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Arsenic Contamination in Drinking Water of District Jamshoro, Sindh, Pakistan

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Abstract
(As) as a carcinogenic involved in disease ratio it becomes a threat for the normal life. In Sindh, Pakistan, ground water become contaminated with the arsenic in large scale. Present study was conducted to reveal present situations of water toxicology Risk of metals on human health was evaluated in this study using Hazard Quotient (HQ) of Arsenic, phase wise variation revealed contamination variation with adverse potential health effects and carcinogenic risk of As was found higher than 10^{-6}. In ours study even surface water was found contaminated with arsenic more than World Health Organization (WHO) permissible limit with ground water as well, which is alarming situation for the living communities which relies on surface water and ground water for drinking purposes, which can have potential adverse health effect on local residents of district Jamshoro, Sindh, Pakistan. In our study finding all examined parameters found increased in Phase 2 than Phase 1 as well as Health quotient of Arsenic Chronic and Carcinogenic which may be overcome by maintain upper stream flow of river and gates regulation of Manchar Lake Regulators.

Keywords: Arsenic contamination, cancer risk, ground water, hazard quotient.

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Introduction

Drinking water pollution is one of the most severe environmental problems worldwide. Elevated metal concentration in water supplies may pose a risk of adverse effect on human health. Ingestion of water containing significant amounts of metals may cause serious health effects varying from shortness of breath to several types of cancers in human beings [1].

Arsenic (As) is recognized as a big threat to public health in many countries like Bangladesh, India, China, Vietnam, Nepal and Myanmar [2]. In Sindh, Pakistan, 16–36% of population has been exposed to As contaminated water with over 10–50 ppb [3]. Lake Manchar (Sindh, Pakistan) is a biggest Asian lake and main source of water for domestic, irrigation and fishing purposes. The Main Nara Valley Drain (MNVD) is a most important source of As enrichment in this lake, as reported in previous work [4].

Arsenic exposure has been related to the appearance of some types of cancer. Arsenic is a known carcinogen in humans, causing lung, liver, skin and bladder cancer [5].The most serious sources of As pollution include emissions and wastewater of the ore mining and processing industry, dye manufacture facilities, tanneries, thermal power plants, and application of certain insecticides, herbicides and pesticides [6]. The situation is further aggravated as some areas have a contamination of above 50µg/L and in Sindh, Pakistan even exceeds 200µg/L (see at: http://www.pcrwr.gov.pk/Arsenic_CS/ACS_TOC.htm)[7].

In present study arsenic reaching 96 µg/L in ground water and 157 µg/L in surface water (Manchar Lake, Sindh) has been documented [8]. The aim of this study was to understand the arsenic contamination of drinking water (both ground and surface water) of district Jamshoro, Sindh, Pakistan.

Material and Methods

The study stretched from Manchar Lake to Jamshoro city in Sindh province of Pakistan, along with the Indus Catchment through Indus Highway, approximately the distance covering more than 160km area. Samples were collected from selected villages and major populated areas of Sehwan Sharif, Lucky Shah Saddar, Aamri, Chhachhar, Sann, Manjhand, Jamshoro and Kotri (Sindh, Pakistan).

A total of 67 samples were collected in two phases (August 2013, November 2013) with gap of three month. Phase 1 was collected in flood season. Water samples were collected from Manchar Lake, Cannals, River, Water Supply Schemes and Ground water and analyzed at Institute of Biochemistry and Hi-Tech Research Laboratory, University of Sindh, Jamshoro, Sindh, Pakistan. The detail of sources and number of samples is given in **Table 1**.

Arsenic was measured with HACH Arsenic kit (EZ arsenic test kit 2822800) Hach Company USA for 0.01-0.5 mg/L. This test generates arsenic hydride which reacts with the mercury bromide present in the analytical strip to form a yellow brown mixed arsenic Mercury halogenide. The concentration of arsenic was measured by visual comparison of the reaction zone of the analytical test strip with scales of fields of color [9].Electric conductance (EC), total dissolved salts/solids (TDS) and pH measured by conductivity and pH Meter, while as, appearance, color and odor was identified physically by sensing.

