Research Article
Volume 9:8, 2022

Journal of Environmental Analytical Chemistry

ISSN: 2380-2391

Open Access

Evaluation of Arsenic Health Risk Assessment to Human Population by Consumption of Cereal Food Crops Irrigated with Diverse Types of Water

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Abstract

Arsenic considered as in the concentration of the soil, water and cereals of Sargodha, Punjab, Pakistan. Three different sites of Sargodha that were selected for sampling, these sites were irrigated with 3 different water resources. Site one irrigated with municipal sewage, the site two irrigated with canal water and the site three irrigated with ground water. The site 1 in which municipal sewage have high level of the heavy metals. For soil maximum PLI (Pollution load index) was perceived in *Zea mays* (3.02 mg/kg) and the minimum PLI concentration was in *Linum usitatissimum* (1.83 mg/kg). For soil maximum BCF (Bio-concentration factor) was detected in *Pennisetum glaucum* (0.38 mg/kg) and the minimum BCF concentration was prescribed in *Zea mays* at site 1. For soil the maximum Enrichment factor (EF) was prescribed in *Triticum aestivum* (100.8 mg/kg) and the minimum EF concentration was detected in *Pennisetum glaucum* (10.41mg/kg) at site one. For soil the maximum DIM (Daily intake of metals) was prescribed in *Zea mays* (1.46 mg/kg) and the minimum DIM concentration was detected in *Linum usitatissimum* (0.00106 mg/kg) at site 1. For soil the maximum Health risk index (HRI) was prescribed in *Pennisetum glaucum* (6.12 mg/kg) and the minimum HRI concentration was detected in *Zea mays* (0.048 mg/kg) at site 1. In water, the Arsenic value was higher than standard value and also fewer in soil and cereal crops. The DIM value, BCF, PLI, EF, and HRI were higher than standard limit.

Keywords: Municipal wastewater • Standard limit • BCF • PLI • EF • DIM • HRI

Abbreviations: AAS: Atomic Absorption Spectrophotometer • DIM: Daily Intake of Metals • PDTI: Provisional Tolerable Daily Intake • HRI: Health Risk Index

Introduction

The metals can build up in the body, resulting in oxidative stress and clinical symptoms. Thus, painful gullet, upper body pain, headache, coughing, faintness, and lung difficulties are observed in Arsenic, they also cause cancer and inhibit protein synthesis [1]. In environment the major anthropogenic sources of arsenic are from the burning of the coal as well as a petroleum [2]. Arsenic is volatilized form burned coal, but can be reduced downstream in fine particulate materials [3]. In the world-wide coal industry that estimated the Arsenic concentration that is 5mg kg^{-1} and their contribution are annual and cumulative. In fact, the arsenic concentration in coal that fluctuate over high range from 0.3 – 93 mg kg^{-1} or from 0.34-130 mg kg^{-1} [4,5]. In other countries like Europe, New Zealand, USA and New South Wales contained Arsenic trace are 200 mg kg^{-1}. Even in China some Arsenic coals have several thousand mg As kg^{-1} [6].

Wastewater is contaminated with the waste of industries and hazardous metals. In Pakistan, freshwater resources are scarce, so wastewater is used for agriculture. Long-term use of wastewater leads to the accretion of harmful metallic elements in agronomic loams and floras. Wastewater is continuously utilized for irrigation and carriages a hazard to the healthiness of the creatures [7]. It is prominent from various articles that wastewater irrigated soil is linked with impurity of heavy metals, it become an important concern today. The collection of unneeded investigated heavy metals in the environment could cause probable noxious influence on human health [8,9]. Owing to the absence of any laws related to the prevention of wastewater for crop irrigation this is being used at a huge scale as a consequence gathering of metals in top crops, water, and soil. Food safety is in danger when the wastewater irrigation is lengthened, and the buildup of metals goes beyond the boundary in soil and crops [10].

