# Health Risk Assessment of Trace Metals During Pre- and Post-Monsoon Seasons in Drinking Water of Jamshoro, Sindh

Amjad Hussain Memon[a, b], Allah Bux Ghanghro[b], Taj Mohammad Jahangir[c], Aftab.A.Khand[d], Gul Muneer lund[e], Qipeng Yuan[a]

[a] State Key Laboratory of Chemical Resource Engineering School of life science, Beijing University of Chemical Technology, Beijing 100029, China

[b] Institute of Biochemistry University of Sindh Jamshoro

[c] Hitech Research Lab university of Sindh Jamshoro

[d]Tshinghua University, School of life Sciences, Beijing,100084, China

[e] School of Life Sciences, Northeast Normal University, Changchun, Jilin, China

Corresponding author: Allah Bux Ghanghro, Qipeng Yuan

**Abstract:** Human health risk assessment of trace elements was carried out via calculating Chronic Daily Intake (CDI), Hazard Quotient (HQ) and carcinogenic risk of the trace metals. The results indicate the order of abundance of these heavy metals in the water samples as Zn > Cu > Mn > Co > Ni > As >Fe> Cd in Phase-I and Fe >Mn > Zn > Cu > Ni > Co > As > Cd in Phase-II. HQ non-carcinogenic of As was above than unity in 18 and 13 samples of phase-I and Phase-II, respectively. 12 and 13 samples of Phase-I and Phase-II crossed unity in terms of HQ for iron. The carcinogenic risk of As was higher than 10-6 for 70% and 76% of the population in August and November season. HQ oral of arsenic and iron was higher than recommended value for both weights. It can be concluded that water available to the local residents was unsafe for human consumption, suggesting these trace metals poses potential adverse health impacts on local residents of district Jamshoro, Sindh.



**Keywords:** Trace metals, Jamshoro, Health risk assessment, drinking water, Sindh

## Introduction

The elements required by the living organisms in a minute or low quantity are commonly known as trace elements or micronutrients or heavy metals and are necessary for living creatures to sustain a healthy life. These elements or metals play an important role in biochemical and enzymatic reactions inside cellular compartment of plants, microbes, and animals including human beings. They are commonly found in different sources of water from natural ultra-trace concentration at the ppb level and act as micronutrients but become toxic beyond definite concentration due to natural processes and anthropogenic activities [1][2]. Some of the trace metals have no beneficial or positive role in the human body and are very harmful even in minor level. Drinking water is an important and direct source of heavy metals for humans food. The water pollution is directly related to the extent of contamination of our environment. Rainwater collects impurities such as dirt, dust, smoke and germs while passing through the air; and rivers and streams accumulate pollutants from the over land flow (surface run off) and through the sewage and industrial waste water discharges; these are carried to the reservoirs, lakes or rivers that supply our drinking water. All of the chemical substances produced by humans will eventually flow into our water supplies and enter the rivers, lakes, and underground water, and can contaminate our water environment [3].

Ingestion of drinking water contaminated with significant amounts of trace metals may cause adverse impact on human health ranging from dyspnea to several types of cancers [4][5][6][7]. Heavy metals health risk can be calculated from metal contaminated drinking water. Health risk assessment based on metal contaminated water intake is highly notable due to the direct, severe and continuous human exposure to metals. Several ways have been employed to calculate the potential health risks of contaminants In drinking water, dividing the effects into non-carcinogenic and carcinogenic. Assessment of non-carcinogenic risk from exposure to toxicants such as trace metals is usually based on the calculation of hazard quotient (HQ), a ratio of the potential exposure to a toxicant to the dose level of which there will not be any significant risk. On the contrary, carcinogenic or cancer risk (CR) assessments are the incremental probability of an individual developing any type of cancer over a lifetime due to carcinogenic exposure [8]. In a study conducted previously in Arizona reported that health risk caused by trace metals in drinking water through ingestion pathway [9]. The 90th percentile values for non-carcinogenic risk were less than the recommended level for arsenic, cadmium, and nickel, while the mean, median, and 90th percentile values for arsenic carcinogenic risks were all greater than$10^{-6}$ [9]. Because of the importance of these elements on metabolism, analysis of trace metal is important for studying human health risk.