Table 1: Sources and Number of water samples in Phase 1 and Phase 2

Sr. No	Sources	Phase 1	Phase 2
1	Manchar Lake & Canals	2	1
2	Water Supply Schemes	6	6
3	Indus River	7	10
4	Ground water sources	11	15

Sampling and pretreatment

The sampling network was designed to cover a wide range of determinates of the whole district including surface and ground water origins. From each sampling site, fresh surface water samples, river (RS) municipal water (WS), Manchar lake samples (MS) and (GS) ground water samples were collected. The collection of samples was performed by using sterilized Van Dorn plastic bottles (1.5 L capacity) and were kept in well-stoppered polyethylene plastic bottles previously soaked in 10% nitric acid for 24 h and rinsed with ultrapure water. All water samples were stored in insulated coolers containing ice and delivered on the same sampling day to the laboratory for analysis.

Exposure assessment

Through several pathways including food chain, dermal contact and inhalation arsenic enters into human body but all others are negligible in comparison with oral intake [10]. According to following formula [11], the average daily dose (ADD) through drinking water intake was calculated.

$$ADD = C \times IR \times ED \times EF/BW \times AT$$

Where C represents the As concentration in water (lg L^{-1}), IR water ingestion rate (L day^{-1}), ED exposure duration (assumed 67 years), EF exposure frequency (365 days/year), BW body weight (70 kg) and AT average life time (24,455 days), respectively.

Human health risk assessment

Both the chronic and carcinogenic risk levels were also assessed in this study, by the following equation [12] generally, the HQ can be calculated.

$$HQ=ADD/RfD$$

When the HQ values are>1 the health risk generally occurs [13]. Reference Dose (RfD) of different metals is given in **Table 2**.

Using the following formula cancer risk (CR) was calculated.

$$CR = ADD \times CSF$$

Cancer slope factor (CSF) for As is 1.5 mg kg^{-1} day^{-1}, according to U.S. EPA (2005) database, greater than one in a million (10^{-6}) CR value was generally considered significant [14]. However, according to the national standards and environmental policies this standard may change [15,16].

Table 2: Reference dose for different metals [17, 18]

Sr. No	Element	RfD mg/kg/day
1	Cu	0.04
2	Fe	0.3
3	Mn	0.02
4	Ni	0.02
5	As	0.0003
6	Cd	0.0005
7	Co	0.003
8	Zn	0.3

Results

In the physical parameters samples were un-objectionable except some ground water and Manchar lake samples which were slightly saline. Some riverine samples were found with unpleasant smell where there sewerage system was closed with source of drinking. River and water supply scheme samples were mostly turbid in color in both phases.

Electric conductance (**Figure 1**) increased in phase 2 compared to phase 1 except Manchar lake samples and from canals which are linked with it. EC have also been found increased in Sehwan water supply scheme as compare to others because it is closer one and first one water supply scheme from Manchar lake, which also indicate impacts of Manchar lake effluents. Manchar lake sample shows high EC in phase one than phase two due to its outlets were closed at that time in flood conditions. Sample number shows variation in phase and support previous statement that due to the gate closed sample taken from initial inters of lake in river showed less EC as compare to when outlets of Manchar Lake were open. Remaining Ground water samples shows also variation with the time.

TDS stands for total dissolved salts/solids, WHO normal range of TDS is 1000mg/L. According to analysis in which first four samples related to Manchar lakes have high concentration in phase 1 than phase 2 (**Figure 2**). Studies have demonstrated that TDS correlates with water flow [19,20] but sample from Aral Wah (canal) and Sehwan river indicates high concentration in phase 2 as all other samples from rivers and water supply schemes indicates due to open of Manchar regulating canals toward Indus river that's why sample from water supply scheme of Sehwan also indicates variation in phase 2as compared to phase 1. TDS of ground water samples also varies with the climate change and source which is close to lake indicates high concentration of TDS, it means ground water source have also been contaminated with the lake water near to lake surroundings.