In water, trace metals are discharged through different sources that inudating with water in vegetables [11]. In plants the most consumable portion

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Date of Submission: 03 August 2022, Manuscript No. jreac-22-71166; **Editor Assigned:** 05 August 2022, PreQC No. P-71166; **Reviewed:** 19 August 2022, QC No. Q-71166; **Revised:** 25 August 2022, Manuscript No. R-71166; **Published:** 02 September 2022, DOI:10.37421/2380-2391.2022.9.384

are the vegetables. They have important features that can be efficiently used to develop the body. In Pakistan various types of vegetables are grown. Vegetables are commercially used in a basic store, and they admired mostly to increase the sugar contents [12]. The eatable parts of the vegetables in which metals are exchanged, laterally these lines that turn into pieces of our consumption routine that cause sever health issues, for those which consuming that vegetation high in dangerous metals [13].

Present study in which the concentrations of Arsenic metalloids were estimated in water and soil cereals. This work was completed to determinate the effect of metalloid accumulation in the soil and cereals at GWI-I, CWI-II, and WWI-III and to observed the basis of the contamination within the location and HRI to humans.

Material and Methods

Sites description

Firstly gathered a variety of samples of Cereal crops, soil, and blood of humans and water from four dissimilar places of District Sargodha. Work was started from April-2020 to May 2021, an individual sites in which three repeats of every specimen was selected.

Water sampling

The water samples were selected from the related cereals. For digestion water sample took in a 2ml bottle then saved it Table 1.

Cereal crops sampling

Five cereal crops in which 25 specimens were collected, then select five copies of every specimen for each site. Firstly collected the Corn Wheat, Flax (Alsi), Jodar, and Milllet from the sides of roads for each site. Then show the cereal samples in the air to dry. Then, kept them in the oven at 75°C for one week. After drying the samples completely they are grinded and converted into fine powder and 2 gram sample was protected for the digestion.

Soil samples

Fourty five samples were collected from different sites of the Sargodha soil. For all selected sites are used a colorless steel auger to dig up at 12-15 cm in deep layers. For sampling, at least 2g of soil samples were put in plastic bags. Soil samples were dried in air for almost 3-5 days and after that in Oven for 72 hours at 80°C. In the end, saved these samples in plastic bags for additional digestion methods. Soil sample for digestion was prepared by Khan ZI, et al. [14,15] with some modifications.

Blood serum

First of all, choose many specimens of blood from specific places of District Sargodha. The work followed the ethical criteria outlined in the World Medical Association Declaration of Helsinki (WMA 2013), for medical research involving human subjects. After thoroughly presenting the study methodology, informed consent indicating a willingness to engage in the study was obtained, and those who volunteered to participate in the study on their own were included. The volunteers agreed to give a 3-ml blood sample.

The sample was taken via vein puncture by a qualified technician from the licensed laboratory By Thyrocare, they follow the normal blood collection method. Blood samples were collected in 3 ml EDTA tubes, shaken well, and taken to Thyrocare Technologies Limited for analysis on the day of collection, air was conveyed to Mumbai in a frozen form, and analyzed by (ICP-MS) inductively coupled plasma-mass spectrometry. To get the serum, the blood and blood plasma samples were centrifuged for 15 min at 3000 rpm. Then stored it in polyethylene tubes and frozen them at –20°C. The metal serum analysis was prepared by Ashfaq A, et al. [16] with some modifications.

Table 1. Site locations for water sampling.

Site	Irrigation Type	Name
Site -1	Municipal wastewater (MWW)	Sargodha
Site -2	Canal water (CW II)	Sargodha
Site -3	Ground water (GWIII)	Sargodha

Metal investigation

A few steps were in consideration to assess the level of metals are Digestion, Dilution, Filtration and Spectrophotometer/Atomic Absorption.

Chemicals and Instruments

Four beakers (100 and 250 mL), Gloves, two digestion flasks (100 mL), two hydrogen peroxide (H_2O_2) 50%, hot plate, Sulphuric acid (2 mL), stirrer, filter paper 50 mL measuring cylinder Tripod stands, newly produced distilled water, and tiny plastic bottles.

