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Detection of arsenic in wheat and wheat bran animal feeds in Faridpur sadar upazilla

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ABSTRACT

Arsenic is naturally occurring element. Chemically, arsenic is always present as compounds with oxygen, chlorine, sulpher, carbon and hydrogen on one hand and with lead, gold and iron on the others. It is significantly threatening in case of Bangladesh as 61 out of 64 districts are affected by arsenic. Arsenic is spreading in various ways in the environment and creating various hazards. With a view to detect the level of arsenic concentration in animal feed chain this study was performed. For this purpose the FI-HG-AAS (Flow Injection Hidride Generator Atomic Absorption Spectophotometer) method was used. Wheat and wheat bran samples, two commonly used animal feeds, were collected from arsenic contaminated areas of Faridpur district of Bangladesh. After collection, the samples were prepared by a series of steps such as, washing, drying, weighing and digestion; finally arsenic was detected by atomic absorption spectophotometric method. Atomic absorption measures the amount of energy absorbed by the samples. The mean arsenic concentration in wheat and wheat bran were 0.11±0.008 ppm (n=24) and 0.15±0.005 ppm (n=06) respectively. In this study it was found that the level of arsenic both in wheat and wheat bran is greater than that of the maximum permissible level in drinking water (0.05 ppm, WHO). The study indicates that the feed used for animal consumption in the arsenic contaminated areas causes serious health risk for animal and human.

Introduction

Arsenic (As) is one of the heavy metals which is a threatening factor for soil, plants, water, animals as well as human beings. Organic arsenic is generally less toxic than inorganic arsenic. Arsenic in elemental form is insoluble in water. It is soluble in oxidized form. Arsenic occurs in many minerals, usually in conjunction with sulfur and metals, and also as a pure elemental crystal. It was first documented by Albertus Magnus in 1250. Arsenic is a metalloid. Arsenic appears in three allotropic forms: yellow, black and grey; the stable form is a silver-gray, brittle crystalline solid. It tarnishes rapidly in air and at high temperatures burns forming a white cloud of arsenic trioxide. Arsenic occurs naturally in the environment within the earth's crust, in water and even in smoke from volcanoes. It may be found in soil, water and human foods, such as chicken. People may become exposed to arsenic by eating or drinking it, breathing it in and in rare cases, touching it. People are regularly exposed to arsenic in small doses and can usually metabolize and excrete it without ill-health effects (Friberg et al., 1986).

Arsenic contamination in groundwater has been reported at different times from West Bengal, India and countries like U.S.A., Argentina, Chile, Mexico, Taiwan, Hungary, Finland, Nepal and Bangladesh (Sanyal, 1999). In West Bengal, the presence of As in groundwater in concentrations exceeding maximum acceptable concentration (MAC) was first detected in 1978, while the first case of As poisoning in humans was diagnosed at the School of Tropical Medicine in Calcutta in 1983 (Acharya, 1997). Arsenic in groundwater is generally present as dissolved, de-protonated / protonated oxyanions, namely arsenates. The arsenites are much more soluble, mobile, and toxic than arsenates in aquatic and soil environments at pH 6-8 (Sadiq, 1997).

High arsenic concentration in groundwater is generally associated with the geothermal environments of volcanic deposits, geothermal systems and basin-fill deposits of alluvial lacustrine origin (Welch et al., 1988). As regards the widespread As contamination in groundwater in parts of West Bengal, India and Bangladesh, confined within the delta bound by the rivers Bhagirathi and Ganga-Padma, two major hypotheses, both of geogenic origin, 5 have been proposed. According to the earlier one (Mandal et al., 1996).

