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Arsenic concentration in paddy soil and its accumulation in rice: a health risk assessment

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Abstract

Arsenic (As) is one of the metalloids which is known for its toxicity and associated health risks. It is released both naturally and anthropogenicaly into environment. The present study was carried out to quantify the As concentrations in paddy soil, its subsequent concentration in rice (Oryza Sativa L.) grown on contaminated soil and associated health risk. Soil and rice samples were collected from District Chitral, Chitral City (Drosh, Ayun, Bumborat, Buny and Garam Cheshma and analyzed for As concentration. The findings revealed that the highest amount of As was found in the soil of Gabur (18.5 mg/kg) followed by Mastuj (13.2 mg/kg), Brun (11.8 mg/kg), Gharm Chashma (10.8 mg/kg), Ayun (9.1 mg/kg), Buny (6.31 mg/kg) and Bamborait (2.8 mg/kg). Similarly, the highest concentration of As was found in rice sample collected from Gabur (5.2 mg/kg) followed by Ayun (4.3 mg/kg)> Gharm Chashma (3 mg/kg), Mastuj (3 mg/kg)>Broun (2.9 mg/kg)>Bamborait(2.8)>Buny (2.12). The daily intake of As in rice was within permissible limit collected from Gabur (0.0318 - 0.0674) followed by Ayun (0.0236- 0.0535) > Gharm Chashma (0.0183 - 0.0373), Mastuj(0.0183 -0.0373)>Broun(0.0177 an- 0.0535)>Bamborait (0.0171 - 0.0348)>Buny (0.0129 and (0.0263) for adults and children, respectively, set by WHO but the health risk index was higher than 1 for rice in all areas which showed that the people of the study area are at high risk due to consumption of rice contaminated with As and considered as main food item in the study area for both children and adults.

Keywords: Arsenic, Rice, Food intake, Health risk.

1. Introduction

Arsenic (As) is a metalloid which is known for its carcinogenicity and easy availability to plants (Traina and Laperche, 1999). It is the 20th most abundant element found on planet, earth crust and present in soil, water and inside the bodies of plants and animals (Khosa, 2010). As can transfer from soil to food chain through plants and herbivores and carnivores and cause severe health problems (Pan and Yu, 2011). As it is found in soil and plants and accumulate after uptake in edible parts of the plant and become part of food chain (Martinez-Sanchez, 2011; Khan et al., 2014; Adrieno, 1992). Arsenic is found on earth crust in different forms like in an organic and inorganic, the most toxic farm is inorganic that is As (III) and As (IV) (Khan et al., 2014;Narigu et al., 2007).

In soil arsenic concentration ranges from 0.50-80.00 mg/kg (Martinez-Sanchez, 2010). In soil, it occurs naturally but is also released through anthropogenic activities and become part of soil such as mining and agricultural chemicals. Due to the natural weathering process of supplied ore (pyrite and pyrrhotit) which is rich in As is release in soil (Martinez, 2010). In soil As is present this As is available to plants in solution farms like other essential elements and these plants has the capacity to uptake this solution (Khan et al. 2008). Arsenic responsible for many disease and cancer is one of major disease cause by them through food chain contamination (Khan et al., 2014). The presence of As is now a days threats for third world countries.(Hussain et al., 2015;Jarup, 2003; Atta et al., 2009;). As enters through natural cycles into our food chain (Yu et al., 2008).Through different natural process like weathering of rocks in mountainous areas,soil erosion through air wind and water and volcanism it enters to human environment (Waqas et al., 2015).Another mean of contamination of food chain by As is different activitiesof human these activities includes chemicals from agriculture activities from our house holds and market places etc. (Oti, 2015;Singh, 2001) The total average is 5 mg/kg of arsenic in soil but the variation is found throughout the world (Koljonen et al., 1989) if the bed rocks are rich in arsenic the arsenic contents will be high in that area and also in adjacent areas due to erosion. Concentration upto 4000mg/kg is also recorded in Siyria, Austria due to the presence of Iron pyrite ore (Geiszinger et al., 2002). It is found in 568 minerals other than that (IMA, 2014). In Europe about 7.5–20 mg/kg average As is reported (Lado et al., 2008), while in America the mean concentration is found 5mg/kg (Smith et al., 2014).

