can lead to an accumulation of As in soils (Ali et al., 2003).

Phytoremediation has been successfully used to remediate the soils contaminated with heavy metals, excepting As. Up to now, there has been no cost-effective method to clean up As-contaminated soils, and the technologies currently used for the cleanup of As-contaminated drinking water have significant drawbacks, such as high cost, generating high volumes of toxic sludge and brine, and low water recovery. The only known As hyperaccumulating plant, a fern in the *Pteris* genus, was identified by Ma et al. (2001). Successful application of this finding will have profound and long-lasting impacts on the phytoremediation industry of As. The objectives of this study were to (1) assess As concentrations in groundwater in some areas of the District of Chapai Nawabganj, (2) compare As concentrations among different rice varieties grown in Bangladesh and (3) investigate the effects of arsenic concentrations on the accumulation of arsenic in plant tissues.

2. Materials and Methods

2.1. Arsenic in *P. vittata* (pot experiment) and rice grains

A pot experiment was carried out to investigate uptake behavior of As by a plant, ladder brake fern (*Pteris vittata* L.) during 2006. The test plants were germinated from spores and grown in soils used throughout the experiment. At the three-to-four frond stage, seedlings were transferred to plastic pots, each containing 4 kg of air-dried soil. The concentrations of As in the soil were measured. Soil pH was determined in a soil: water (1:2.5) suspension. The soil was amended with arsenate (Na_2HAsO_4) at As concentrations of 0, 5, 10, 15 and 20 mg/kg. Arsenic doses were applied with deionized water. Each treatment was replicated four times.

Because studies have shown that *P. vittata* can accumulate higher amounts of As in the presence of higher As content in soils, we used low As doses to reflect more typical soil As concentrations. Plants were harvested on day 55 after transplanting. After sun drying, fronds and roots were dried for 24h at 65°C and then ground in a Wiley Mill to pass through a 1 mm-mesh screen. We collected different rice grain samples from different As affected areas of Bangladesh to compare As content in rice grains. Sampling sites are shown in Fig. 1. Our survey encompassed areas with both high and low average As tube well waters. Grain was sourced from markets and directly from farmers. Only the edible portion of the sample was analyzed.

Arsenic concentrations in soils were determined by atomic absorption spectrophotometer equipped with hydride generator situated at Soil Science laboratory of Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh (APHA, 1998). Total As content of *P. vittata* and rice grains were determined by digesting the respective dried-ground plant sample and rice grains with tri-acid mixture (HNO_3: H_2SO_4: $HClO_4$ =10: 1: 4) until whitish colored. The digest was cooled and then filtered through Whatman No. 42 filter paper and finally diluted to 50 mL. A Perkin-Elmer Analyst 100 atomic absorption spectrophotometer equipped with a FIAS-100-flow injection hydride generation system was used for all As determinations. All samples were pre-reduced with concentrated HCl (1 mL), 5% KI and ascorbic acid mixture prior to hydride generation. All glassware and plasticware was previously acid washed in 2% HNO_3, rinsed in deionized water and dried. Three replicates of rice grains and five replicates of *P. vittata* were analyzed for each sample.