Trace metal concentrations in both ground and surface water of Sindh usually cross the maximum permissible concentrations for drinking water. Several attempts have been made to analyze the quality of surface and ground water from different sources of the Sindh [10][11][12][13]. However, these studies mainly investigated the levels of metals and potential sources and did not report any health risk by metals.In our previous studies, metals concentration in drinking water from Johi, Dighri and Indus Lake of Sindh province of Pakistan with potential risk assessment of metals were reported [14][15][16]. To our understanding, investigating the trace metals concentration and assessing the human health risk form metal contaminated water during a flood and after the flood were the critically important and existing gaps to resolve the emerging issue of heavy metals contamination in Jamshoro, Sindh. This study was aimed at determining the presence of seven heavy metals, namely arsenic cadmium, cobalt, copper, manganese nickel, iron and zinc concentration in drinking water Pre Monsoon (August) and Post Monsoon flood (November), and estimate the health risk of these metals by calculating HQ, CR values of metal contaminated drinking water by US-EPA model.

## Materials and Methods

### Sampling area and Pretreatment

The present study was conducted from lake Manchar to Jamshoro city in the Sindh province of Pakistan along with the Indus Catchment through Indus highway, approximately the distance covering more than 160 km area. Water samples were collected from selected villages and major populated areas of Sehwan, Lucky Shah Saddar, Aamri, Chhachhar, Sann, Manjhand, Jamshoro and Kotri, Sindh, Pakistan (Figure No. 01). Sindh has a long history of being affected by flood due to monsoon rains and improper managements. This study was conducted during a flood caused by monsoon rain and after a flood. In this study, 68 samples were collected in two phases (thirty-four in each phase) with the gap of three months. In Phase-I, 2 samples from Manchar lake (M), 9 samples from river (RS), 6 samples from water supply schemes (WS), 2 samples from canals (MC), and 15 ground water samples (GS) were collected during flood session in August, while in Phase-II, 2 sample from Manchar lake (M), 9 samples from river (RS), 6 samples from water supply Schemes (WS), 2 samples from canals (MC) and 15 ground water samples (GS) were collected after the flood session in November 2013.The water samples of different sources were collected by using Van Dorn plastic bottles (1.5 L capacity) and were stored in well-stoppered plastic (polyethylene) bottles previously soaked in 10% nitric acid for 24 hours and rinsed with ultrapure water. All water samples were kept in insulated coolers containing ice and transferred on the same sampling day to the laboratory for analysis.

### Methodology:

Arsenic concentration was analyzed by HACH Arsenic kit (EZ Arsenic Test Kit 2822800; Hach Company, USA) for 0.01-0.5 ppm. Briefly, this test produces arsenic hydride, which reacts with the mercuric bromide impregnated on to analytical strip to form a yellow-brown mixed arsenic mercury halogenide. The level of arsenic was estimated through visual comparison of the reaction region of the analytical test strip with scales of fields of color [17]. Other metals like cadmium, zinc, nickel, manganese, copper, cobalt and iron were analyzed by using Perkin-Elmer atomic absorption spectrometer (AAS-PEA-700).

**Exposure and risk assessment:**

Equations 1 and 2, adapted from US Environmental Protection Agency [18][19][20] were used to calculate the chronic daily intake through ingestion and dermal absorption pathways [21].

$$\text{CDI (oral)} = \text{CW} \times \text{IR} \times \text{ABSg} \times \text{EF} \times \text{ED/BW} \times \text{AT} \quad (\text{Eq} = 1)$$

$$\text{CDI (dermal)} = \text{CW} \times \text{SA} \times \text{Kp} \times \text{ABSd} \times \text{ET} \times \text{EF} \times \text{ED} \times \text{CF} / \text{BW} \times \text{AT} \quad (\text{Eq} = 2)$$

The abbreviations used in equation 1 and 2 are shown in Table 1. The health quotient (HQ) for non-carcinogenic (chronic) risk was calculated using the following equation 3 to find out percentage exposure of every trace metal [21].

$$HQ = CDI / RfD \quad (Eq = 3)$$

Cancer hazard (HQ carcinogenic) linked to intake contact was calculated by means of the subsequent formula [22]

$$\text{R} = \text{CDI} \times \text{SF} \quad (\text{Eq} = 4)$$

Where R is the surplus probability of developing cancer over a lifetime as a consequence of exposure to a chemical. According to the USEPA, Risk (R) value above than one in a million ($10^{-6}$) is considered intolerable [23]. On the contrary, this recommended value could change and possibly as elevated as 10−4 [24][25]. SF is a slope factor of a carcinogen and RfD is the reference dose of analyst were obtained from USEPA (Table 2). HQ values higher than 1.00 indicate potential for adverse health effect on human health.