Salinity is measurement of salts present. According to comparison of both phases, phase 1 (**Figure 3**) was found less contaminated because of heavy flow of water and lake effluents gates were closed that's why Manchar samples shows more salinity in sample 1.Because, source discharge of pollutants were closed same like water supply scheme samples have been found normal in phase 1 but in phase 2 gates were open that's why lakes discharging its contamination in river resulting in salinity increased much more in phase2. From the point where lake water meets with river which also puts effects on water supply scheme of Sehwan found more salinity than phase 1 same like ground water sources near to lake. Village MolaBux have been found more contaminated as compare to those which are away from the lake. Different variations in ground water samples have been observed because of the aquifers.

pH stands for power of Hydrogen, normal WHO range of water is 6.5 to 8.5, which observed higher in phase I (**Figure 4**) than phase 2 but in normal range, which might be due to the short flow of water in phase 2. Samples from Manchar Lake showed slightly more in phase 1 because highly storage of water in lake and gates were closed in flood conditions. Samples from water supply schemes showed fluctuation in between 6 to 7 pH in both phases, pH in ground water samples also showed same kind of trend.

Turbidity is a measure of the cloudiness of water. It was used to indicate water quality and filtration effectiveness (such as whether disease-causing organisms were present). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, and diarrhea. Phase 1 as taken in flood season that's why it is showing more turbidity (**Figure 5**) than Phase 2, except, ground water samples in both phases due to filters installation in Hand Pumps and no any direct impact of flood water on them. WHO permissible limit is less than 5 NTU, in both phases, all surface water samples found highly turbid which may cause reason of diseases

Table 3: Phase wise health quotient and average daily dose of arsenic

As	Phase # 1		Phase # 2		Phase # 1		Phase # 2	
	BW 70 HQ				BW ADD 70 kg mg/kg-d			
Sample station	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**
M & MC	9.52E-01	4.76E+00	0.00E+00	2.38E+00	2.86E-04	1.43E-03	0.00E+00	7.14E-04
RS	9.52E-01	4.76E+00	4.76E-01	4.76E+00	7.14E-04	1.43E-03	7.14E-04	1.43E-03
WS	4.76E-01	9.52E-01	4.76E-01	4.76E-01	1.43E-04	2.86E-04	1.43E-04	1.43E-04
GS	9.52E-01	2.38E+01	9.52E-01	2.38E+01	2.86E-04	1.43E-03	7.14E-04	1.43E-02

Table 4: Carcinogenic Health Quotient of arsenic

Cancer Risk As	Phase # 1		Phase # 2		
	BW 70 HQ				Normal HQ
Sample Station	**Minimum**	**Maximum**	**Minimum**	**Maximum**	
M &MC	4.29E-04	2.14E-03	2.14E-04	1.07E-03	10^{-6} - 10^{-4}
RS	4.29E-04	1.07E-03	2.14E-04	1.07E-03	
WS	4.29E-04	1.07E-03	2.14E-04	4.29E-03	
GS	4.29E-04	1.07E-02	4.29E-04	1.07E-02	