The latter finds its way into groundwater through oxidation of arsenopyrite in aquifer sediments as atmospheric oxygen invades the aquifer in response to lowering of groundwater level by its large-scale abstraction for agricultural irrigation, especially for cultivation of summer (boro) paddy during the lean period of January to April when the groundwater reaches at its minimum (Sanyal, 1999). This process would lead to the formation of iron sulphates and sulphuric acid. This hypothesis is not consistent with the slightly alkaline status of groundwater in the affected delta or with its low (trace) concentration of sulphate or high concentrations of bicarbonate, iron (II), arsenite, calcium and magnesium (Sanyal, 1999; Bhattacharya et al., 1997; Nickson et al., 1998).

The arsenic disaster of Bangladesh has been called the most terrible environmental catastrophe of the twentieth century. WHO described the condition as "the largest mass poisoning of a population in history" (WHO, 2004). It was estimated that 59 out of 64 districts and about 29% of the total tube wells in Bangladesh are contaminated with arsenic (Khan et al., 2006a; Chakraborti et al., 2010; Neumann et al., 2010) and about 85 million people are at risk of drinking arsenic contaminated water and foodstuffs (Hossain, 2006; Wahed et al., 2006). In a recent report (Chakraborti et al. 2010) showed that hand tube wells of the tableland and hill tract regions of Bangladesh are primarily free from arsenic contamination, while the flood plain and deltaic region including the coastal region are highly contaminated with arsenic. The extent of this environmental disaster is greater than any other recorded in human history. Although the exact time of onset of arsenic exposure in Bangladesh is mysterious, but suspected that it was started during the 1960s and 1970s when government of Bangladesh in collaboration with UNICEF started to install hand-pumped tube wells to provide pathogen-free drinking water to the people (Smith et al., 2000).

Arsenic can enter into food chain causing wide spread distribution throughout the plant and animal kingdoms (Kile et al., 2007). The evidence of arsenic calamity in animal feed chain is scarce. Contamination of animal feed by arsenic is a newly uncovered disaster on a massive scale (Sapkota et al., 2007). This poses a potential dietary risk to human, although little research has focused on food as an additional source of arsenic exposure. Food may contribute up to 30-50% of the total dietary intake of arsenic when feed is generated from arsenic contaminated sources (Naidu et al., 2006). Arsenic is an approved animal dietary supplement and is found in specifically approved drugs added to poultry and other animal feeds. Although several research groups have begun to elucidate the effects of arsenic use in animal feed on its environmental concentrations in areas where animal waste has been land applied (Jackson et al., 2006; Stolz et al., 2007). It increases arsenic accumulation in chicken meat and adds arsenic in our environment (Wallinga, 2006). Researchers from the National Institutes of Health and the USDA's Food Safety Inspection Service reported alarmingly high levels of arsenic contamination in the broiler flesh (Lasky et al., 2004). It is assumed that arsenic ingested through chicken pose potential risks to human health.

Arsenic is one of the most toxic elements that can be found. Despite their toxic effect, inorganic arsenic bonds occur on earth naturally in small amounts. Humans may be exposed to arsenic through food, water and air. Exposure may also occur through skin contact with soil or water that contains arsenic. Levels of arsenic in food are fairly low as it is not added due to its toxicity. But levels of arsenic in fish and seafood may be high, because fish absorb arsenic from the water they live in. Luckily this is mainly the fairly harmless organic form of arsenic, but fish that contain significant amounts of inorganic arsenic may be a danger to human health Arsenic exposure may be higher for people that work with arsenic, for people that live in houses that contain conserved wood of any kind and for those who live on farmlands where arsenic-containing pesticides have been applied in the past. Exposure to inorganic arsenic can cause various health effects, such as irritation of the stomach and intestines, decreased production of red and white blood cells, skin changes and lung irritation. It is suggested that the uptake of significant amounts of inorganic arsenic can intensify the chances of cancer development, especially the chances of development of skin cancer, lung cancer, liver cancer and lymphatic cancer (Das et al., 2004). For the above reasons the present study was conducted to detect arsenic in animal feeds such as wheat and wheat bran in arsenic contaminated areas of Sadar upazilla of Faridpur district.

