ARSENIC CONCENTRATION IN RICE HUSK PRODUCED IN THE TRANS INDO-GANGETIC PLAIN OF INDIA

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ABSTRACT
Rice (Oryza Sativa) is a staple food for over half of the World's population and around 90 percent is produced and consumed in Asia. Its different fractions are rice husk, bran, brown and white rice. Concerns have been raised regarding the elevated levels of Arsenic (As), a toxic metalloid, in rice. Arsenic toxicity is associated with cancer and other health related disorders. Arsenic levels in white rice has been studied widely however, few studies have been focused on the levels of arsenic in rice husk. This is of major concern as rice husk is used as animal fodder. Total arsenic in rice and its different fractions varies geographically depending on the arsenic concentration of soil and irrigation water. Therefore, this study was undertaken to assess the arsenic concentration in rice husk produced in the Trans Indo-Gangetic plain (TIGP) of India. Total arsenic was estimated using Inductively Coupled Plasma- Mass Spectrometry. WHO (2011) recommended permissible limit of 1.0 mg As kg^{-1} for white rice; however no recommended limit has been established for the arsenic concentration in rice husk. The total As concentration in rice husk of TIGP ranged, from 0.377 to 4.724 mg As kg^{-1}, (dw), with a mean value of 1.724 mg As kg^{-1} (dw). When results of the present study were compared with WHO limit, the Arsenic level was found to be higher than the limit. Therefore, this study concluded that rice husk produced in the TIGP of India is not safe to be used as animal fodder.

Keywords: Toxic, rice grain, metalloid, TIGP, WHO, animal fodder

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1. INTRODUCTION

Groundwater is used as the dominant source of irrigation for crops, to meet the increasing demand of agriculture. In the Indo-Gangetic Plain (IGP) of India, irrigation is mainly done using 80% of the groundwater; this has led to over-exploitation of the groundwater (Patil et al., 2014). In the last couple of years researchers have reported that the groundwater is contaminated with arsenic (As) and this arsenic contaminated groundwater is being used for the irrigation of crops. Arsenic (As) is a toxic metalloid and according to the International Agency for Research on Cancer (IARC, 1987), it is a class I carcinogen. Arsenic intake can lead to gastrointestinal symptoms, severe disturbances of the cardiovascular and central nervous systems, and even death. Bone marrow depression, haemolysis, hepatomegaly, melanosis, polyneuropathy and encephalopathy have also been reported to be associated with As toxicity (WHO 2001). When fields are irrigated with arsenic contaminated water it elevates the arsenic concentration in the soil as well as in the crops which are grown on these soils (Ullah, 1998; Imamul Huq et al., 2003; Rahman et al., 2007a,b). Rice plants are particularly susceptible to accumulate arsenic more efficiently (approx. 10 folds) than any other cereal crops when grown on the arsenic contaminated water or soil, as it is generally grown under flooded conditions where arsenic mobility is high (Heikens, 2006).

Significant variations have been reported in the total arsenic concentration in different fractions of rice (hull, polished rice, whole rice, and bran). The arsenic concentration is highest in rice husk followed by bran, whole rice, and polished rice (Rahman et al. (2007b). Rice hulls (or rice husks) are the outer protective covering of the rice grain (paddy) (Juliano and Bechtel, 1985). Rice husk are used as fertilizer

and also as a source of fiber in pet foods (Iyenagbe et al., 2012). They are also used as fodder for animals. Therefore, if rice husk is contaminated with As it might increase the concentration of As in soils when used as fertilizers or in animals who are exposed to rice husk. Most of the studies on arsenic contamination have been done in the other regions of India. Therefore, in the present study effort is directed towards assessment of arsenic concentration in rice husk produced in the Trans Indo-Gangetic Plains (TIGP) of India. Total arsenic (tAs) content of rice and its different fractions varies geographically depending on the As content of soil and irrigation water therefore on a massive scale arsenic contamination in rice and in different fractions of raw rice is a newly uncovered disaster. The objective of the present study was to assess the arsenic concentration in rice husk produced in the Trans Indo-Gangetic Plain (TIGP) of India.

2. MATERIALS AND METHODS

Study Area

The study was conducted in total six different administrative districts of the three states Punjab, Haryana and Delhi located in the Trans Indo-Gangetic Plain of the Northern India. Purposively selected districts were Amritsar, Jalandhar and Ludhiana from Punjab; Sonipat and Panipat districts from Haryana; and North-West district from Delhi. In each district, two villages were selected randomly for assessing the arsenic concentration in rice husk. In each village, two tube well operated paddy fields were selected for collection of samples (duplicates). To collect samples, fields were selected based on two parameters: (a) where the only source of irrigation water was tube well, to avoid arsenic contamination from any other source of irrigation water; (b) availability of the standing crops in the fields.