Similarly Arsenic may be known to its carcinogenicity /cancer-causing agent (Jia et al. , 2012). It is also toxic in very low quantity (Hussain et al., 2015). A considerable measure for wellbeing related issues are connected with it and is recognized as community health risk (Baig et al., 2009). The health issues related with arsenic are high blood pressure, PVD skin related issues like gangrene, and hyper pigmentation issues of skin, keratosis and human lungs are also effected by it(IARC, 2004; Al-Ashkar Ramadan and, 2007; Fatmi et al., 2009;).

This investigation in regards concerning illustration substance done soil, rice furthermore cohorted wellbeing danger might have been led done region Chitral in distinctive places. These are the enter districts from the place the sample specimens holding Likewise been gathered. In this study, the aggregation for similarly as in rice might have been resolved furthermore its connected wellbeing danger might have been likewise evaluated utilizing statistical modeling.

The metalloid As is present in Chitral is associated with sulphide and carbonates and in different areas of valley of Tirchmir and is considered as gold indicator that's why exploited through mining as chances of availability of gold increased with the availability of As (Investor information package KP 2014).

2. Materials and methods

2.1. Study area

The study area consists of Chital which is the largest district of Khyber Pakhtunkhwa. The location is 35o-50' to 35o-34o, and71o-34/to 71o-46/to north latitude,east longitude respectively (Pervez,2014).This diversity in land features holding area lies in the north of Pakistan. In the Chitral high including high peaks above 4,000m high. The mountains of the study ares remain snow cover in winters but also is the paradise for grazing animals in summer. The area covered by the study area is 14850 km2 (Figure. 1.1). The samples were gathered from Ayun, Bony ,Drosh, Bamborat, Chitraal city and Garm ,Cheshma.

2.2. Samples collection and major techniques

2.2.1. Soil sampling

The sample were collected from Drosh, Buny, Ayun,Garm-Cheshma, Bumborat, and Chitral city. Random sampling techniques were applied for the collection of samples, soil samples were collected from the surface layer with the depth of 0.00 to 20.00 cm from the selected sites. The samples were properly sealed in a clean and dry polyethylene bags for further analysis. The soil samples were dried and were grounded, sieved and preserved for further analyses.

2.2.2. Rice sampling

The samples of rice were collected from the same sites from where soil samples were collected, and were analyzed. The samples which were collected are cleaned with normal, drinking water and after with doubled de-ionized water. Then the shoots were separated from roots samples were then oven dried at 70.00 oC for whole day to remove access of water contents(Khan et al., 2008). The rice samples are then grinded for further processing.