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Materials and methods

The experiment was conducted at the Arsenic Detection and Mitigation (ADM) Laboratory, Department of Pharmacology, Bangladesh Agricultural University, Mymensingh, Bangladesh. The experiments were designed and performed according to the methods adopted in that laboratory. Information about severely arsenic contaminated areas were obtained from secondary sources (Ahmed et al., 2006), where concentrations of arsenic exceeding 0.181 ppm were reported in few tube wells (FAO, 2007). In this study, one of the worst arsenic affected district Faridpur was selected. In Faridpur district 6 unions (Ambikapur, Aliabad, Kanaipur, Kaijuri, Krishnanagar Majchar) of sadar upazilla were selected and animal feed samples such as wheat and wheat bran were collected. All required samples were collected during the month of May (Summer season) in the years 2012. In all cases, two types of samples (wheat and wheat bran) were collected in the five days of sample collection period. A standardized personal interview of each owner was carried out based on a prearranged questionnaire. The questionnaire was pretested and finalized after incorporation of feedback. Owners were briefly questioned by visiting door-to-door during sample collection and information obtained from the interview was recorded. Questionnaire was structured including general information (area, cultivation season, harvesting season, varieties) of specific wheat and wheat bran. Information about history of water irrigation by the study subjects including water source were obtained on the basis of the questionnaire. Wheat and wheat bran used as ration of respective animals were considered for possible sources of arsenic contamination. Different varieties of wheat were considered. The wheat grain (that generally consumed by dairy cows and poultry) and wheat bran (*adlibitum*) were collected in zip-type bag, labeled and kept in a polyethylene bag and finally transferred to the laboratory and stored in desiccators until analysis.

Wheat samples were sun dried to reduce water percent. About 0.95-1gm sample was taken separately into digestion tube and 10 ml of 69% concentrated HNO3 and 70% of perchloric acid mixture at the ratio of 5:3 was added. The samples left to react overnight in a chemical "hood", then heated in a block digester (M-24 plazas/samples, JP Selecta, Spain) at 120ºC until colorless clear watery fluid appears. Tubes were gently shaken several times to facilitate destroying all the carbonaceous material. This digestion converts all arsenicals to inorganic arsenic for FI-HG-AAS determination. Digestion was considered complete when production of reddish-orange fumes and foam within the tube had subsided; the solution had become 40 clear and did not bubble or react upon agitation. Tubes were removed from the digestion block, cooled, diluted to 50 mL adding Millipore water and filtered through filter paper (Whatman No. 41) and stored in 50 ml polythene bottles. The sample solution at that stage was ready for determination of its total arsenic. In each set, blank reference material were prepared following same digestion procedures

Wheat bran samples were sun dried to reduce water percent. About 0.95-1gm sample was taken separately into digestion tube and 10 ml of 69% concentrated HNO3 and 70% of perchloric acid mixture at the ratio of 5:3 was added. The samples left to react overnight in a chemical "hood", then heated in a block digester (M-24 plazas/samples, JP Selecta, Spain) at 120ºC until colorless clear watery fluid appears. Tubes were gently shaken several times to facilitate destroying all the carbonaceous material. This digestion converts all arsenicals to inorganic arsenic for FI-HG-AAS determination. Digestion was considered complete when production of reddish-orange fumes and foam within the tube had subsided, the solution had become clear and did not bubble or react upon agitation. Tubes were removed from the digestion block, cooled, diluted to 50 mL adding Millipore water and filtered through filter paper (Whatman No. 41) and stored in 50 ml polythene bottles. The sample solution at that stage was ready for determination of its total arsenic. In each set, blank reference material were prepared following same digestion procedures.