| **Element** | **RfD dermal (µg/kg/day)** | **RfD ingestion (µg/kg/day)** | **Kp (cm/hour)** |
|---|---|---|---|
| Ni | 5.4 | 20 | 29E-4 |
| As | 0.123 | 0.3 | 1.00E-3 |
| Cd | 0.005 | 0.5 | 1.10E-0 |
| Cu | 12 | 40 | 19E-3 |
| Co | 0.003 | - | 49E-4 |
| Cr | 0.015 | 3 | 29E-3 |
| Fe | 45 | 300 | 19E-3 |
| Mn | 0.8 | 20 | - |

**Table 2** Reference dose (Rfd) dermal and reference dose ingestion and permeability coefficient (Kp) for different metals [20][26].

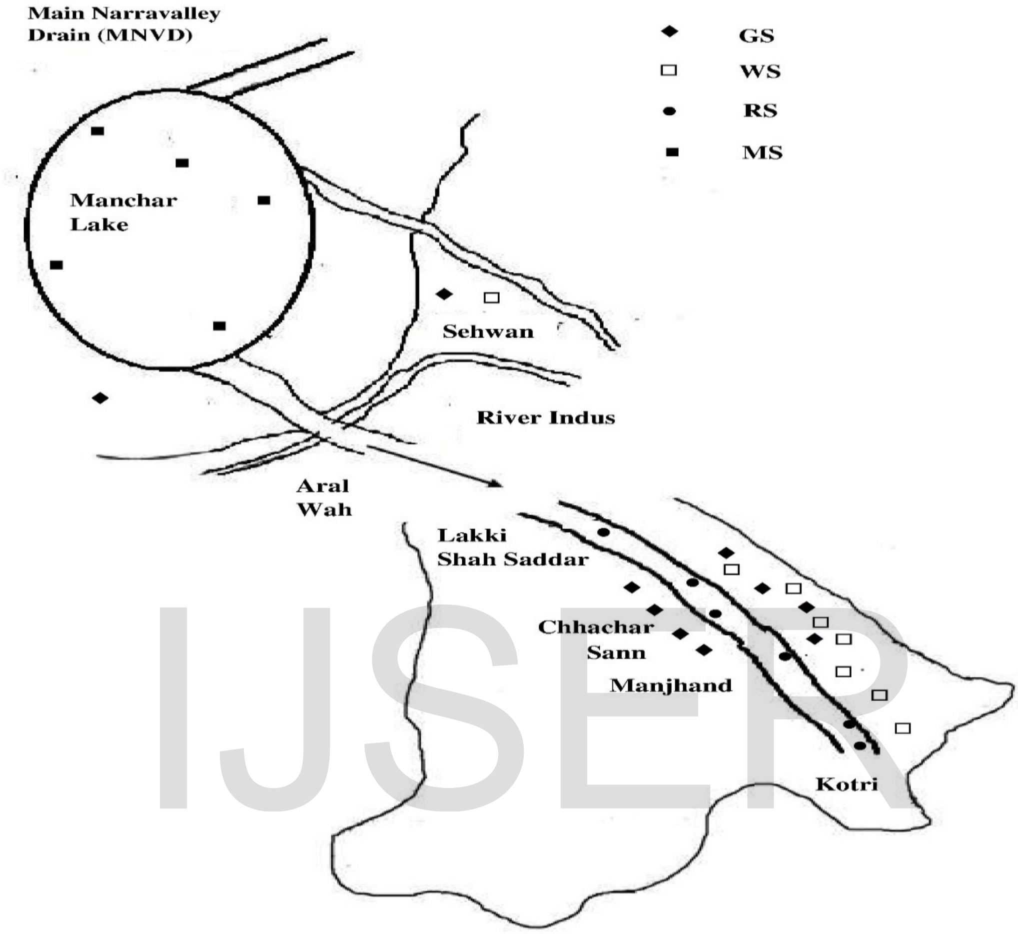


Figure 1. Map showing sampling area (Manchar Lake and Jamshoro district, Sindh)

**Table 1** The full names of abbreviations used in eq. 1 and their values.

| **Abbreviations** | **Parameters and Units** | **Values** | **Reference** |
|---|---|---|---|
| $C_W$ | Metal concentration in water (µg/L) | 0-250 | This study |
| BW | Adult body weight (Kg) | 70 | [20] |
| BW | Child body weight (Kg) | 15 | |
| ED | Exposure duration (Adult) | 70 | |
| ED | Exposure duration (Child) | 6 | |