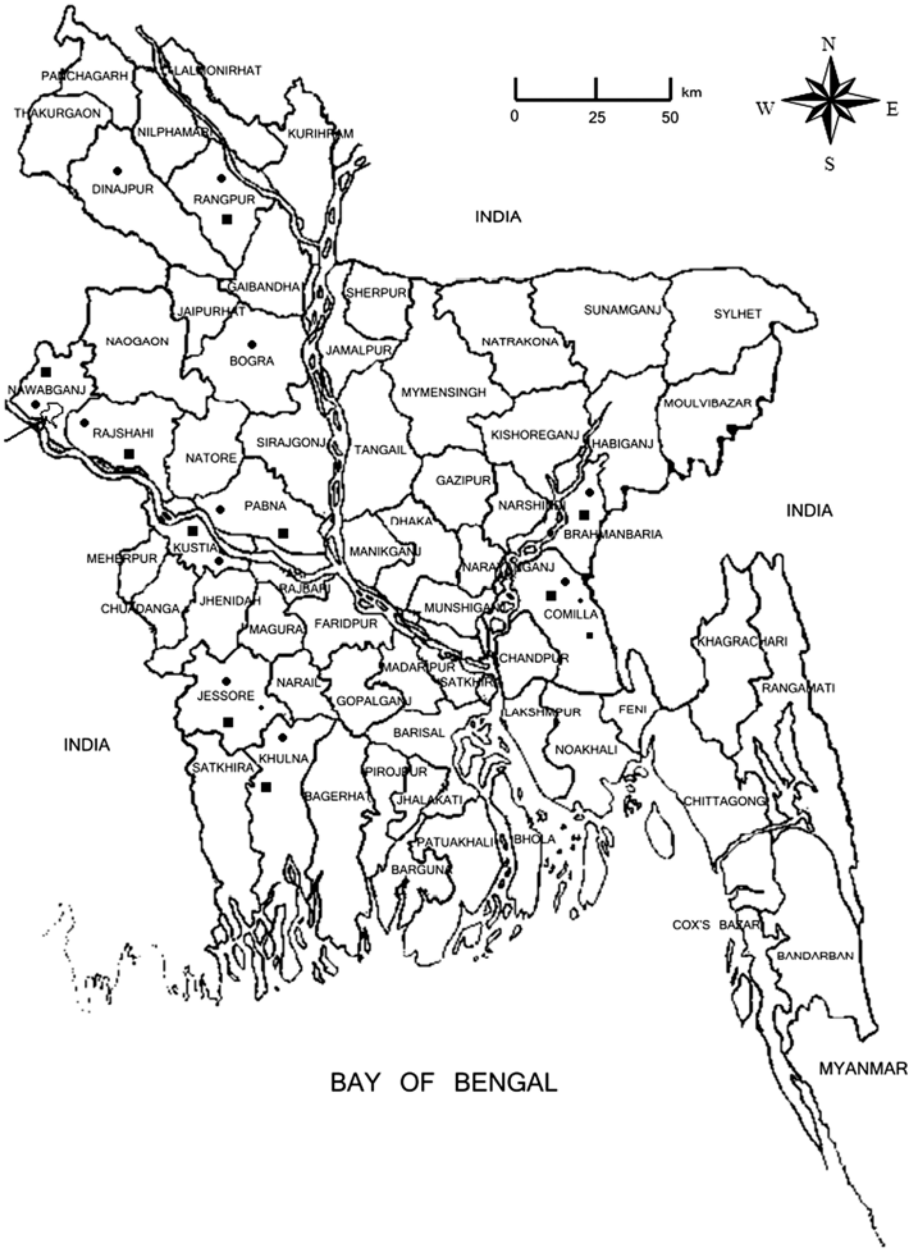

Fig. 1. Map of the sampling sites of the different rice varieties collected from different Districts of Bangladesh during 2005. Big and small circles represent the sample no. 1 and sample no. 3 against the respective Districts. Big and small rectangles correspond to the sample no. 2 and sample no. 4 of the respective Districts. An open circle with arrow mark indicates the water sampling location of Sadar Upazilla region of the District of Chapai Nawabganj.

2.2. Collection of groundwater and determination of arsenic concentrations

We collected 100 tube well water samples from an As affected area of Sadar Upazilla of the Chapai Nabwabganj District (Fig. 1), to evaluate groundwater As status of that area. The depth of the tube wells ranged from 20 m to 70 m. Samples were collected during the dry (March ~ April) and rainy (July ~ August) seasons during 2006. Sampling times were selected to assess the variability in groundwater As concentrations during the dry and rainy season. Water samples were collected following technique as outlined by APHA (1998). Samples were collected in pre-cleaned polyethylene bottles that were previously rinsed with ultra-pure water. Before sampling, polyethylene bottles were again rinsed 2 to 3 times with samples, and collected samples were stored in the dark at 4°C. All glassware and plasticware were previously acid washed in 2% HNO_3, rinsed in deionized water and dried. The As concentration was determined by Perkin-Elmer Analyst 100 atomic absorption spectrophotometer equipped with a FIAS- 100-flow injection hydride generation system and all water samples were pre-reduced with concentrated HCl (1 mL), 5% KI and ascorbic acid mixture prior to hydride generation.