Sample Collection

Paddy (Oryza sativa) samples were collected from each selected fields of the selected area in the month of November, 2016. Five sub-samples of paddy were collected at each sampling site, from a plot (2 m^2 areas), and then, aggregated into one representative composite sample of a field for further treatment. Grains from the paddy crops were hand-picked during the harvesting stage (Rahaman et al., 2013; Abedin et al., 2002) and stored in airtight polyethylene bags at room temperature with proper labeling(Bhattacharya et al., 2010). Paddy were sun-dried, and then hulled to get rice husk. Rice husk were then oven dried at 70ºC for 48 h prior to analysis.

Estimation of total arsenic

A sub-sample of homogenized rice husk samples (1-2 g) was ground and weighed (0.5 g) accurately into microwave digestion vessels. High-purity nitric acid (70 % w/w, 8 ml) was added into the vessels, which were then inserted into the rotor of the microwave. All samples were digested for 1 hour and 25 min. Digestion of the samples were done in the following manner: Firstly, temperature was increased to 100ºC in 15 min, held for 30 min. Secondly, temperature was increased from 100ºC to 190ºC in 10 min, held for a further 30min, and then cool for 10 min. After digestion the vessels were allowed to stand at room temperature for further 15 min, and then digested samples were diluted and made up to 25 ml in plastic vials of 50 ml. Total As in the samples were analyzed using ICP-MS (Element XR, Thermo Fisher Scientific, Germany) instrument. The ICP-MS operating conditions were as follows: mass range 1 to 240 amu with automatic resolution control, sensitivity (Concentric Nebuliser) 109 counts sec-1 for 1 ppm, quantification Limit 1ppt, Radio Frequency Generator 27 MHz, RF Power 2 KW, Computer controlled three Argon Mass Flow Controller for torch and nebulizer. Nebulizer for normal acid based solution: flow rate of 50 µL min-1 and 100 µL min^{-1} (IITB).

Statistical Analysis

The data statistical analysis was performed using statistical package, SPSS 20.0 and MS Excel for windows (SPSS Inc, USA).

3. RESULTS AND DISCUSSION

Total As concentration in Rice Husk

The concentrations of total As in husk of rice grain samples collected from 12 villages of Trans Indo-Gangetic Plain (TIGP) of India are presented in Table 1. The total As concentration in rice husk of TIGP ranged, from 0.377 to 4.724 mg As kg^{-1}, (dw). The range of As concentration in the present study was wider, this was due to the contribution of one sample with higher As (4.724 mg As kg^{-1}). The mean ± SD for all 48 rice husk samples was 1.724 ± 0.9 mg As kg^{-1}(dw), with a median value of 1.594 mg kg^{-1} (dw). Rahman et al. (2007b) studied the total arsenic concentrations in rice husk collected from arsenic-contaminated area (Satkhira district) of Bangladesh. They resulted that As Concentration in rice husk was in the range of 0.7–1.6 mg As Kg^{-1} (dw), with mean ± SD, 0.8 ± 0.2 mg As kg^{-1} (dw). When our present study data was compared with this published data, the range and mean value was found to be higher in the present study. They also assessed the As concentration in different fractions of rice grain and reported that the highest arsenic concentration was present in the rice husk followed by bran, whole rice and polished rice. This might be because rice husk acts as a translocation barrier for As, which hinders As not to mobilize easily into the grains (Rahman et al., 2007). It is a remarkable shield of rice grains from the contaminated irrigation water and soil (Bhattacharya et al. 2009). Ren et al. (2007) also determined the total arsenic concentration in fractions of Chinese whole grain rice, and found that arsenic concentrations were highest in bran, followed by whole grain and polished rice, showing the same trend reported by Rahman et al. (2007b).

There are no recommended limits for the fractions of rice grain i.e., husk, bran or unpolished rice. However, WHO has recommended permissible limit of 1.0 mg As kg^{-1} for white rice (Rahman et al. 2007). When the As concentration in rice husk samples were compared with WHO limit, the As level in the present study was higher than the limit. Around 83% of the total rice husk samples had As concentration higher than the WHO limit and around 17% of the samples had As concentration lower the WHO limit. When used as fodder for animals or fertilizers for crops, it might increase the As concentration in animals or in the fields. Thus, it can be stated that As levels in rice husk of TIGP region are contaminated with arsenic and should not be used as a fodder for animals or fertilizers for crops.