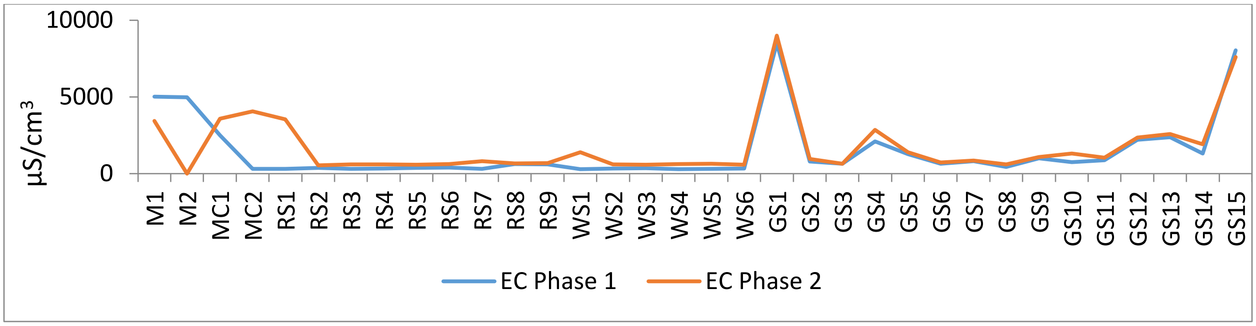

Figure 1: Comparison of electric conductance between phase 1 and phase 2

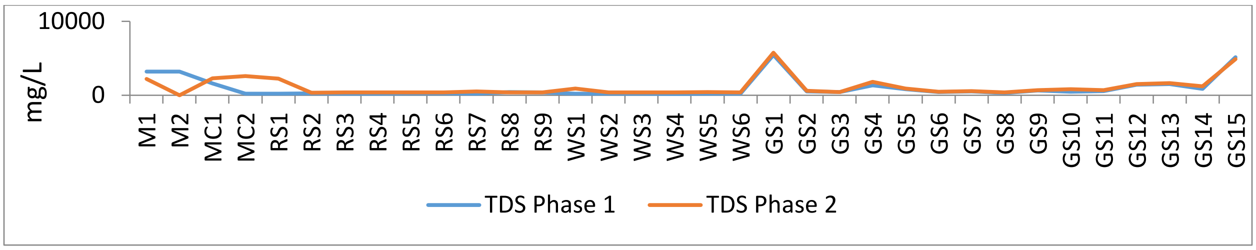

Figure 2: Comparison of total dissolved solids between phase 1 and phase 2

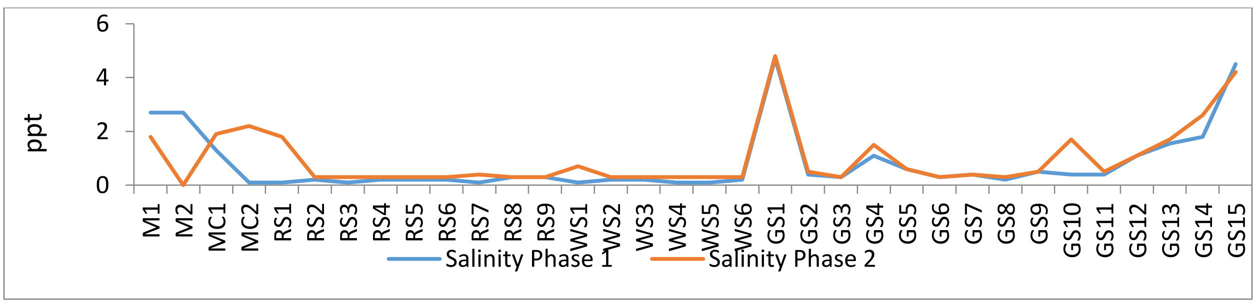

Figure3: Comparison of Salinity between phase 1 and phase 2

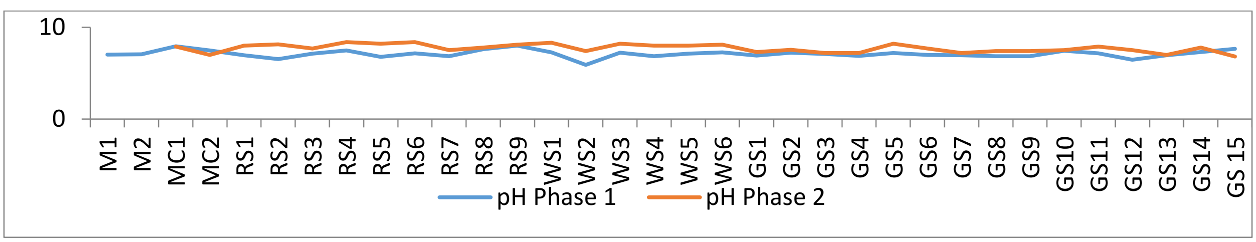

Figure4: Comparison of pH between phase 1 and phase 2

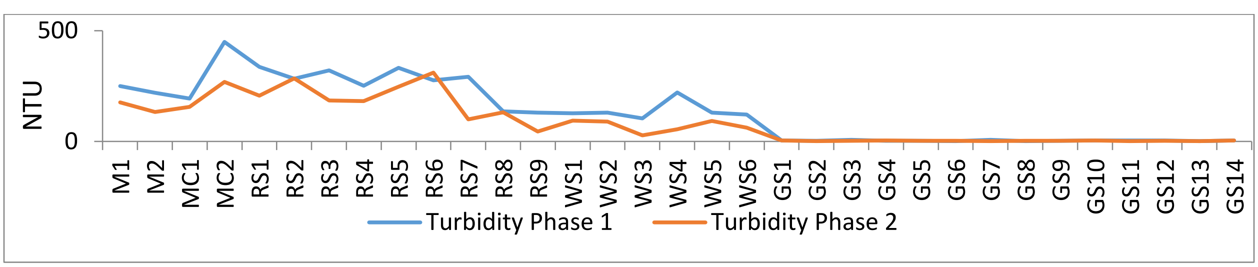

Figure5: Comparison of turbidity between phase 1 and phase 2

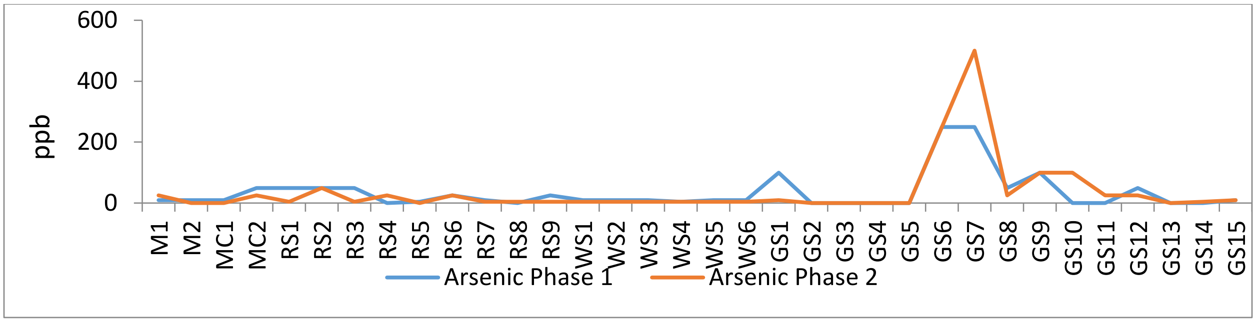

Figure 6: Comparison of Arsenic between phase 1 and phase 2

Discussion

WHO standard of arsenic is 10 ppb (μg/L). Arsenic cause a decrease in white and red blood cells production, gastrointestinal irritation, disrupt the heart rhythm, damage blood vessels and cause "pins and needles" sensation in hands and feet. Long time exposure to arsenic can cause melanosis, leukomelanosis, hyperkeratosis, cardiovascular disease, black foot disease, neuropathy and cancer. Phase 1 during flood season shows more concentration of arsenic which may be due to flood's water was rich of arsenic. Aral Wah (gates of lake were closed) showing 50 ppb in stagnant remained water of lake, Sehwan, Lucky Shah Saddar, and Aamri and Sann River analyzed to carrying arsenic content more than normal WHO limit which shows itself flood contamination, water supply schemes shows 10ppb of arsenic which is impact of river water itself. Few ground water samples found highly contaminated in those villages, there was no any source of drinking rather than that which may be due to nature of aquifer or specially indicated more in closer to Lake Source like village MolaBux. In Phase 2, Manchar sample shows more contamination of arsenic than phase 1 because during phase 1 MNVD was closed due to flood conditions. In 1995, Manchar lake arsenic contamination found zero [21], but in 2008 researchers found it in 97.5-28.9ppb [4] which shows fluctuation of contaminations during different periods. Danastar and Aral Wah (canal) showing amount of arsenic more than WHO Limit. River samples like Manchar-River link, Lucky Shah Saddar which is second station of river consuming water after Sehwan carrying same amount of