Wet acid (Digestion) method

Dried powdered dirt (soil) specimens of one grams were placed in a digestion flask with 8 (mL) H_2SO_4 on top. Then this acid and soil mixture was heated for almost 30 min, 10 (mL) H_2SO_4 more addition with flame even the deposits became brilliant. After that, 4 (mL) H_2O_2 was added and heated once more. Distilled water is used for the dilution of solution exceeds the volume up to 50 (mL) and saved until metal analysis. With the ratio of 4 and 2 H_2SO_4 and H_2O_2 were used to digest the one gram cereals samples at 250°C for at least 3 to 4 hours even colorless solution formed with heavy and colorless white vapors emerged in the flask.

Distilled water was used to wash the flask remains and filtered by using Whatman filter paper. 50 (mL) diluted solution formed by the addition of distilled water for remaining analysis. The blood was centrifuged after it had been heparinized. After that, blood plasma 2 (mL) was mixed with 2 (mL) H_2SO_4, and this sample mixture was allowed to sit overnight to continue the digestion phenomenon. The sample mixture was break down at 120°C, till all the considered organic was dissolved. H_2O_2 2 (mL) was added to speed up the oxidation process of digestion. Samples after digestion were chilled, and ultrapure water was utilized to dilute the digested samples to 60 (mL), then put them in tubes (glass) for analysis. After digestion, all the given samples were diluted with ultra-pure water even to make the sample of 50 (mL). After that observed samples of soil, forages blood, and hair was subjected to a filtration process then these samples have to be preserved in bottles (plastic).

Metal analysis

The arsenic (As) samples were examined in a fluorometric [17], and AAS Perkin Elmer Aanalyst 400 [18].

Statistical study

The mean contents of the toxic metals were obtained from soil, Cereals, and blood samples were existing in separately repeat. Then used SPSS Software and ANOVA to find out Variance and correlations.

Pollution load index

PLI found by using this formula:

i) $$PLI = \frac{\text{Value of metals (mg/kg) in studied soil}}{\text{Metals reference values in soil}}$$

Bio-concentration factor

Cui YJ, et al. [19] methods were used in these calculations for BCF

i) $$BCF\ \text{soil-cereal} = \frac{\text{Metals content in cereals}}{\text{Value of metals in the soil}}$$

ii) $$BCF\ \text{cereal-plasma} = \frac{\text{Amount of metals in plasma}}{\text{Metals value in cereals}}$$

Daily intake of metals

(DIM) Daily intake of metals can be determined in this method:

iii) DIM = C metal * D food intake / A average weight

Health risk index (HRI)

Estimation of HRI done by this procedure

iv) HRI = DIM / Rf D

Enrichment factor (EF)

It is determined by this methodology

v) (EF)=

$$(EF)= \frac{\text{(Metal content in cereals /Con .of metal in soil) sample}}{\text{Value of the metal in the crop / Concentration of the metal in soil standard}}$$

Results

Water

In site 1 the maximum mean concentration of Arsenic in water was prescribed (0.029 mg L^{-1}) and the minimum concentration in water was present in site 3(0.0002 milligram/liter). Order of the sites are Site one > Site two > Site three (Table 2).

Soil

In site 1 the maximum concentration of Arsenic (As) in soil was present in *Zea mays* (9.08 mg/kg) and the minimum value was detected in *Triticum aestivum* (8.21 mg/kg). And the order of the concentration was prescribed as *Zea mays> Pennisetum glaucum > Avena sativa Linum usitatissimum >Triticum aestivum*.

At site 2 the maximum value was in *P. glaucum* (7.33 mg/kg) and the minimum value was in *Z. mays* (5.41 mg/kg). And the order of concentration was *Pennisetum glaucum > Triticum aestivum > Avena sativa> Linum usitatissimum> Zea mays*. The maximum value at site 3 was prescribed in *Avena sativa*. (5.72 mg/kg). Minimum value was in *L. usitatissimum* (5.51 mg/kg). And the order of the concentration was prescribed *Avena sativa > Triticum aestivum > Zea mays> Pennisetum glaucum > Linum usitatissimum* (Table 3). Various soil factors and pH affect the availability of metals by the plants from the soil and plants have different potential for absorbing the metals. Factors persuading the bioavailability of metals and their incidences in crops were found as soil pH, organic matter content, cation exchange capacity, soil texture, and interaction among the target elements. It is concluded that total metal concentrations in soils are the main controls on their contents in plants. It has been observed that metals are sparingly soluble under alkaline conditions (pH = 8.0). Metal solubilities are higher when under slightly acidic conditions (pH = 5.0), and increased drastically when pH is kept at 3.3. Concentration and pH parameters in the formation of complex compounds affect the mobility of heavy metals in the soil. At low pH, heavy metals will be released and thus the mobility will increase. These could be the factors that are responsible for different concentrations of arsenic at different sites (Table 3).