Table 1: Arsenic levels (mg As kg^{-1}, dw) in rice husk samples collected from 12 villages of Trans Indo-Gangetic Plain (TIGP) of India

Village	District	State	n	Mean	SD
Khasa	Amritsar	Amritsar	4	0.851	0.518
Atari	Amritsar	Amritsar	4	1.577	0.118
Bidhipur	Jalandhar	Amritsar	4	1.714	0.222
Paragpur	Jalandhar	Amritsar	4	1.877	0.585
Khanna	Ludhiana	Amritsar	4	1.078	0.427
Doraha	Ludhiana	Amritsar	4	2.079	1.575
Raipur	Sonipat	Haryana	4	3.162	1.782
Joshi Jat	Sonipat	Haryana	4	1.549	0.120
Patti Kalyana	Panipat	Haryana	4	1.098	0.490
Bhodwal Majri	Panipat	Haryana	4	1.964	0.105
Naya Bansh	North-West Delhi	Delhi	4	1.336	0.242
Khera Khurd	North-West Delhi	Delhi	4	2.410	0.373

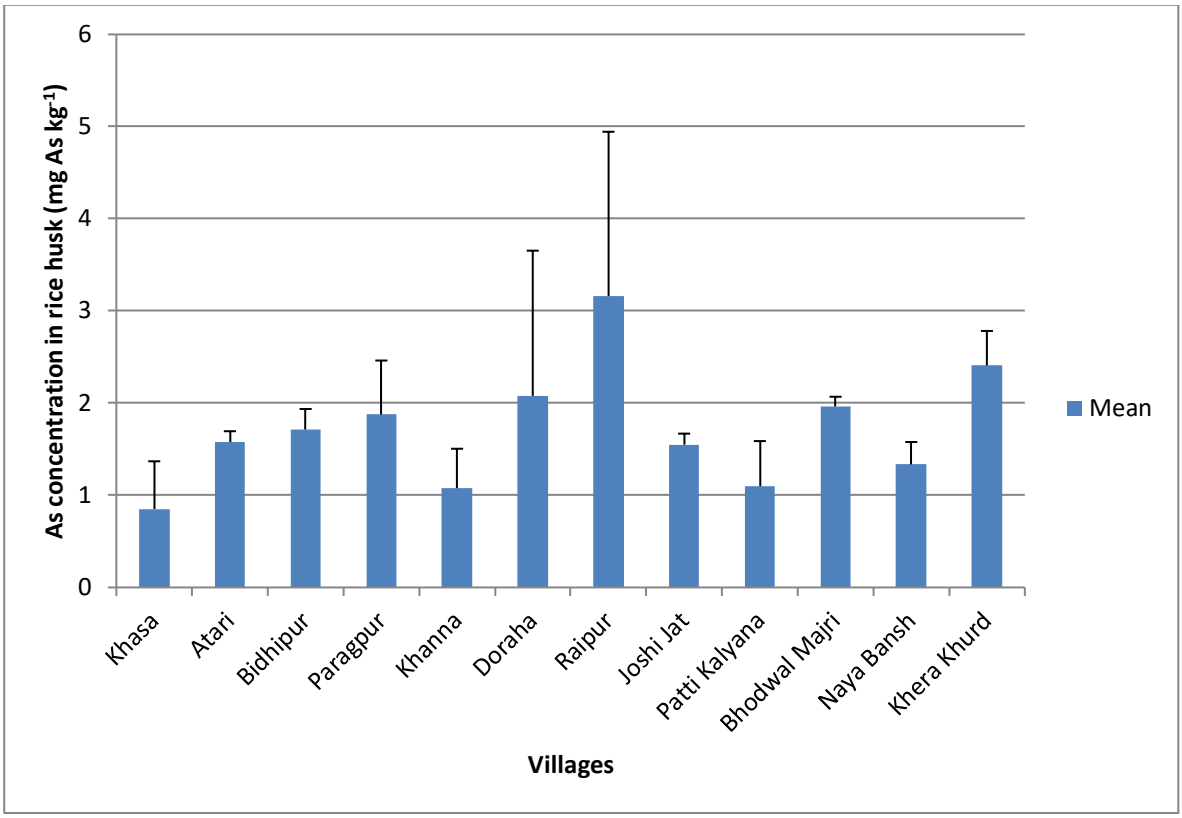

Fig 1: Mean As content in rice husk from 12 villages of Trans Indo-Gangetic Plain (TIGP) of India (error bars are SD)