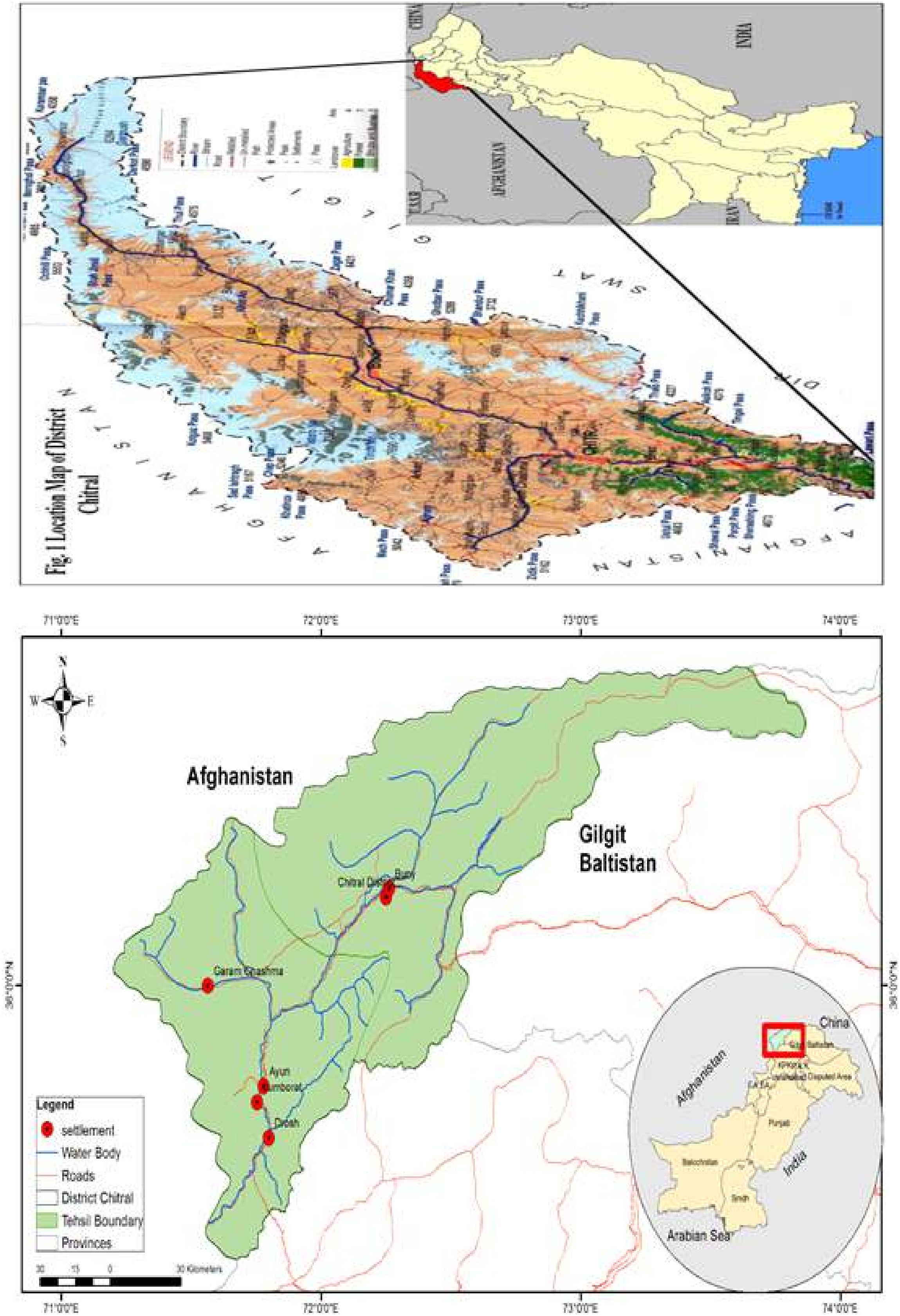

Fig. 1. Study area map.

2.3. Laboratory methodology

0.5 gram of weight of each sample was taken from dry grinded rice and was digested using HNO3 in digestion block till discoloration. Then, the extracted solution were strained using filter paper. The volume of the solution were made 50ml by adding distilled water. The same procedure were carried out with soil samples by taking 1g sample and addition of Hydrogen per oxide and Nitric Acid (Khan et al., 2014). The amount of Arsenic in the samples were found Atomic Absorption Spectrophotometer (AAS, Perkin-Elmer, A700).The research work were carried out in the Environmental Laboratory Pakistan Council of Science and Industrial Research (PCSIR), Peshawar, Khyber Pakhtunkhawa, Pakistan.

2.3.1. Accuracy and precision

The plant material GBW07603 – GSV-2 for plants and GBW07406-GSS-6 for soil are used for samples to verify the either the procedure is correct or not. Blanks were used to check the accuracy of the digestion. The recovery of As were checked in percentage (97%) for samples.

2.4. Translocation factor

The Translocation factar (Tf) in rice is find out as follows:

Tf = Crice/Cpaddy soil……… (Equation 1)

In equation 1.1, Cplant shows the amount of As in plant, while Cpaddy soil shows the amount of As in soils on dry weight basis.

2.5. Estimated daily intake of As

The Estimated Daily Uptake of As (EDI) by the people to consume rice was calculated by the following equation:

EDI = Ed × Ef × Ir×CAs/Bw× Le.....(2)

Ed, Ef, CAs, Bw and Le shows exposure time (70 years), frequency of exposure (365 days per year), CAs concentration of As in rice, weight of body (65 kg), and expected life(25550 days) (Zhuang et al., 2009;Li et al.,2011;). Consumption rice rate (IRRice) of 398.3 g/adultperson/day (Zheng et al.,2007).

2.6. Hazard quotient (HazQ)

The Hazard quotient (HazQ) which Arsenic can cause in Chitral by the consumption of rice were measured as:

HazQ = EDI/RefD……………………..(3)

In equation number .3, RefD 0.0003 mg/kg-day is oral dose reference which is set by EPA-US . When the Hazq value is greater than 1 it means that it can cause health risk (Khan et al 2008).

