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Seasonal variation of arsenic and its accumulation in straw and grain of rice plant in Ambagarh Chowki block of Rajnandgaon district Chhattisgarh

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Abstract
Rice is the major food crop of this area, as the cultivation of rice requires huge volume of water and long term use of arsenic contaminated ground water for irrigation and arsenic contaminated soil may result into the bio-accumulation of arsenic in rice crop. Accumulation of arsenic was found in rice plant and results revealed that in rice straw arsenic content ranged from 0.006 to 0.082 mg kg^{-1} with an average of 0.024±0.0198 mg kg^{-1} and in rice grain, the content of arsenic ranged from 0.003 to 0.057 mg kg^{-1} with an average of 0.011±0.0123 mg kg^{-1} which is lower than the permissible limit of arsenic in rice plant that is 1 mg kg^{-1} (WHO). It was observed that the accumulation of arsenic is high in straw as compared to grain of rice crop.

Keywords: Arsenic, Rice crop, Bio-accumulation

1. Introduction
Arsenic is an elusive element, with a mysterious ability to change colour, behaviour, reactivity, and toxicity. For example, two arsenic sulphide minerals, red-colour realgar (As_4S_4) and bright yellow orpiment (As_2S_3), were described by the ancient Greeks, but they considered them to be two entirely different substances (Irgolic 1992) [10]. Arsenic has a long history with humans, having been used as both a poison and a curative, in metallurgy, for decoration and pigmentation, and in pyrotechnics and warfare (Miller *et al*. 2002; Nriagu 2002). Arsenic trioxide (As_2O_3), for example, is a tasteless, odourless, white powder. Arsenic a metalloid, third-row, group 15th element, arsenic is seated beneath nitrogen and phosphorus in the periodic table and thus has an excess of electrons and unfilled orbital's that stabilize formal oxidation states from +5 to –3. The electron configuration for neutral arsenic is [Ar] $3d^{10}4s^24px^1$ $4py^14pz^1$, a state that supplies up to five valence electrons for participation in chemical bonding and empty p-orbital's for electron occupation.
Arsenic (As) is a toxic metalloid found in rocks, soil, water, sediments and air. It enters into the soil and water ecosystem through natural process and as a result of anthropogenic activities. Elevated concentration of arsenic in the biosphere pose a significant threat to humankind. Arsenic contamination of surface and ground water's occurs worldwide and has become a socio-political issue in several parts of the globe.
Arsenic is a non-essential element for plants, and inorganic arsenic species are generally highly phytotoxic. Biomass production and yields of a variety of crops are reduced significantly at elevated arsenic concentration. Arsenic concentrations are generally low in plants. The limited translocation of arsenic by roots and its limited translocation to the shoots, is usually used by most plants such as carrot, tomato and grass. These plants contain relatively low arsenic and accumulate arsenic primarily in their root systems. In all plant species tested so far, it has been shown that arsenate is taken up *via*. the phosphate transport systems.(Banejad *et al*. 2011) [2].
According to Huq *et al*. (2001) [5]. Panda and Das (2001) [14]. Lehoczky *et al*. (2002) the uptake of arsenic by agricultural plants is a function of both availability of arsenic (content, water requirement, soil properties) and physiological properties.

Mandal (1998) [11] reported that the higher concentrations of arsenic in potato, arum, amaranth, radish, lady's finger, cauliflower, brinjal, etc, is due to the arsenic-contaminated irrigation water.

Higher amount of arsenic was reported to accumulate in the root of the rice plant as compared to other parts (Rahman *et al*., 2007; Bhattacharya *et al*., 2010a) [16, 4]. On average the arsenic accumulation in tuberous vegetables > leafy vegetables > fruity vegetables (Roychowdhury *et al*., 2002; Alam *et al*., 2003a; Samal, 2005) [17, 1].

The accumulation of arsenic in rice is viewed as a newly recognized disaster for South-East Asia, where rice is a staple food (Meharg, 2004) [12]. Arsenic can find its way into the grains of plants, such as rice and wheat, and into some vegetables and fruit plants through irrigation with arsenic contaminated water (Onken and Hossner, 1995; ICAR report, 2001; Roychowdhury *et al*., 2002; Meharg, 2004; Zhao *et al*., 2006) [17, 12, 19]. but it was found that the vegetables, pulses and spices were of less importance to total arsenic intake than that of water and rice (Williams *et al*., 2006) [18].

Materials and Methods

Studied area

The studied area (Ambagarh chowki block of Rajnandgaon district Chhattisgarh, India) is contaminated with arsenic. 10 villages of Ambagarh chowki block of Rajnandgaon district (Kaudikasa, Biharikala, Atargaon, Dhadutola, Jadutola, Joratarai, Mangatola, Sangali, Sonsaytola and Telitola) have been chosen for the present study. In all these areas, the level of arsenic in ground water is frequently exceeding World Health Organization (0.01 mg l^{-1}) permissible water limits (WHO 1992).