Arsenic buildup in cereals

Analysis of variance points out a significant level of Arsenic at the Site, site*cereals. The maximum concentration of As at a site 1 was present in *P. glaucum* (3.45 mg/kg) and the minimum value was present in *Z. mays* (1.04 mg/kg). And order of the concentration was prescribed in *Pennisetum glaucum > Avena sativa >Triticum aestivum> Linum usitatissimum> Zea mays.*

At site 2 the maximum value was prescribed in *Pennisetum glaucum* (1.7 mg/kg) and the minimum value was in *Z. mays* (0.02 mg/kg) (Figure 1). And order of the concentration was in *Pennisetum glaucum > Avena sativa> Triticum aestivum> Linum usitatissimum> Zea mays.*

At site 3 the maximum value was present in *P. glaucum* (1.7 mg/kg) and the minimum value was present in *Z. mays* (0.02 mg/kg). And order of the concentration was *Avena sativa > Triticum aestivum > Zea mays> Pennisetum glaucum.> Linum usitatissimum* (Table 4).

Analysis of arsenic in human blood

Maximum mean concentration of the Arsenic was present in site one (0.0006 mg/liter) and As in human blood the minimum concentration was existing in site 3 (0.0001 mg/L). Order of the sites are as Site one > Site two > Site three (Table 5).

Correlation

All Correlations between soil-cereal, and cereal-blood are non- significant (Table 6).

Table 2. Analysis of water variance of arsenic metal.

Site	Site1	Site 2	Site 3
Mean concentration of As	0.0292 ± 0.0078	0.0030 ± 0.0008	0.00022 ± 0.00006
Mean square	0.001**		

*, **, ***= significant at 0.05, 0.01 and 0.001 level ns = non-significant.

Table 3. Arsenic concentration (mg/kg) in collected soil samples (Mean ± S.E).

Cereal Crops	I	II	III
T. aestivum	8.2147 ± 0.063	7.2390 ± 0.444	5.6246 ± 0.062
L. usitatissimum	8.4991 ± 0.289	6.4432 ± 0.011	5.5146 ± 0.133
Z. mays	9.0808 ± 0.333	5.4157 ± 0.058	5.6239 ± 0.073
A. sativa	8.9143 ± 0.315	6.8892 ± 0.282	5.7279 ± 0.067
P. glaucum	8.9081 ± 0.214	7.3384 ± 0.113	5.5325 ± 0.066

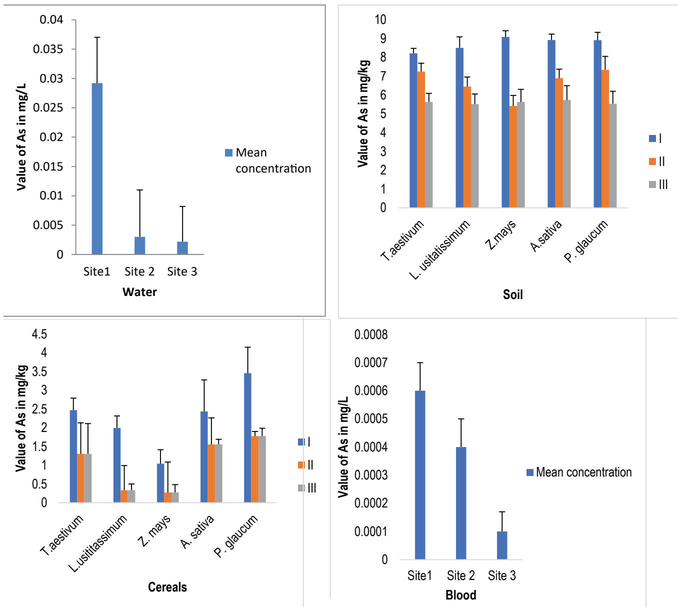


Figure 1. Fluctuation in the level of Arsenic in water sample, soil, cereals and human blood that are treated with Ground, canal, and municipal wastewater

Table 4. Concentration of arsenic (mg/kg) in collected cereals sample (Mean ± S.E).