arsenic and also indicated from Dari Gaincha, Sann River and Karachi canal as well. Arsenic 5ppb also found in all water supply schemes which shows impacts of river water on house hold consumers. Arsenic identified in ground water samples as well from some stations which may be due to the nature of aquifer. Arsenic concentrations in surface and underground water range from 3.0 to 50.0, and 13 to 106 $\mu g\ l^{-1}$, respectively. In most of the water samples As levels exceeded the WHO provisional guideline values 10 $\mu g\ l^{-1}$[22]. Research work found in surface water samples phase 1, 5 to 50$\mu g\ l^{-1}$ and phase 2 (Fig-6)25-5$\mu g\ l^{-1}$, respectively, which shows seasonal variation changes in contamination of water. During time change minimum range of arsenic exceeded in our study but maximum range fluctuate with respect to season with respect to previous study. In Ground water samples, arsenic level was 5 to 250$\mu g\ l^{-1}$ in phase 1 and 5 to 500$\mu g\ l^{-1}$ in phase 2, which shows underground water has become more contaminated during time change and with respect to seasonal variations as well. Due to widespread water logging from Indus river irrigation system which causes high saturation of salts in this semi-arid region and lead to enrichment of As in shallow groundwater caused by the high level of As in under study area, from coal combustion at brick factories and power generation plants may be concluded the source to generate As. Due to the alkaline nature of the understudy groundwater samples it becomes a cause to mobilized promotionally. Chronic health impact of arsenic varies with source type and phase wise (**Table 3**), Manchar and its outlet samples Health Quotient is more than one which is not a significant in both phases and ADD of Manchar with its outlet is 2.86E-04 mg/kg-d minimum and maximum is 1.43E-03 mg/kg-d in phase one, phase 2 min ADD is 0.00E+00 mg/kg-d and 7.14E-04 mg/kg-d is max. From the River samples HQ in both phases got more than one which reflects health concerns regarding source of drinking and factors of contamination which are present in its surrounding, ADD minimum is 7.14E-04 mg/kg-d and maximum 1.43E-03 mg/kg-d present in both phases. Water supply scheme samples HQ is less