3. Results and Discussion

3.1. Arsenic in Sadar Upazilla and causes of contamination in Bangladesh

During July and August in 2006, we collected 100 tube well water samples from Nawabganj Sadar Upazilla of Chapai Nawabganj District. Approximately 50% of the water samples were above the permissible limit (Fig. 2) recommended by WHO (0.01 mg/L). Around 15% of the samples were within the range of 0.05 to 0.1 mg As /L and nearly 7% of the samples had As concentrations above 0.10 mg/L. According to the recommended limit, 75% of the water samples were above the recommended limit. These As concentrations show the imminent danger for human health associated with well water in this region. With increases in groundwater As concentrations, As concentrations in food grains and vegetables also increase. Consequently, a person is getting more chances to consume As and increasingly affecting by different diseases caused by As in an As-affected area. During the period of March-April in 2006, approximately 80% of the water samples were above the permissible limit recommended by WHO (0.01 mg/L). Among the collected water samples, about 42% of the samples were above the recommended limit of 0.05 mg/L (BAMWSP, 2006).

In collaboration with the Department of Public Health & Engineering (DPHE), UNICEF (1999) reported that among the analyzed groundwater samples, approximately 20-25% areas of Bangladesh are still under the recommended limit of Bangladesh (0.05 mg/L). While 0.1-20% groundwater were above the recommended limit in the $1/4^{th}$ areas of the whole Bangladesh. The rest 50% areas contain the different percentages of groundwater As above the recommended limit. Due to overdrawn of groundwater for irrigation, drinking and domestic uses, an increasing trend of high As concentration may gradually continue in higher As-contaminated (>0.05 mg/L) areas in the near future. Until now alternative sources of water for drinking and irrigation uses have been too few. A British Geological Survey conducted in 1998 collected 2022 water samples from 41 Districts out of 64 Districts of Bangladesh and reported that 35% were found to have As concentrations above 0.05 mg/L and 8.4% showed As concentrations above 0.30 mg/L. Based on population density, the number of people exposed to As concentrations above 0.05 mg/L was about 21 million (WHO, 2000). This number would be approximately doubled if WHO's As standard (0.01 mg/L) were adopted.

Arsenic is a common constituent of the earth's crust that comes to the surface by agricultural irrigation or groundwater withdrawal. Arsenic in groundwater mainly results from