Cereal crops	I	II	III
T. aestivum	2.4690 ± 0.120	1.3016 ± 0.083	1.3016 ± 0.081
L. usitatissimum	1.9940 ± 0.001	0.3320 ± 0.066	0.3320 ± 0.017
Z. mays	1.0426 ± 0.037	0.0275 ± 0.008	0.0275 ± 0.010
A. sativa	2.4373 ± 0.084	1.5543 ± 0.071	1.5543 ± 0.139
P. glaucum	3.4570 ± 0.069	1.7783 ± 0.124	1.7783 ± 0.208

Table 5. Analysis of variance of arsenic in human blood.

Site	Site1	Site 2	Site 3
Mean concentration of As	0.0006 ± 0.00001	0.0004 ± 0.00001	0.0001 ± 0.0007
Mean square	0.001***	-	-

*, **, ***= significant at 0.05, 0.01 and 0.001 level ns = non-significant

Table 6. Correlation between soil-cereal, cereal-blood of different sites.

Site	Soil-Cereal	Cereal-Blood
Site -1	-0.102^{ns}	-0.297^{ns}
Site-2	0.843^{ns}	-0.494^{ns}
Site-3	0.370^{ns}	-0.463^{ns}

*, **, ***= significant at 0.05, 0.01 and 0.001 level ns = non-significant

Pollution load Index (PLI)

In soil the PLI (maximum Pollution Load Index) was detected in *Zea mays* (3.02 mg/kg) and the PLI minimum concentration was existing in *L. usitatissimum* (1.83 mg/kg). PLI at site one dictate was in *Zea mays>Avena sativa> Pennisetum glaucum >Linum usitatissimum>Triticum aestivum* (Figure 2). PLI at site 2 was prescribed in *Pennisetum glaucum>Triticum aestivum>Avena sativa>Linum usitatissimum>Zea mays*. The PLI at site three was prescribed in *Avena sativa>Triticum aestivum>Zea mays> Pennisetum glaucum>Linum usitatissimum* (Table 7).

Bio-concentration factor

In soil the maximum Bio-concentration Factor (BCF) was detected in *Pennisetum glaucum* (0.38 mg/kg) and BCF minimum concentration was present in *Zea mays*. The order of BCF at site 1 was prescribed in *Pennisetum glaucum>Triticum aestivum>Avena sativa>Linum usitatissimum >Zea mays*. BCF at site 2 was prescribed in *Pennisetum glaucum>Avena sativa> Zea mays> Triticum aestivum>Linum usitatissimum*. At site three BCF instruction was detect in *Pennisetum glaucum>Avena sativa>Triticum aestivum>Linum usitatissimum>Zea mays* (Table 8).

Enrichment factor

In soil the maximum Enrichment Factor (EF) was detected in *Triticum aestivum* (100.8 mg/kg). And EF minimum concentration was present in *Pennisetum glaucum* (10.41 mg/kg). At the site one, the order of Enrichment Factor was prescribed in *Pennisetum glaucum>Triticum aestivum>Avena sativa>Linum usitatissimum>Zea mays*. At the site two, EF was prescribed in *Pennisetum glaucum>Avena sativa>Triticum aestivum>Linum usitatissimum>Zea mays*. At site three, Enrichment Factor was prescribed in *Avena sativa>Triticum aestivum>Linum usitatissimum>Zea mays> Pennisetum glaucum* (Table 9).

Daily intake of metals

Maximum Daily Intake of Metals (DIM) in the soil was detected in *Zea mays* (1.46 mg/kg) and DIM minimum concentration was presents in *Linum usitatissimum (*0.00106 mg/kg). At site one, the order of DIM was prescribed in *Pennisetum glaucum>Triticum aestivum>Avena sativa>Linum usitatissimum>Zea mays* (Figure 3). At site 2 the direction of the DIM was detect in *Zea mays>Pennisetum glaucum>Avena sativa>Triticum aestivum>Linum usitatissimum*. Order of DIM at site three, that was prescribed in *Zea mays> Pennisetum glaucum>Avena sativa>Triticum aestivum>Linum usitatissimum* (Table 10).