Comparison of As content in rice husk of TIGP within the states

Mean As content in rice husk from 12 villages of Trans Indo-Gangetic Plain (TIGP) of India (error bars are SD) are shown in the Figure 1. The total As concentration in rice husk of Punjab ranged from 0.377 to 3.737mg As kg^{-1}, (dw) with mean As concentration of 1.529 ± 0.794 mg As kg^{-1} (dw). The total As concentration in rice husk of Haryana ranged from 0.488 to 4.724 mg As kg^{-1} (dw), with mean As concentration of 1.943 ± 1.147 mg As kg^{-1} (dw). In Delhi, As concentration ranged from 1.050 to 2.863mg As kg^{-1} (dw), with mean 1.873 ± 0.643 mg As kg^{-1} (dw). The average concentration of As in rice husk samples was found in the order of Raipur > Khera Khurd > Ludhiana > Bhodwal Majri > Paragpur > Bidhipur > Atari > Joshi Jat > Naya Bansh > Patti Kalyana > Khanna > Khasa. In the present study there was no significant difference observed in the As concentration of rice husk samples between the states.

4. CONCLUSION

The present study reveals the total As concentration in the rice husk samples of TIGP region, India. Arsenic concentration was higher in rice husk samples when compared with the published data and WHO recommended permissible value. This suggests that they are not safe to be used as fertilizer or animal fodder. Therefore, present study suggests the regular monitoring of arsenic content in rice husk.

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5. REFERENCES

[1]. Abedin MJ, Cresser MS, Meharg AA, Feldmann J, Cotter-Howells J (2006). Arsenic accumulation and metabolism in rice (Oryza sativa L.), Environ. Sci. Technol.; **36**:962-968.

[2]. Heikens A., (2006). Arsenic contamination of irrigation water, soils and crops in Bangladesh:

[3]. http://www.rsic.iitb.ac.in/icp-ms.html. Last accessed on 6th Jan 2018.

[4]. IARC (International Agency for Research on Cancer). Arsenic and arsenic compounds, IARC monographs on the evaluation of carcinogenic risks ofchemicals to humans. Overall evaluations of carcinogenicity: updating ofIARC monographs, vol. 1– 42. Lyon: IARC, (1987). p. 100 (Suppl. 7).

[5]. Imamul Huq, SM, Rahman A, Sultana S, Naidu R (2003). Extent and severity of arsenic contamination in soils of Bangladesh. In: Ahmed, F., Ali, M.A., Adeal, Z. (Eds), Fate of arsenic in the environment. Preprints of BUET-UNU International Symposium, Dhaka, Bangladesh. 69-84.

[6]. Juliano, BO (1985). Factors affecting nutritional properties of rice protein. Trans. Natl. Acad. Sci. Technol. (Philipp.), **7**, 205-216.

[7]. lyenagbe B, Ugheoke and Othman M (2012). A critical assessment and new research directions of rice husk silica processing methods and properties. Maejo Int. J. Sci. Technol., **6** (03), 430-448

[8]. Patil1 NG, Tiwary P, Bhattacharyya T, Chandran1 P, Sarkar D, et al., (2014). Natural resources of the Indo-Gangetic Plains: a land-use planning perspective. Current Science, **107**(9), 1537-1549.

[9]. Rahaman S, Sinha AC, Pati R, Mukhopadhyay D (2013). Arsenic contamination: a potential hazard to the affected areas of West Bengal, India, Environ Geochem Health **35**:119-132

[10]. Rahman MA, Hasegawa H, Rahman MM, Islam, MN, Miah MAM, Tasmin A (2007b). Effect of arsenic on photosynthesis, growth and yield of five widely cultivated rice (Oryza sativa L.) varieties in Bangladesh. Chemosphere, **67**, 1072-1079.

[11]. Rahman MA, Hasegawa H, Rahman MM, Miah, MAM Tasmin A(2007a). Arsenic accumulation in rice (Oryza sativa L.): Human exposure through food chain. Ecotoxicol. Environ. Safety, Article in press, doi:10.1016/j.ecoenv.2007.01.005.

[12]. Ren XL, Liu QL, Wu DX, Shu QY (2007). Variations in concentration and distribution of health related elements affected by environmental and genotypic differences in rice grains. Rice Sci **13**, 170–8.

[13]. Risk implications for sustainable agriculture and food safety in Asia. Bangkok: FAO, ftp://ftp.fao.org/docrep/fao/009/ag105e/ag105e00.pdf

[14]. Ullah, SM (1998). Arsenic contamination of groundwater and irrigated soils of Bangladesh. In: International conference on arsenic pollution of groundwater in Bangladesh: causes, effects and remedies. Dhaka Community Hospital, Dhaka, Bangladesh, **133;** 8-12.

[15]. WHO. (2001). Environmental health criteria **224**, arsenic and arsenic compounds. Inter-organization programme for the sound management of chemicals. Geneva.