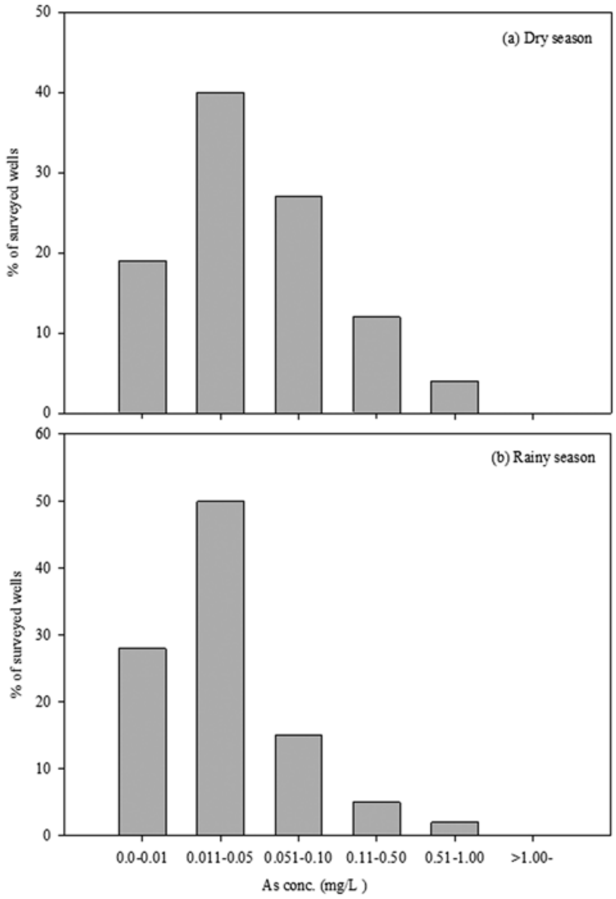

Fig. 2. Groundwater arsenic concentrations of the surveyed wells in Sadar Upazilla area of the Chapai Nawabganj District during the dry season (March-April) and the rainy season (July-August) in 2006.

minerals dissolved from weathered rocks and soils (Mandal and Suzuki, 2002). Arsenic contamination in groundwater of Bangladesh is geogenic in nature, originating from sedimentary aquifers of Ganges-Brahmaputra-Meghna delta (Nickson et al., 2000; Smedley and Kinniburgh, 2002). The most widely accepted mechanism for high concentration of As in groundwater is reduction of Fe(III) oxides and release of associated As to solution (McAuthur et al., 2001; Nickson et al., 1998). The principal hypotheses about the genesis of As in groundwater are: (1) As derived from the oxidation of As-rich pyrite in the shallow aquifer due to lowering of the water table from overexploitation of groundwater for irrigation and (2) As derived by desorption from ferric hydroxide minerals present as coatings in the aquifer sediments under reducing conditions (Nickson et al., 1998).

High As concentrations in groundwater have been found in many environmental conditions originating from natural processes and from anthropogenic sources (Konstantina Tyrovola et al., 2006). Recent alterations in irrigation pumping practices have changed groundwater flow patterns, possibly decreasing the residence time of groundwater and perhaps flushing As from the Holocene aquifer. Groundwater levels in Bangladesh may be becoming lower due to unplanned extraction of groundwater for irrigation and excess withdrawal of water from upstream of the river flowing from India. Large scale surface water withdrawal in India after construction of the Farakka caused a drastic fall in the Ganges low-flow condition within the Bangladesh territory during every dry period. The average lowest flow in the Ganges was 552 m^3/s, which is about 73% less than that in the pre-Farakka time (Rahman et al., 2000). This has caused the deterioration of surface and ground water quality of the south-west of Bangladesh. The ultimate consequence is the intrusion of seawater in the southern part of Bangladesh. Lowering of the water table in ground causing increase of oxygen in layer resulting in oxidation of pyrites, and release of acid due to chemical reaction with iron pyrites and oxygen and produces As in soluble form, is one of the major source of As in Bangladesh.

It is commonly accepted that As can be isomorphically substituted for reduced sulfur in the pyrite structure (Nesbitt et al., 1995; Strawn et al., 2002) and arsenite (As-III) is the dominant oxidation state measured in most groundwater samples with relatively minor As(V) concentrations (BGS and DPHE, 2001). Excessive groundwater withdrawal could induce infiltration of high As-groundwater and contaminate deeper aquifers (Harvey et al., 2002; Ravenscroft et al., 2001; van Geen et al., 2003). However, As contamination of shallow fluvio-deltaic aquifers in the Bangal Basin has also resulted in increasing exploitation of groundwater from deeper aquifers that generally contain low concentrations of dissolved As (Stollenwerk, 2003).

3.2. Arsenic accumulation in rice grains

Crop quality and the effect of As on crop quality and yield is becoming a major worldwide concern, particularly for rice which forms the staple for many South-Asian countries (Duxbury et al., 2003; Meharg and Rahman, 2003). A greenhouse study revealed that reduced yields resulted from using irrigation water with As concentrations in the range of 0.2 to 8 mg/L (Abedin et al., 2002b). Rice is the main staple food crop in Bangladesh, but its cultivation requires huge quantity of water, especially in the dry season. People in Bangladesh not only drink As contaminated groundwater, but also irrigate their crops with this As contaminated groundwater due to limited alternative sources for irrigation. To feed the growing population of Bangladesh, more areas are being irrigated with groundwater for intensive agriculture, especially for rice cultivation.