Sample collection

Soil samples were collected by composite sampling from the fields irrigated with the arsenic contaminated water and transferred to airtight polyethylene bags. Soil samples were collected with the help of auger during pre-monsoon and post-monsoon season. Plant samples were collected after harvesting from the fields irrigated with the arsenic contaminated water and transferred to airtight polyethylene bags. Rice, Grain and Straw were collected from different fields after harvesting.

Sample treatment

Soil samples were immediately sun dried after collection and later dried in the Hot Air Oven at 600 C for 72 h. The dried soil samples were then ground and passed through 2.0 mm pore sized sieve to get homogenized powder. Plant samples were immediately sun dried after collection and later dried in the Hot Air Oven at 60 ^{0}C for 72 h.

Sample Digestion

Soil sample, root, straw, husk, and grian portions of the rice sample were digested separately following heating block digestion procedure (Rahman *et al*. 2007) [16]. About 0.5 g of the sample was taken into clean dry digestion tube and 5ml of concentrated HNO3 was added to it. The mixture was allowed to stand overnight under fume hood. In the following day, the digestion tubes were placed on a heating block and heated at 60 ^{0}C for 2 h. The tubes were then allowed to cool at room temperature. About 2 ml of concentrated HClO4 was added to the plant samples. For the soil samples 3 ml of concentrated H2SO4 was added in addition to 2 ml of concentrated HClO4. Then the tubes were heated at 160 ^{0}C for about 4-5 h. The heating was stopped when the dense white fume of HClO4 was emitted. The content was then cooled, diluted to 50ml with de-ionized water and filtered through Whatman No. 42 filter paper for soil samples and Whatman No. 41 for plant samples and finally stored in polyethylene bottles. Prior to sample digestion all glass good were washed with 2% HNO3 followed by rinsing with de-ionized water and drying.

Sample analysis

The total arsenic of the digested plant samples were analyzed by the flow injection hydride generation atomic absorption spectrophotometer (FI-HG-AAS, Perkin Elmer PinAAcle 900F) using external calibration through arsenate as standard (Welsch *et al*. 1990). The optimum HCl concentration was 10% v/v and 0.4% $NaBH_4$ produced the maximum sensitivity. For each sample three replicates were taken and the mean values were obtained on the basis of calculation of those three replicates.

Results and Discussion

Seasonal variations in arsenic concentration showed that the concentration of arsenic in soil during pre-monsoon season is higher as compared to post-monsoon season. (Table 1) and (Fig 1). Seasonal variations of arsenic concentration is due to various reasons such as, arsenic desorbs to the standing water and is then removed laterally, the top layer may be eroded and run off during heavy rainfall, volatilization of arsenic during prolonged periods of flooding and leaching of standing water desorbing and transporting arsenic from the top soil to deeper layer. (Islam *et al*. 2005) [9]. Similar finding were also observed by the Samal *et al*. (2010) [15, 4, 3]. And Islam *et al*. (2005) [9].

Similar seasonal variations in arsenic content was also found by Hussain *et al*. (2014) [6]. In ground water of Bolaram and Patancheru Industrial Area, Andra Pradesh, India and Samal *et al*. (2010) [15, 4, 3]. in ground water of Nadia district of West Bengal.

After analysis of plant sample it is revealed that in the straw of rice plant, the concentration of arsenic varied from 0.006 to 0.082 mg kg^{-1} with an average of 0.024±0.0198 mg kg^{-1}. In straw, the highest accumulation of arsenic was recorded from the paddy straw of Atargaon1 (0.082 mg kg^{-1}) followed by Joratari2 (0.050 mg kg^{-1}) and the lowest accumulation of arsenic was recorded from the rice straw of Dadhutola2 (0.006 mg kg^{-1}). (Table 2 and Fig.2).

In rice grain the concentration of arsenic varied from 0.003 to 0.057 mg kg^{-1} with an average of 0.011±0.0123 mg kg^{-1}. In grain, the highest accumulation of arsenic was found in rice grain of Atargaon1 (0.057 mg kg^{-1}) followed by Sonsaytola1 (0.019 mg kg^{-1}) and the lowest accumulation was found in rice grain of Kaudikasa2 (0.003 mg kg^{-1}). (Table 2 and Fig. 2).

In general, both the straw and grain of rice plant contained <1 mg kg^{-1} arsenic (Table 2 and fig. 2) and did not exceed the WHO recommended permissible limit in rice (1.0 mg kg^{-1}). Bhattacharya *et al*. (2010) [15].

The data on accumulation of arsenic in rice plant as presented in Table 2 and depicted in Fig. 2, showed that accumulation of arsenic is higher in rice straw as compared to rice grain. Similar results were also found by Bhattacharya *et al*. (2010) [4]. huq *et al*. (2006) [7, 8]. and samal *et al*. (2010) [15, 4, 3].