Health risk index

For soil the maximum HRI (Health Risk Index) was detected in *P. glaucum* (6.12 mg/kg) and HRI the minimum concentration was present in *Zea mays* (0.048 mg/kg). At site one, Order of HRI was prescribed in *Pennisetum glaucum>Triticum aestivum>Avena sativa>Linum usitatissimum>Zea mays*. The value HRI at the site two, was in *Pennisetum glaucum>Triticum aestivum>Avena sativa>Linum usitatissimum>Zea mays*. The order at the site three, was prescribed in *Pennisetum glaucum>Triticum aestivum>Avena sativa>Linum usitatissimum>Zea mays* (Table 11).

Discussion

Heavy metal contamination of water that can increase the risks of human health through a variety of exposure mechanisms. Only oral intake has been deliberated in the current study for considering the health risks in the adult population. Arsenic maximum mean concentration was present in water at site one (0.029 mg/L) and the As minimum concentration was present in site three (0.0002 mg/L) noted the content of As in water (0.1 mg/kg) [20]. This concentration was higher than our present value. At site 1, maximum As concentration was present in *Z. mays* soil (9.08 mg/kg) and the minimum value was prescribed in *Triticum aestivum* soil (8.21 mg/kg). At site 2 the maximum value was in *P. glaucum* (7.33 mg/kg) and the minimum value was present