Results and discussion

In the present study, wheat and wheat bran were collected from the arsenic effected 6 unions of Sadar upazilla in Faridpur district and analyzed. The results show that concentrations of arsenic in wheat ranged from 0.00011 to 0.17666ppm (Table 1) with a mean value of 0.1180±0.0084 (±SEM) ppm (*n*=24) (Table .2). Interestingly, arsenic concentration in wheat bran was significantly higher (P<0.01) than that of wheat (Figure 1). Concentrations of arsenic in wheat bran ranged from 0.140082 to 0.176132 ppm with a mean value of 0.151752±0.0052 (±SEM) ppm (*n*=6). A great fluctuation was found in the concentrations of arsenic in wheat bran in comparison to that of wheat (Figure 2). The fluctuations could be due to differences in the absorption and distribution of arsenic in the plant. Another reason could be due to variation in the soil arsenic concentration from plot to plot. Moreover, we know that the root of a plant (e.g., Wheat) absorbs and accumulates the highest levels of arsenic than other parts (Rahman et al., 2007) and as wheat is seed grain it is assumed to have lesser and steady amount of arsenic. Another study showed that the trend of arsenic concentration in four measured tissues was leaves> stems> bracts> kernels (Ding et al. 2011). In China, a study to investigate the impact of irrigation with high arsenic burdened groundwater on the soil-plant system has shown that arsenic concentration in plant parts decreased roots towards leaves, stems and seeds (Neidhardt et al., 2012).

Table 1. Arsenic concentrations (ppm) in wheat and wheat bran collected from arsenic contaminated areas of Faridpur district

Serial number	Arsenic concentrations (ppm) in wheat	Arsenic concentrations (ppm) in wheat bran
1	0.168418	0.140082 (minimum)
2	0.112902	0.150984
3	0.125382	0.145176
4	0.010122	0.153631
5	0.148976	0.144507
6	0.135815	0.176132 (maximum
7	0.000119 (minimum)	
8	0.14666	
9	0.146667	
10	0.167192	
11	0.12624	
12	0.128154	
13	0.106211	
14	0.114487	
15	0.089907	
16	0.120558	
17	0.127291	
18	0.118285	
19	0.096548	
20	0.109187	
21	0.13114	
22	0.176663 (maximum)	
23	0.105713	
24	0.121617	

Table 2. Average concentration of arsenic (ppm) in wheat and wheat bran collected from contaminated areas of Faridpur district

Sample name	Average	S.D	S.E.M	n
Wheat	0.118094	0.041187	0.008407	24
Wheat bran	0.151752	0.012887	0.005261	6

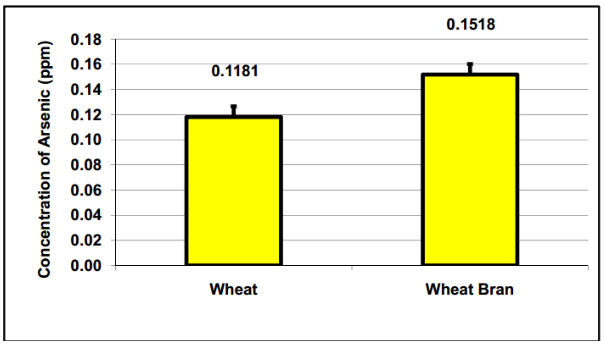

Figure 1: Average concentration of arsenic (ppm) in wheat and wheat bran collected from Sadar Upazila of Faridpur district

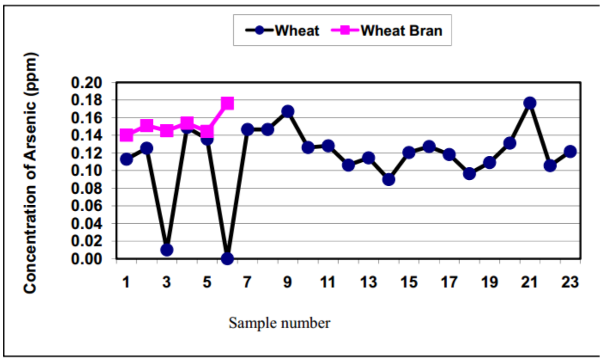

Figure 2. Graphical presentation of arsenic concentration (ppm) in wheat and wheat bran collected from arsenic contaminated areas of Sadar upazilla of Faridpur district.