Pot studies (Jahiruddin et al., 2004) showed that higher As concentration in irrigation water (0.1 to 2.0 mg/L) and soil (5 to 50 mg/kg) resulted in lower yields of a local rice variety (BR-29). For *boro* rice production, paddy fields are irrigated with groundwater from shallow tube wells. The resulting As input to soils may lead to additional long-term risks for the environment and human health, because As may accumulate in surface soils and eventually decrease soil fertility and enter the food chain via plant uptake. Of particular importance to Bangladesh is the fact that rice has higher As levels than other food products because of increased As availability under reducing soil conditions found in many paddy fields. For example, *boro* rice had a significantly greater As concentration than rain-fed *aman* rice and that the As levels corresponded reasonably well with As in drinking water wells (Duxbury et al., 2003). However, in some areas, exposure to As through rice could amount half that through drinking water containing As at 0.05 mg/L (Duxbury et al., 2003).

Because of the potential risk to human health through consumption of agricultural produce grown in fields irrigated with As-contaminated water, we analyzed some rice varieties grown in different Districts of Bangladesh. It has been reported that increasing the concentration of arsenate in irrigation water significantly decreased plant height, grain yield, the number of filled grains, grain weight, and root biomass, while the As concentrations in root, straw, and rice husk increased significantly (Abedin et al., 2002a). Table 1 indicates that different rice varieties of Bangladesh absorbed large amount of As from the soil and irrigation water. Our results show that As accumulation in rice varies among different varieties. However, accumulation in rice grain was less than the maximum permissible limit of 1 mg/kg (NFC, 1993). Out of 23 samples, grain As concentrations ranged from 0.07 to 1.12 mg/kg where 3 samples were above the recommended limit. The highest reported values are close to 2 mg/kg (Meharg and Rahman, 2003). A market-based survey carrreid out in the USA found that rice had the highest levels of inorganic As (Schoof et al., 1999). These As concentrations may have the potential for adverse health effects in cattle and an increase of As exposure in humans via the plant-animal-human pathway.

3.3. Arsenic hyperaccumulation in *Pteris vittata*

Phytoremediation has the potential to become an environmentally friendly and low-cost alternative remediation technique compared to currently used remediation techniques.

Some tropical and sub-tropical plant species can tolerate and uptake As (Meharg and Hartley-Whitaker, 2002; Tu et al., 2002). Tu and Ma (2002) reported that ladder brake fern (*Pteris vittata* L.) could survive in soils contaminated at levels of 500 mg As/kg and that up to 26% of the As

Table 1. Arsenic contents in different rice varieties collected from different Districts of Bangladesh in 2005 (N=3 replicates)

Collection sites (Districts)	Rice variety (local name)	As contents of grains (mg/kg)
Comilla-1	Khatobada	0.08 (±0.010)
Comilla-2	Pajam	0.29 (±0.015)
Comilla-3	Swarna	0.17 (±0.026)
Comilla-4	BR 11	0.12 (±0.020)
Dinajpur-1	BR 11	0.15 (±0.021)
Bogra-1	BR 11	0.25 (±0.025)
Jessore-1	BR 11	0.35 (±0.015)
Jessore-2	Pajam	0.09 (±0.010)
Jessore-3	BR 8	0.38 (±0.032)
Rangpur-1	BR 11	0.17 (±0.017)
Rangpur-2	Pajam	0.09 (±0.015)
Nawabgonj-1	Gocha	0.39 (±0.032)
Nawabgonj-2	Kalia	0.28 (±0.021)
Rajshahi-1	BR 11	0.35 (±0.035)
Rajshahi-2	Pajam	0.12 (±0.017)
Kushtia-1	BR 3	0.33 (±0.023)
Kushtia-2	BR 11	0.07 (±0.015)
Khulna-1	Binni	0.22 (±0.040)
Khulna-2	BR 29	0.32 (±0.026)
Pabna-1	Chapali	1.02 (±0.030)
Pabna-2	Chaina	0.34 (±0.010)
Brahmanbaria-1	BR 11	1.12 (±0.042)
Brahmanbaria-2	BR 29	1.03 (±0.026)
Mean		0.34
Median		0.28
SD		0.30