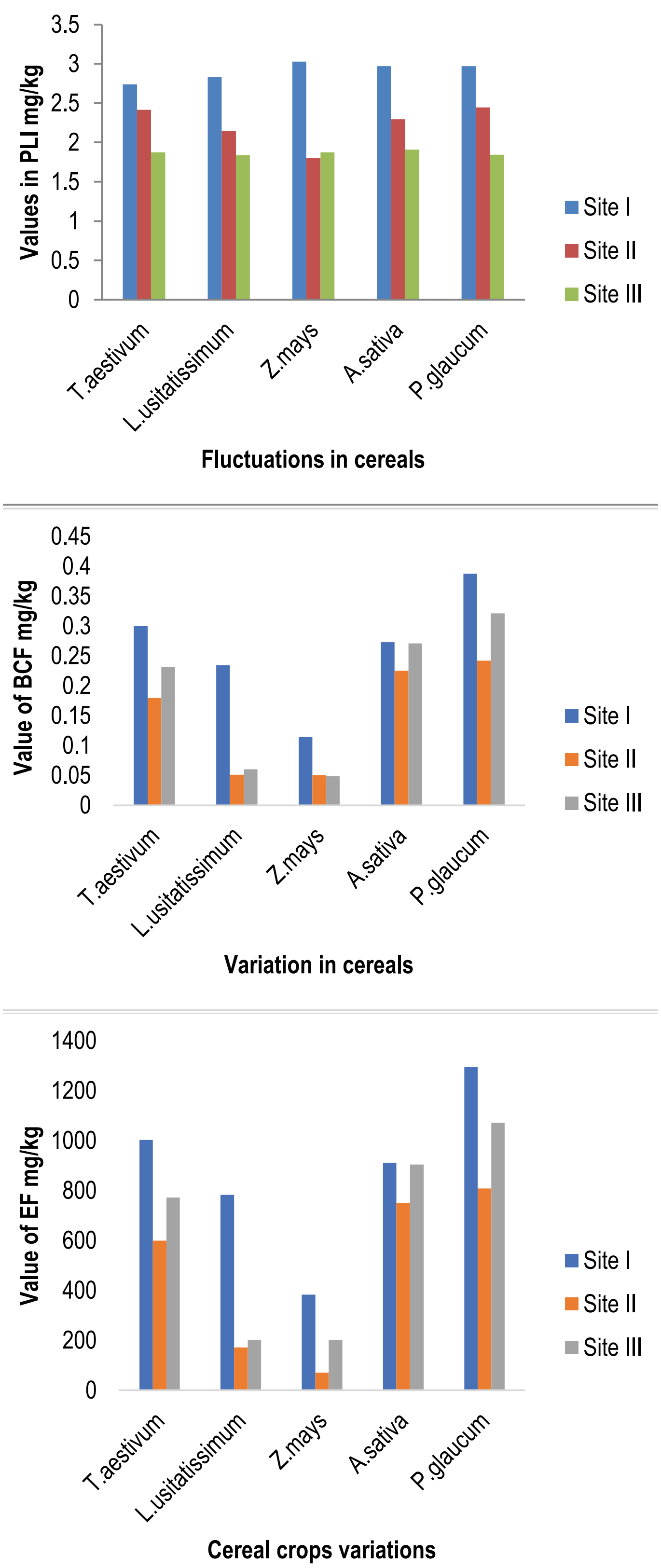


Figure 2. Fluctuations in the value of PLI in Arsenic metal, BCF and EF that are treated with Ground, canal and municipal wastewater.

in *Z. mays* soil (5.41 mg/kg). And the order of concentration was at site 3 maximum value was in *A. sativa* soil (5.72 mg/kg) and the minimum value was in *L. usitatissimum* (5.51mg/kg). FAO/WHO reported the concentration of As in soil (9.36 mg/kg). This concentration was higher than our current value of As. Alloway BJ, [21] reported the As concentration in soil (20 mg/kg). This concentration is greater than our present value. Singh R, et al., [20] reported the As concentration in soil (29.0 mg/kg). This concentration was higher than

Table 7. Pollution load index of soil for arsenic metal.

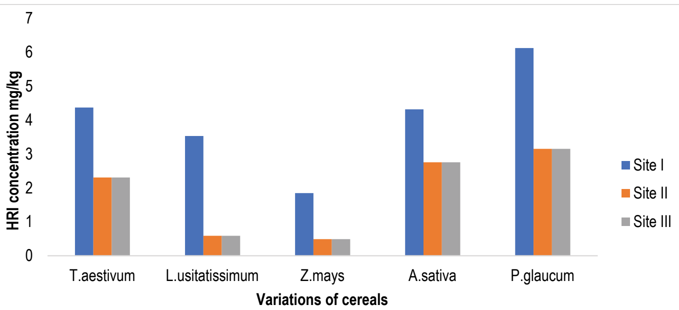
Cereal crops	PLI I	PLI II	PLI III
T. aestivum	2.738244	2.413	1.874878
L. usitatissimum	2.833044	2.147733	1.8382
Z. mays	3.026944	1.805233	1.874644
A. sativa	2.971444	2.2964	1.909311
P. glaucum	2.969378	2.446156	1.844189

Table 8. Analysis of bio-concentration factor of arsenic metal.

Cereal crops	EF (Site I)	EF (Site II)	EF (Site III)
T. aestivum	0.300558	0.179804	0.231411
L. usitatissimum	0.234612	0.051527	0.060204
Z. mays	0.114813	0.005078	0.00489
A. sativa	0.273414	0.225614	0.271354
P.g laucum	0.388072	0.242326	0.321424

Table 9. Analysis of enrichment factor of arsenic.

Cereal crops	DIM Site I	DIM Site II	DIM Site III
T. aestivum	100.86	59.3467	77.37
L. usitatissimum	78.04	17.7567	20.68
Z. mays	38.71	16.926	16.3
A. sativa	91.38	75.0467	90.5133
P. glaucum	129.573	80.753	10.413



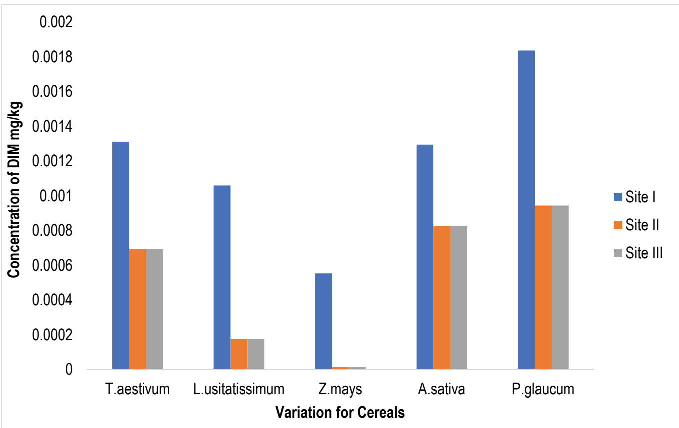


Figure 3. Fluctuations in the level of Arsenic in DIM indices and HRI that are treated with Ground, canal and municipal wastewater.