ISSN 2229-5518

| | | | |
|---|---|---|---|
| EF | Exposure frequency (events/year) | 365 | [26] |
| SA | Skin-surface area (cm2) | 18000 | [20] |
| SA | Skin-surface area (cm2) | 6600 | [27] |
| CF | Conversion factor (L/cm3) | 1/1,1000 | |
| AT | Average time (days) | 25,550 | [26] |
| AT | Average time (days) | 2,190 | |
| AbSd | Dermal absorption factor | 0.001 (for As 0.03) | [23] |
| IR | Ingestion rate (L/day) | 2.2 | [26] |
| ABSg | gastrointestinal absorption factor (%) | 100 | |

## Results and Discussion

### Trace Metal concentration:



Arsenic (As) is a carcinogen occurs in the drinking water, resulting from both human activities and geogenic sources [28][29][30]. Arsenic contamination has become a serious public health problem in Bangladesh, China, India, Myanmar, Vietnam including Pakistan [31]. The WHO standard values for arsenic in drinking water is 10 ppb(µg/l).In this study, The maximum concentration of arsenic was 250 ppb and minimum concentration was 5 ppb in Phase-I, while maximum concentration in phase-II was 500 ppb and minimum concentration was 5 ppb (Table 3). These results are in accordance with the results previously reported from Matiari Sindh [32], Johi, Sindh [14] and Dighri, Sindh [15].In a recent study, arsenic concentration of 96µg/L in groundwater and 157 µg/L in surface water (Manchar Lake, Sindh) has been documented [33].International Agency for Research on Cancer(IARC) classified arsenic as a Category 1 carcinogenic agent for humans, involved in skin, bladder and lung cancers [34](IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2004). The chronic exposure to inorganic arsenic is linked to metabolic and cardiovascular disorders [35][36][37]. These health effects have mostly been observed in communities exposed to elevated arsenic concentration in drinking water [38].

Cadmium (Cd) is a toxic metal and has no any beneficial role in human health. It is called the “pseudo-macho” or the “violent” or the “lethal” metal because severe health problems are associated with it [12].The normal WHO limit for Cd concentration in drinking water is 0.003 mg/L. The maximum concentration of cadmium was 25.38 ppb and 462.8 ppb in Phase-I and Phase-II, respectively. The minimum concentration was not detectable in Phase-I and 1.47 ppb in Phase-II samples. Similar results were reported in previous studies in which high level of cadmium was found in ground water samples of Khyber Pakhtunkhwa and Sindh compared to Punjab province of Pakistan [39].In Khairpur district of Sindh, cadmium concentration in drinking water detected above the WHO permissible limit in 38 samples out of 68 samples [12]. The cadmium exposure can cause both acute and chronic health problems in humans. Cadmium is classified as category 1 carcinogenic to humans by IARC, associated with lung, kidney and prostate cancer [40]. Long term exposure to cadmium leads to kidney, lungs, skeletal damage and itai itai disease [41][42].

Cobalt (Co) is an important metal for the normal body functions as it is a part of Vitamin B12, which is essential for human health. It is relatively low in concentration in drinking water. It is found in nature usually together with other metals like arsenic and nickel. There is no health-based recommended value for cobalt in drinking water established by the WHO [25]. This may be due to the relatively low concentration of cobalt in drinking water. According to Wisconsin Department of Natural Resources, the maximum contamination level of cobalt in drinking water is 40 µg/L [43]. No permissible limit for cobalt set by PCRWR, however, cobalt limit in drinking water in New Zealand is 1000 µg/L [44]. The estimated average daily intake of cobalt from food is 5–40 µg/day, most of which is inorganic cobalt. Several research papers reported the recommended value of cobalt concentration in drinking water is 0.1 mg/L (except for Radioactive Cobalt) and claimed to be declared by US EPA, however, the source or reference of this information is relatively poor (Information Protected). In this study, cobalt concentration of water samples was found between 45 ppb and 823 ppb in Phase-I, and 2.7 ppb and 814 ppb in Phase-II. In a previous study, the concentration of Cobalt in Manchar Lake was noted up to 7 µg/L and 4.5 to 9.5 µg/L in the month of August and November 2011 [45]. In groundwater of Taluka Nawabshah, Sindh, Cobalt concentration of water samples was found between 0 and 33 µg/L [46]. The cobalt is essential for normal body functions with no any health hazard, however, over consumption of cobalt via drinking water or food may cause thyroid, lung, heart problems [47].