was removed. In the present study, As concentrations in roots and shoot fronds of *P. vittata* increased significantly with increasing As concentration applied to the soil (one-way AVOVA, $p<0.01$). Arsenic accumulation was higher in shoot fronds than roots (Table 2). Arsenic concentrations in fronds and roots were directly proportional to the concentrations of As added to the pots. The concentrations of As with highest As treatment in shoot frond (up to 16.03 mg/kg) and in root (up to 2.23 mg/kg) suggest that As can be readily translocated to the shoot. Previous studies (Ma et al., 2001; Wang et al., 2002) reported that the majority of As was concentrated in the shoot fronds of *P. vittata*. Our results also support the results of previous studies. *P. vittata* was found to hyperaccumulate As concentrations up to 22,630 mg/kg in the shoot (frond) by weight in pot experiment when 1,500 mg/kg was added to a soil (Ma et al., 2001). Furthermore, the bioconcentration factor, defined as the ratio of shoot As concentration to soil As concentration, was greater than 10. The fern possesses three key features that are typical of metal/metalloid hyperaccumulator plants: an efficient root uptake, an efficient root to shoot translocation, and a much-enhanced tolerance to As inside plant cells.

Table 2. The comparison of arsenic contents (mg/kg dry wt) in the shoot and root tissues of a fern (*Pteris vittata* L.) according to various arsenic contents of soil (mg As/kg of soil), showing a significant difference

As in soil	Shoot As	Root As
0	3.68 (±0.21)	0.23 (±0.029)
5	5.41 (±0.29)	0.35 (±0.015)
10	10.33 (±0.17)	0.92 (±0.033)
15	11.33 (±0.18)	2.05 (±0.11)
20	16.31 (±0.14)	2.31 (±0.37)

It seems that soil pH is of great importance in regulating As bioavailability (Mitchell and Barr, 1995). The soil pH used for the present study was 6.3. The importance of the source of soil As is another major factor that can control As bioavailability (Warren et al., 2003). However, it did not appear to be of major significance related to plant As uptake in this study. The amount of the soil As was 8 mg/kg. Previous studies established that the total and bioavailable fractions of soil As may not have a consistent relationship to each other (Sheppard, 1992). Arsenate is the predominant As species in aerobic soils, whereas arsenite dominates under anaerobic condition (Smith, 1998). Arsenate acts as phosphate analog and can disrupt phosphate metabolism, whereas arsenite reacts with sulfhydryl groups of enzymes and tissue proteins, leading to inhibition of cellular function and death (Meharg and Hartley-Whitaker, 2002). The transfer of As from soil to plant is low for most plant species. This may be because of several reasons: (a) low bioavailability of As in soil, (b) restricted uptake by plant roots, (c) limited translocation of As from roots to shoots and (d) As phytotoxicity at relatively low concentrations in plant tissues. However, the lowest root As concentration of 0.23 mg/kg was observed in the control treatment, which increased progressively in the successive treatments and reached 2.31 mg/kg in the highest As treatment (Table 2).

3.4. Bangladesh Government and NGO policy

The Government of Bangladesh and various non-government organizations (NGOs) are trying to mitigate As contamination in Bangladesh. In an effort to provide safe drinking water from rainwater, surface water, tankers, etc. the government has adopted mitigation policies such as using less groundwater for irrigation, creating awareness among people, especially regarding public health and emphasizing that arsenicosis /keratosis is not a contagious disease. Other approaches include proper disposal of wastes containing As and treatment of water using appropriate methods of removal of As.