3. Results

Five (05) locations of densely populated area of ,Chitral City include Garam Cheshma, Bumborat, Drosh, Ayun, and Buny were selected for sampling . The analysis revealed that the 7.40-7.75, is the range of pH whereas the mean pH was 7.54. The ranged of organic matter 1.1-3.0 % and the average is 1.98 %. Similarly, the electrical conductivity (EC) ranges from 0.050- 0.70mS/cm with the average of 0.066mS/cm. Furthermore, particles of the soil are in the range of >1.00mm is 42.920%, within the range of 250.00µm-64.00µm, 34.25%. Similerly, 64µm-20µm,range of only 19.98% noted. While, < 20µm, only 2.85% was noted (Table.1).

3.1. As concentrations in soil

The concentrations of As in paddy soil in the study area were found to be in the range from 2.8 to18.5 mg/kg (Table 2). The concentration of As in Gabur was highest where the concentration in Bamborait was lowest. Skewness (Sk) and Standard-deviation (σ) is used in soil for the degree of dispursion, the analysis showed that the highest values of SD was found at Ayuon (1.30σ) and Garam-Chashma (1.30σ), however in other locations express flux. Similarly, in terms of Skewness, Garam Chashma (1σ), and show highest value followed by Gabur which is 0.7σ. The rest of the locations show S fluctuations. The lowest value is recorded at Gabur (-0.9).

3.2. As concentrations in rice

The highest average concentration is noted in Gabor (05.20 mg / kg), while in Buny the concentration of As was lowest that is 02.12mg/kg (Table 3).The mean concentrations of As varied from site to site such as Garam Chashma (3 mg/kg), Boborait (2.8 mg/kg), Mastuj (3 mg/kg), and Broun (2.9mg/kg).

Table 1. Soil's Physico-chemical parameters collected from study area.

Parameters	**Range**	**Average**
pH	7.40-7.75	7.54
Organic Matter(%)	1.1-3.0	1.98
EC (mS/cm)	0.05-0.7	0.065
Soil particle (%)		
>1mm		42.92
250µm-64µm		34.25
64µm-20µm		19.98
<20µm		2.85

Table 2. As concentrations in soils of the study area.

Name of Site	Average (mg/kg)	Skewness (Sk)	Standard Deviation (σ)
Ayun	09.10	0.40	1.30
Garam Chishma	10.80	01.00	1.30
Bamborait	02.80	-1.20	1.50
Buney	06.31	-0.10	0.60
Mastuj	13.20	-0.30	0.90
Gabur	18.50	0.70	0.70
Braun	11.80	-0.50	0.60

Table 3. As concentration in rice grown in the study area.

Name of Site	Average (mg/kg)	Skew ness	Standard Deviation (σ)
Ayun	04.30	-.30	±01.50
Garam-Chashma	03.00	0.10	±0.7
Bamborait	02.80	01.30	±0.7
Buny	02.12	-0.50	±0.6
Mastuj	03.00	-0.60	±0.9
Gabur	05.20	-0.90	±1
Broun	02.90	0.20	±0.6

3.3. Transfer factor of As from soil to rice

Bioaccumulation and translocation of metal can affect plants genetics and physiology (Ramirez-Andreotta et al., 2013). The range of As transfer from soil to ricewas0.23-1.0. The highest TF value was observed at Bamborait and the lowest at Mastuj. The value of transfer factor is higher then one for some plants (Kloke et al., 1984).

3.4. Health risk index and daily intake of As in adults and children

The daily intake of As was calculated for children and adults of the study area. The daily intake of As was high in the children of Gabur >Ayun>Broun>Mastuj>Bamburait,Gharam chashma>Buny and in Adults high intake of As was foundin Gabur followed by Ayun >Mastujand Garam Chashma >Broun >Bamburait >Buny>.

The HQ, the value in Gabur is highest in case of children (224.6) then second highest in **Ayun** (178.33), **Broun** (178.3), **Mastuj** (124.33) and **Bomborait** (116),**Garam-chashma** (104.33), Buny 78.66. In adults, in the area of Gabur higest values were shown i.e. 106 second highest is recorded in **Ayun** (78.66) **Mastuj** (61),**Gharam-Chashma** (61), **Broun** (59) and **Bomborait** (57).

All the readings shows that all the sites had HQ more than 1 which mean the residents of the study are at risk.

Table 4. Transfer factor of As from soil to grown rice.