Copper (Cu) is an important element for human health and plays an important role in both plant and animal life. It is a component of many metalo-enzymatic reactions and respiratory pigments. For drinking water WHO set maximum acceptable concentrations of

1000µg/L for copper. The recommended dietary allowance (RDA) for adults is 0.9 mg/day. Copper concentration was higher in samples of Phase-II as compared to Phase-I. The maximum concentration of copper was 1076 ppb and 2368 ppb in Phase-I and Phase-II, and the minimum concentration was 24 ppb and 74 ppb in samples of Phase-II and Phase-II, respectively. The samples of phase-II were highly contaminated in case of copper compared to Phase-I. In a study conducted previously in the Manchar Lake, the copper concentration ranged from 90-105 µg/L in August 2011, and 92-117 µg/L in the month of November [45]. Increased consumption of copper can cause anemia, liver and kidney damage, and stomach and intestinal irritation [48] [25].

Iron (Fe) is an essential element for the normal physiology of living organisms and it's a component of a number of proteins including hemoglobin and enzymes. In drinking water, it's present as Fe2+, Fe3+ in suspended form. WHO has set a guideline value of 300 µg/L for iron in drinking-water. However, according to National Environmental Quality Standards-Pakistan, the permissible range of iron in waste water is 8 mg/L [49]. The concentration of iron during this study ranged between 140ppb and 30 ppb in the month of August and 8476 and 29 ppb in the month of November. Iron is one of the major contaminants in surface and ground water of Pakistan. PCRWR reported I country-wide study that 28% of ground water samples and 40% of surface water samples were contaminated with iron beyond permissible limit [50].A study reported 4.28 mg/l of iron in water from Jamshoro, Sindh, whereas the concentration of iron in this study found double than this which may be due to the post monsoon water burden [51]. This elevated concentration of iron in drinking water could pose a possible risk for the local residents' health. Iron overexposure is less common in compared to iron deficiency, but higher concentration than permissible value can cause serious health problems including cancer, neurodegenerative disorders, diabetes, liver and heart diseases [52][53][54][55].

Manganese (Mn) is an important element for normal body functions and plays important role in bone mineralization, carbohydrate, protein, and energy metabolism. WHO permissible limit for manganese in drinking water is 500 µg/L. In the present study, manganese concentration ranged from undetectable to 1200 µg/L in water samples of Phase-I and 21 to 4700 µg/L in samples of Phase-II. The concentration of manganese in drinking water was much higher in samples of post monsoon compared with pre-monsoon samples.The high level of manganese (2.56 mg/L) in ground water samples was reported from Khyber Pakhtoonkhwa, Pakistan and 1060µg/L in water samples from Faisalabad, Punjab [56]. However, the majority of studies in Pakistan revealed manganese concentration within safer limits in drinking water [39]. The excess amount of manganese consumption can cause neurological disorder with symptoms similar to those of Parkinson's disease [57][58].

There is no proven beneficial role of nickel (Ni) in the human body but beneficial roles of nickel-containing enzymes have been reported in plants and microbes led to its classification as trace element that is “possible” essential by WHO in 1996. The maximum permissible level of nickel in drinking water set by WHO is 20 µg/L. In the present study, the nickel concentration ranged from 10.49 µg/L to 296 µg/L and 2.9 µg/L to 835 µg/L in samples of Phase-I and Phase-II, respectively. Midrar-Ul-Haq reported the elevated concentration of nickel in ground water samples from Karachi (0.01–2.19 mg/L) and around 75% of surface water samples from Karachi exceeded the USEPA permissible level for Nickel [56]. According to IARC, Nickel is classified as group 1 carcinogen and can cause pulmonary, and paranasal sinuses and nasal cavity cancers [34].

Zinc (Zn) is an essential micronutrient for normal body growth and reproduction [59]. The human body contains 2-3 g of zinc with the highest percentage (up to 90%) in muscles, liver, kidneys, bones and prostate [60]. The levels of zinc measured in all the samples of Phase-I and except two samples of Phase-II were below the WHO limit of 3000 µg/L. The zinc concentration ranged from 2000 to 3000 µg/L and 2300 to 3200 µg/L in the month of August and November 2011 in samples of Manchar lake reported previously [45]. Another study reported conflicting data showing a higher Zn concentration of 4.02 mg/L in Karachi [61]. The chronic/high intake of zinc may cause acute gastrointestinal effects and headaches, impaired immune function, changes in lipoprotein and cholesterol levels, reduced copper status, and zinc-iron interactions [62].