Table 1: seasonal variations of arsenic in soils of different villages of Ambagarh chowki block.

Village	Pre-monsoon arsenic in soil (mg kg^{-1})	Post-monsoon arsenic in soil (mg kg^{-1})
Kaudikasa1	4.916	4.286
Kaudikasa2	4.76	4.203
Bihrikala1	3.16	2.426
Bihrikala2	3.366	3.073
Dadhutol1	4.446	4.06
Dadhutol2	4.026	3.433
Sonsaytol1	5.48	5.226
Sonsaytol2	5.056	4.666
Telitola1	5.34	4.906
Telitola2	5.426	4.956
Joratari1	5.833	5.436
Joratari2	5.593	5.293
Mangatol1	5.683	5.446
Mangatol2	5.55	5.023
Atargaon1	3.133	2.743
Atargaon2	4.066	3.506
Sangali1	4.36	4.123
Sangali2	3.273	2.780
Jadutola1	5.173	4.713
Jadutola2	4.336	3.910
Range	3.13-5.83	2.743-5.436
Average	4.6482	4.2105
Total	20	20

Fig 1: Seasonal variation of arsenic in soils of Ambagarh chowki block during pre and post monsoon season

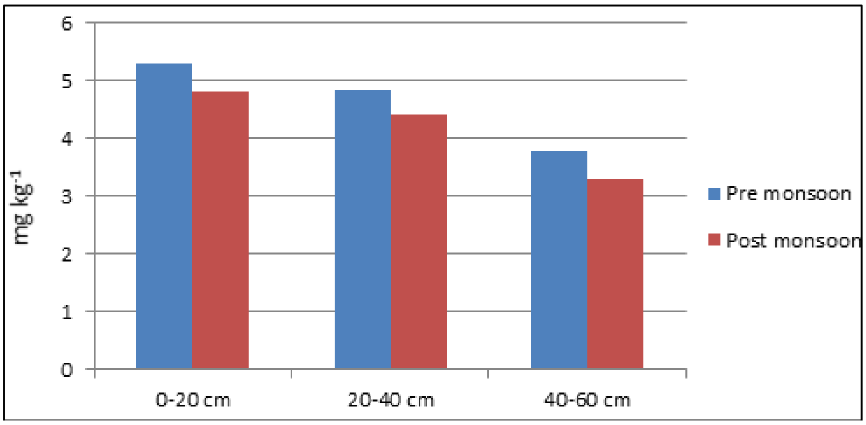
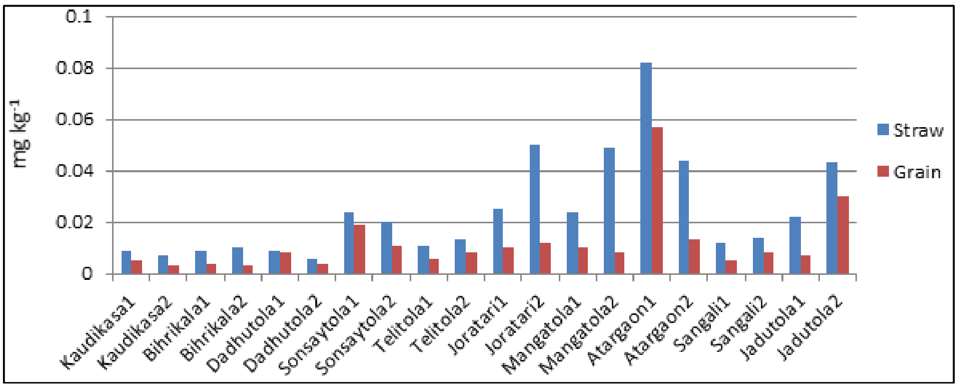


Table 2: Accumulation of arsenic in straw and grain in rice crop of different villages in Ambagarh chowki block

Village	Straw(mg kg^{-1})	Grain(mg kg^{-1})
Kaudikasa1	0.009	0.005
Kaudikasa2	0.007	0.003
Bihrikala1	0.009	0.004
Bihrikala2	0.010	0.003
Dadhutola1	0.009	0.008
Dadhutola2	0.006	0.004
Sonsaytola1	0.024	0.019
Sonsaytola2	0.020	0.011
Telitola1	0.011	0.006
Telitola2	0.013	0.008
Joratari1	0.025	0.010
Joratari2	0.050	0.012
Mangatola1	0.024	0.010
Mangatola2	0.049	0.008
Atargaon1	0.082	0.057
Atargaon2	0.044	0.013
Sangali1	0.012	0.005
Sangali2	0.014	0.008
Jadutola1	0.022	0.007
Jadutola2	0.043	0.030
Range	0.006-0.082	0.003-0.057
Average	0.024±0.0198	0.011±0.0123
Total	20	20

Fig 2: Accumulation of arsenic in straw and grain of rice crop and its variation across different villages of Ambagarh chowki block



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