Study-area	Soil-sample	Rice-sample	Transfer-Factor
Ayun	09.10	04.30	0.47
Garam-Chashma	10.80	03.00	0.28
Bamborait	2.8	2.8	1.00
Buny	6.31	2.12	0.34
Mastuj	13.2	03.0	0.23
Gabur	18.50	05.20	0.28
Broun	11.80	02.90	0.25

Table 5. D I A and H R I in adults and children and via consumption of rice.

Study area		EDI	HazQ
Ayun	Adult	0.0236	78.66
	Children	0.0535	178.33
Garam-Chashma	Adult	0.0183	61.00
	Children	0.0373	104.33
Bamborait	Adult	0.0171	57.00
	Children	0.0348	116.0
Buny	Adult	0.0129	43.00
	Children	0.0263	78.66
Mastuj	Adult	0.0183	61.00
	Children	0.0373	124.3
Gabur	Adult	0.0318	106.0
	Children	0.0674	224.6
Broun	Adult	0.0177	59.00
	Children	0.0535	178.3

4. Discussion

The overall analytical data indicate that As concentrations in soil was greater from the values recorded by (Karim et al.,2008) in Feni , Bangladesh. The intake of As was greater than 0.038 µg/kg for adults reported in the Santiago city of, Chile (Munoz et al.,2005), the value is also greater then the vlues recorded by Alam et al 2003 in Bangladesh which is 0.463 µg/ kg and the is also greater then the values recorded by Song et al.,2009 which is 102 µg/kg for children 0.08 for adults Beijing but the value is less than 1000 µg/ kg exceed the European Union standard which is 100 µg kg−1 for children (Randa et al., 2018).

The FAO and WHO had established 2µg/kg as the highest limit for the daily intake of Arsenic (WHO,1981). The use of 1.0 µg of in organic As in food can cause skin lesions (WHO/FAO, 1999).

Rice, is a grain crop usually grown in an area with highest As concentration, it has the ability to bio accumulate arsenic by 10 fold as compared to other grain plants like barley and wheat (Ma et al.,2008; Mitani et al., 2009; Meharg et al., 2009; Mitani et al., 2009;Williams et al., 2007a,b; Williams et al., 2005).The total intake of As through food in Hong Kong through a study shows that As was 0.22 µg/kg-bwt/day and in rice consumption reached to 58% of total exposure (Wong et al.,2013). In row rice iAs intake shows (0.30 ± 0.10 µgkg−1bw day−1) and that of rice which is cooked the values are (0.80 ± 0.40 µgkg−1bw day−1) was found from 6 to 16 years age as compared to 3–6 years and N 16 years, The higher exposure was seen from wheat incase of children of3–6 years the vulnerable age groups are 3-6 and 6-16 as compare to adults. (Hafiza et al 2018). As we know that children are more vulnerable due to their exposure are higher than adults about three times to inorganic As consuming the same food items. It is found that the children exposed to As has high risk of respiratory infection (Gardner et al., 2013). The young children with chronic exposure has developmental problems as well as blood pressure and kidney diseases (Flanagan, Johnston, & Zheng, 2012; Gardner et al.,2013; Hawkesworth et al., 2012). The research study conducted in America shows that 14% increase of urinary As concentration was noted among the children with increase rice consumption (Davis et al., 2012).

5. Conclusion

The rice grown in contaminated soil contained high quantity of As that cause serious health problems. High concentration of As was found in some part of the study area and daily intake of the As by children and adults were calculated and high health risk index showing high values > 1 which mean that people of the study area are at potential, high risk.

So, it is recommended that specifically there is need of control of anthropogenic activities which cause the As to become part of the environment. Health risks can alo be controlled by the control of anthropogenic activities and health problems can be avoided. Proper policies may be designed and implemented to control of Arsenic in northern areas. In addition to that Awareness Campaign must be launched to promote the use of Arsenic free pesticides and organic fertilizers to reduce the health risks. Furthermore it is also suggested that sustainable irrigation practices may be adapt to control over use of water.

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Author's Contribution

Shandana collected the samples and analyzed for selected parameters. Noor Jehan supervised the student and helping in polishing the paper. Muhammad Waqas guided the research work, check the data and help in polishing the paper. Muhammad Amjad Khan did statistical analysis of data, tabulation and paper drafting from first to final versions. Mahnoor helped in preparation of graphs and drafting. Juma Muhammad Worked on paper revision and correction and formatting for JHES submission.

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