**Table 3**Level of trace metals in water in Phase-I and Phase-II, and standards of drinking water [63][64].

| Trace metals | WHO standard | USEPA standard | Phase I | | Phase II | |
|---|---|---|---|---|---|---|
| | | | Minimum | Maximum | Minimum | Maximum |
| | 10 | 10 | 5 | 250 | 5 | 500 |
| Cadmium | 3 | 5 | 0 | 25.38 | 1.47 | 462.8 |
| Cobalt | - | - | 45 | 823 | 2.7 | 814 |
| Copper | 2000 | 1300 | 24 | 1076 | 74 | 2368 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Zinc | 3000 | 5000 | 5 | 2210 | 3 | 3429 |
| Nickel | 20 | - | 10.49 | 296 | 2.9 | 835 |
| Manganese | 500 | 50 | 0 | 1200 | 21 | 4700 |
| Iron | 300 | 300 | 30 | 140 | 29 | 8476 |

*Health Risk Assessment of trace metals Via Drinking Water*

Health quotient (HQ) is a probabilistic chronic measurement of heavy metals by a certain formula that shows health impacts on the consumer of contaminated water. Table 4 shows the health risk assessment of trace metals in terms of HQ chronic for the residents who were exposed to the intake of metals-rich water. The drinking water sources available to the residents in the study area were analyzed for the potential health risk assessment through exposure assessment and risk assessment. HQ chronic (non-carcinogenic) for arsenic was observed above than the normal value (HQ <1) in 18 samples (1 MS, 5 RS, 6 WS and GS) of Phase-I and 13 samples (2 MS, 3 RS, 8 GS) of Phase-II. HQ data explains the contamination burden of flood water in terms of arsenic reflecting health concerns on local residents. HQ chronic for cadmium, manganese, and nickel was within the normal limit in all sample sources in both phases. HQ chronic for copper was within the permissible limit in all samples sources of Phase-I and except 2 samples of GS, all samples of Phase-II were in the normal range. HQ chronic for iron was higher in 12 samples (3 MS, 2 RS, 1 WS and 6 GS) from Phase-I and except 3 samples (2 MS and 1 GS), all samples of Phase-II were within permissible range.

The Carcinogenic risk is defined as the incremental probability of an individual developing cancer as a consequence of exposure to the chemical during one's lifetime under specific scenarios [65][66]. Carcinogenic risk assessment of arsenic was higher in 24 samples of Phase-I and 26 samples of Phase-II than the safe limits of $10^{-6}$ (Normal tolerable value of R by USEPA 2005). However, If the normally tolerable limit is considered $10^{-4}$ then 12 samples from Phase-I and 13 samples from phase-II were above this limit, in the study area. Carcinogenic risk of arsenic in several samples of different sources is an alarming and threatening indication for the residents who are exposed to water contaminated by arsenic. In a study conducted previously, HQ non-carcinogenic for arsenic was higher in 19% of the population and HQ carcinogenic risk was above than $10^{-4}$ for 46% and $10^{-6}$for 90% of the population of Izmir, Turkey [67]. Whereas in this study, carcinogenic risk was above than $10^{-}$

$^{6}$ for 70% of the population in August season and 76% of the population in November, and carcinogenic risk was above than $10^{-4}$ for 35% of the population in August season and 38% of the population in November in the study area (Table 5).

Health impact of trace metals observed more serious during the post-flood condition than during the flood. Hazard quotient (oral) of arsenic showed 60 % and 100% of samples crossed unity (HQ) for 70 kg and 15 kg, respectively. HQ oral of iron observed 50 % and 90% of samples crossed permissible limit for 70 kg and 15 kg. HQ oral of cadmium and nickel was within safe limits in Phase-I for both weights, whereas higher than safe limits in Phase-II samples for both weights. In the case of Cobalt, zinc, and copper, all samples were within the safe limits for both weights.