As tube well water is consider to be the primary source of contamination of crops by irrigation, the level of arsenic of shallow tube well water is compared here the levels arsenic found in wheat and wheat bran Sadar upazilla of Faridpur district. In Sadar upazilla the mean arsenic concentration in shallow tube well water is 0.181 ppm (FAO, 2007), which is 4 times higher than in Bangladesh maximum permissible limit of 0.05 ppm in drinking water (WHO). In this study the wheat and wheat bran were collected from Sadar upazilla of Faridpur district and average concentration of arsenic were 0.118±0.008 and 0.151±0.005 ppm respectively. The average concentration of arsenic in tube well water and that found in wheat and wheat bran are tabulated below (Table 3) and graphically presented in the figure 3

Table 3. A comparison of average arsenic concentration in shallow tube well water with the presence of arsenic found in wheat and wheat bran

Arsenic concentration in shallow tube well water (ppm)*	Arsenic concentration in wheat (ppm)	Arsenic concentration in wheat bran (ppm)
0.181*	0.118±0.008	0.151±0.005

*FAO, 2007

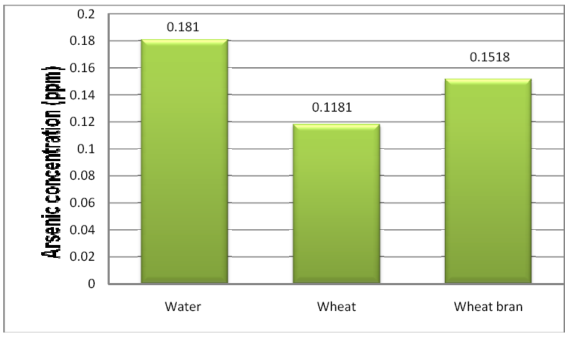

Figure 3. A graphical comparison of average arsenic concentration in shallow tube well water with that found in wheat and wheat bran collected from Sadar upazilla of Faridpur district

Conclusion and recommendation

It is found that the levels of arsenic in wheat and wheat bran is 2.2 times and 3 times greater than that of the permissible level of arsenic in drinking water (0.05 ppm, WHO), respectively. Interestingly wheat grain contains less arsenic than the wheat bran. Whereas, animals are mainly fed with wheat bran, which contains alarming level of arsenic in the arsenic contaminated areas of Faridpur district. As shallow tube well water is most frequently used for irrigation which is more contaminated with arsenic than deep tube well water leading to arsenic contamination in animal feed chain. Therefore, to minimize or to avoid the risk of arsenic contamination in animal, irrigation should be done with deep tube well water or with natural water such as rain water, pond and surface water. Animal should be controlled to graze in heavily contaminated areas. Instead of arsenic sensitive cultivars, arsenate tolerant cultivars of wheat can be cultivated in the arsenic contaminated areas of our country. Arsenate tolerance and sensitivity could be due to possible differential detoxification mechanism (Mallick et al., 2011). Moreover, phytoextraction by crop rotation can be practiced in arsenic contaminated crop lands. Cultivation of arsenic accumulating plants/crops can be followed by cultivation of wheat or other grains. Phytoextraction is a remediation technology with apromising application for removing arsenic from soil sand waters. *Cucumis sativus* (cucumber) has been found to be the best arsenic accumulating plant hence the best candidate plant for phytoextraction of arsenic from soil and water (Hong et al., 2011). Although it was beyond the scope of present study, new innovative experiment should be designed to reduce the risk of toxic effect of arsenic in animal body by chemical and/or herbal method, such as spirulina (Karim et. Al., 1999). This is an initial study; more research in this respect should be undertaken with the objective of mitigation of arsenic problem in Bangladesh.

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