3.5. Arsenic removal techniques used in Bangladesh

Some treatment methods which are being practiced for mitigating As contamination in Bangladesh but in small scale. Most areas of Bangladesh have high iron concentrations in well water. Studies have shown that iron and As coexist in groundwater. In conventional iron removal techniques, iron is precipitated as $Fe(OH)_3$, formed by the oxidation of dissolved iron [$Fe(OH)_2$], and is capable of adsorbing As. Packets of ferric chloride are being used in rural areas by DPHE for removal of As with a limited scale where As concentrations are relatively high. One study showed that 60% of the As in drinking water can be removed using alum treatment in earthen pitchers by allowing 12 hours to form a precipitate, and then using only the decanted water for drinking (Jasim Uddin Ahmad, 2003).

3.6. Some suggestions to mitigate arsenic contamination

As groundwater sources are difficult to manage, surface water may be fit for drinking after treating with bleaching powder. Creating additional reservoirs can be the most effective alternative to mitigate the As problem especially for domestic uses. Surface water may also be treated domestically by using the candle filter developed by experts from Bangladesh and other countries (Jasim Uddin Ahmad, 2003). Collection of rainwater can be an alternative for providing drinking water. Extraction of groundwater should be reduced as well as the economic uses of groundwater must be ensured. However, it is better to avoiding production of dry-season rice where groundwater As levels are high and where groundwater is the only source of irrigation water.

4. Conclusions

Long-term solutions will likely have to be tailored to local environments, and it is counterproductive to defer immediate action until long-term alternatives are more completely implemented. Arsenic contamination was not a problem for Bangladesh in the past but it has become a serious problem now. In near past, arsenic was also in earth crust, nature, and even in drinking water, but as there were no provisions for measurement of As, it was not detected like chloride, iron, pH etc. Panic must not be created but the people should be made aware of the situation for As mitigation. Government efforts are much less than expected compared to the wide range of calamity. An effective integrated master plan is required to address As contamination using locally available materials with low-cost and simple technology. Creation of more reservoirs will be important to reduce the reliance on groundwater. Planned extraction of groundwater for irrigation to maximize the recharge of groundwater and maintaining sufficient river flows should be ensured to minimize the decomposition of pyrites. Finally, proper strategic planning and management efforts are urgently needed including coordination among governmental, NGO, scientific, educational, technological, local administration and political leadership.

요 약

방글라데시에서는 지하수에 대한 의존도가 증가함에 따라 지하수에 기인하는 비소오염이 점차 심각한 문제로 나타나고 있다. 비소는 토양, 자연수, 그리고 심지어 음용수에까지 포함되어 있지만, 비소에 대한 관리 규정이 없어서 최근까지 적절히 측정되지 않고 방치되어 왔다. 그러나 비소오염에 대한 피해가 증가하면서 비소 경감의 필요성이 강조되었다. 본 연구에서 조사된 23 개 지점에서 채집된 쌀의 비소 함량은 평균 0.34 mg/kg 이었으며 3 개 지점은 1.02~1.12 mg/kg 로서 기준치인 1.0 mg/kg을 초과하였다. 비소오염을 줄이는 경제적 방법으로서 식물을 이용한 정화법이 제시되고 있는데 *Pteris vittata* 라는 고사리는 비소를 잘 흡수하여 농축하는 것으로 알려져 있으며 본 연구에서 실험한 결과 비소농도 20 mg/kg의 토양에서 재배한 경우 지상부 식물조직의 비소함량이 16 mg/kg까지 농축되는 것으로 나타났다. 그러나 뿌리의 비소함량은 지상부의 약 15% 정도로 낮은 것으로 나타나 지상부의 제거로서 비소를 제거할 수 있음을 보여주었다. 비소오염이 전국적으로 심각함에도 불구하고 정부의 노력은 광범위한 지역을 관리하기에 아직 충분치 않으므로 경제적이고 간단한 대책들이 필요하며 식물을 이용한 정화법이 하나의 대안이 될 수 있을 것이다.

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