HQ dermal of all water sources irrespective of location, phase and metal observed less than HQ<1 for an adult but HQ for the child was observed closer to the unit that indicates possible health concern in future if the condition remained same in the drinking water sources (Table 6). In previous studies in Johi and Karachi, Pakistan and Nanjing, China, HQ dermal suggested that analyzed pollutants could pose a minimum hazard to the local residents was consistent with the findings of this study [68][14][19].



**Table 4** Health Quotient on carcinogenic (Risk assessment by ingestion pathway)

| Phase I | | As | Cd | Cu | Fe | Mn | Ni |
|---|---|---|---|---|---|---|---|
| MS | Max | 9.95E-01 | 0.00E+00 | 0.00E+00 | 2.43E+00 | 0.00E+00 | 0.00E+00 |
| | Min | 9.95E-01 | 0.00E+00 | 2.87E-02 | 1.69E-01 | 0.00E+00 | 6.59E-04 |
| RS | Max | 2.49E+00 | 0.00E+00 | 0.00E+00 | 5.07E+00 | 0.00E+00 | 0.00E+00 |
| | Min | 9.95E-01 | 0.00E+00 | 2.15E-02 | 5.24E-03 | 0.00E+00 | 6.29E-04 |
| WS | Max | 4.98E-01 | 0.00E+00 | 0.00E+00 | 2.85E+00 | 0.00E+00 | 0.00E+00 |
| | Min | 9.95E-01 | 0.00E+00 | 2.69E-02 | 3.14E-02 | 0.00E+00 | 2.45E-03 |
| GS | Max | 2.49E+01 | 0.00E+00 | 0.00E+00 | 1.46E+01 | 0.00E+00 | 0.00E+00 |
| | Min | 9.95E-01 | 3.99E-02 | 9.2E-08 | 5.6E-06 | 7.54E-02 | 1.38E-06 |
| Phase-II | | | | | | | |
| MS | Max | 2.49E+00 | 1.03E-01 | 0.00E+00 | 1.23E+00 | 0.00E+00 | 1.35E-02 |
| | Min | 0.00E+00 | 3.36E-01 | 0.00E+00 | 1.15E-01 | 2.56E-02 | 3.64E-03 |
| RS | Max | 4.98E+00 | 1.15E-01 | 0.00E+00 | 2.83E-02 | 0.00E+00 | 1.47E-02 |
| | Min | 4.98E-01 | 7.54E-02 | 7.70E-02 | 8.12E-02 | 7.17E-02 | 8.55E-04 |

ISSN 2229-5518

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| WS | Max | 0.00E+00 | 1.18E-01 | 0.00E+00 | 2.10E-02 | 0.00E+00 | 1.09E-02 |
| | Min | 4.98E-01 | 2.31E-03 | 9.48E-01 | 4.71E-02 | 0.00E+00 | 1.82E-04 |
| GS | Max | 4.98E+01 | 1.41E-01 | 1.15E+00 | 3.42E+00 | 0.00E+00 | 0.00E+00 |
| | Min | 9.95E-01 | 6.31E-02 | 9.94E-02 | 1.10E-01 | 1.32E-03 | 5.66E-04 |

**Table 5** Carcinogenic Health Quotient Risk Assessment of Arsenic

| Cancer Risk Arsenic | | Phase I | Phase II | Cancer Risk Arsenic | | Phase I | Phase II |
|---|---|---|---|---|---|---|---|
| Sr.No | Station | BW 70 HQ | | Sr.No | Station | BW 70 HQ | |
| 1 | M1 | 4.49E-04 | 1.12E-03 | 18 | WS5 | 4.48E-04 | 2.24E-04 |
| 2 | M2 | 4.48E-04 | NC | 19 | WS6 | 4.48E-04 | 2.24E-04 |
| 3 | MC1 | 4.48E-04 | 0.00E+00 | 20 | GS1 | 4.48E-03 | 4.48E-03 |
| 4 | MC2 | 2.24E-03 | 1.12E-03 | 21 | GS2 | 0.00E+00 | 0.00E+00 |
| 5 | RS1 | 2.24E-03 | 2.24E-04 | 22 | GS3 | 0.00E+00 | 0.00E+00 |
| 6 | RS2 | 2.24E-03 | 2.24E-03 | 23 | GS4 | 0.00E+00 | 0.00E+00 |
| 7 | RS3 | 2.24E-03 | 2.24E-04 | 24 | GS5 | 0.00E+00 | 0.00E+00 |
| 8 | RS4 | 0.00E+00 | 1.12E-03 | 25 | GS6 | 1.12E-02 | 1.12E-02 |
| 9 | RS5 | 2.24E-04 | 0.00E+00 | 26 | GS7 | 1.12E-02 | 2.24E-02 |
| 10 | RS6 | 1.12E-03 | 1.12E-03 | 27 | GS8 | 2.24E-03 | 1.12E-03 |
| 11 | RS7 | 4.48E-04 | 2.24E-04 | 28 | GS9 | 4.48E-03 | 4.48E-03 |
| 12 | RS8 | 0.00E+00 | 2.24E-04 | 29 | GS10 | 0.00E+00 | 4.48E-03 |
| 13 | RS9 | 1.12E-03 | 2.24E-04 | 30 | GS11 | 0.00E+00 | 1.12E-03 |
| 14 | WS1 | 4.48E-04 | 2.24E-04 | 31 | GS12 | 2.24E-03 | 1.12E-03 |
| 15 | WS2 | 4.48E-04 | 2.24E-04 | 32 | GS13 | 0.00E+00 | 0.00E+00 |
| 16 | WS3 | 4.48E-04 | 2.24E-04 | 33 | GS14 | 0.00E+00 | 2.24E-04 |
| 17 | WS4 | 2.24E-04 | 2.24E-04 | 34 | GS15 | 4.48E-04 | 4.48E-04 |