Table 10. Analysis of daily intake of metal of arsenic.

Cereal crops	Site I	Site II	Site III
T. aestivum	0.001312	0.000692	0.000692
L. usitatissimum	0.00106	0.000176	0.000176
Z. mays	0.000554	1.4605	1.4605
A. sativa	0.001295	0.000826	0.000826
P.glaucum	0.001837	0.000945	0.000945

Table 11. Analysis for health risk index for arsenic.

Cereal crops	HRI Site I	HRI Site II	HRI Site III
T. aestivum	4.373333	2.306667	2.306667
L. usitatissimum	3.533333	0.586667	0.586667
Z. mays	1.846667	0.048667	0.048667
A. sativa	4.316667	2.753333	2.753333
P. glaucum	6.123333	3.15	3.15

our current value.

At site 1, maximum concentration of As was present in cereals *P. glaucum* (3.45 mg/kg) and the minimum value was in *Z. mays* (1.04 mg/kg). At site 2 the maximum value was present in *P. glaucum* (1.7 mg/kg) and the minimum value was present in *Z. mays* (0.02 mg/kg). At site 3 maximum values was found in *P. glaucum* (1.7 mg/kg) and the minimum value was present in *Z. mays* (0.02 mg/kg).

Alloway BJ [21] reported the As concentration in soil (3.0 mg /kg) that was higher than our existing value. Dosumu OO, et al. [22] stated the concentration of Arsenic in cereals (7.0 mg /kg) that was also higher than our present value.

In site 1, maximum Arsenic (As) mean concentration was existing (0.0006 mg/liter) and the minimum As concentration was existing in site three (0.0001mg/liter). For soil, maximum DIM was detected in *Zea mays* (1.46 mg/kg) and the minimum concentration of DIM was present in *L. usitatissimum* (0.00106 mg/kg) however, (WHO/FAO, 2007) stated the DIM (2.14 mg/kg) that was higher than our present value. Arsenic ensured higher values of HRI than site 1 and signifying that these metals ensured high probability to cause human health problems [23-25].

Recommendations and Conclusion

The concentration of Arsenic (As) water was smaller than safe limits. The current value of As in soil was 9.08 mg/kg, and this value was higher than standard limits. As the value in cereals was also greater than standard limits. Analysis of human blood also shows that the concentration of Fe was higher. The value of PLI and HRI for As was less, but the value of EF, and BCF have higher values, and the value of DIM was less.

Such a greater quantity of dangerous metal pollution may create a risk to the local community. This study recommended that both cereals and medicinal plants should be analyzed for heavy metals in polluted regions before being used. The extreme amount of As can cause serious damage to the reproductive system, nervous system, and all body functioning.

Acknowledgement

To all the reviewers, as well as those involved in sampling, design, and paper preparation, we would like to express our gratitude.

Funding

Not applicable.

Credit Authorship Contribution Statement

Conceptualization and Supervision; ZIK, KA, SA, Methodology; KS, AIB, SP, Resources; SA, HM, Software; SA, MN, Original Draft Preparation; SA.Ch, KS, SJ, MF, MAA.

Conflict of Interest

The authors declare that there is no conflict of interest.

Permission to Publish

The authors declare that the manuscript has not been published previously.

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How to cite this article: Khan, Zafar Iqbal, Kanwal Sultana, Kafeel Ahmad and Shahzad Akhtar, et al. "Evaluation of Arsenic Health Risk Assessment to Human Population by Consumption of Cereal Food Crops Irrigated with Diverse Types of Water." J Environ Anal Chem 9 (2022): 384.