**Table 6** Maximum Health Quotient (Dermal)

| HQ dermal | Phase I (Adult) | Phase II (Adult) | Phase I (Child) | Phase II (Child) |
|---|---|---|---|---|
| Cd | 4.16E-04 | 1.23E-03 | 1.23E-03 | 1.03E-02 |
| As | 1.82E-03 | 1.82E-03 | 1.07E-02 | 1.07E-02 |
| Mn | 1.34E-05 | 1.23E-05 | 6.60E-04 | 1.08E-03 |
| Ni | 1.37E-06 | 1.17E-06 | 1.71E-05 | 1.04E-05 |

| | | | | |
|---|---|---|---|---|
| Zn | 1.83E-03 | 1.25E-03 | 1.37E-03 | 1.16E-02 |
| Cu | 1.34E-05 | 1.23E-05 | 1.10E-06 | 1.16E-05 |
| Fe | 1.29E-06 | 1.17E-05 | 1.39E-05 | 1.02E-04 |

**Conclusion:**

This study showed a large variation in contamination and frequency of trace metals concentration in water samples of Phase-I and Phase-II. Phase wise variation revealed that samples of Phase II were highly contaminated as compared to Phase-I. As, Cd, Cu, Zn, Ni and Mn concentration was higher in Phase-II as compared to Phase-I except for Co. The concentrations of the trace metals were found to be in the order Zn (2210ppb) >Cu (1076 ppb) >Mn (1200 ppb) >Co (823 ppb) >Ni (296 ppb) >As (250 ppb) > Fe (140 ppb) Cd (25.38 ppb) in Phase-I and Fe (8476 ppb) >Mn (4700 ppb) > Zn (3429 ppb) > Cu (2368 ppb) > Ni (835 ppb) > Co (814 ppb) > As (500 ppb)> Cd (462.8 ppb)in Phase-II, respectively. For health risk assessment, HQ non-carcinogenic for As was above than USEPA recommended value (*i.e.*, 1.00) in 18 samples of Phase-I and 13 samples of Phase-II, respectively. HQ chronic for iron was higher in 12 samples from Phase-I and except 3 samples, all samples of Phase-II were within normal range. HQ chronic for cadmium, manganese, and nickel was within the normal limit in both phases.HQ chronic for copper was within the normal limit in all samples sources except 2 samples from Phase-II.The cancer risk was above than USEPA recommended value ($10^{-6}$) for 70% and 76% of the population in August and November season, respectively. HQ oral of arsenic crossed recommended value in 60% and 100% samples for 70 kg and 15 kg weights and HQ oral of iron showed 50% and 100% samples beyond unity for 70 kg and 15 g weights. HQ oral of Cd and Ni was within normal range in Phase-I for both weights and above normal in Phase-II for both weights. HQ oral of cobalt, zinc and copper, all samples were within the recommended value for both weights. However, HQ dermal of all metals observed less than HQ<1 in both phases for adult and child. The results of this study show that consumption of metals-contaminated water poses an emerging health threat to the communities in the study area, and hence the study demands the urgent need for remedial and management measures during pre and post-monsoon periods.

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