than one in both phases which is a significant sign and reflects decrease impacts of river contamination on water supply, ADD maximum in phase 1 and phase 2 is 1.43E-04 mg/kg-d, minimum 2.86E-04 mg/kg-d maximum respectively. Ground source samples HQ determined more than one in both phases in the maximum range which also raise the concerned about impact of contamination, ADD in both phases varies in minimum range 2.86E-04 mg/kg-d and 7.14E-04 mg/kg-d but maximum range in both phases which is 1.43E-03 mg/kg-d and 1.43E-02 mg/kg-d respectively.

ADD values of current As study were lower than those in Bangladesh drinking water (5.00E-02 – 5.00E-01 mg kg^{-1} day^{-1}) reported in previous study[23] and in Vietnam drinking water (5.00E_03 – 4.39E_01 mg kg^{-1} day^{-1}) [24] but more than Kohistan region northern Pakistan drinking water surface water contaminated with As had ADD values ranged from 0.00 mg/kg-d to 5.61E_05 mg kg^{-1} day^{-1} and while the people who consumed groundwater, had ADD values ranged from (5.50E_07 - 4.64E_04 mg kg_1 day_1)[25]which reflects area wise variations in average daily dose of arsenic with respect to impact on local water drinking communities and involvement of contamination sources.

Cancer Risk (CR) potential of As values varies with the sample source type and phase wise (**Table3**), in our study, results revealed that irrespective to phases and sources type all samples found less than 10^{-6} which shows a potential carcinogenic risk, health risk for the local communities which had been using these sources for the drinking purpose. Reported by Karimand, 2000; Nguyen et al.,2009 and Muhammad et al., 2010 for drinking water in Bangladesh, Vietnam and Kohistan (Pakistan), the CR index of study area was found lower than those reported by this study, which also reflects the area wise burden of contamination [23, 24, 25].

Conclusion

Our studies have shown that in floods condition physical parameters were normal, some samples especially ground water was saline, color of samples was normal except turbidity in fresh water samples, those fresh water sources samples which were closer to sewerage had some smell due to village out lifting impacts. TDS, EC, Salinity, Turbidity, pH found increased in phase 2 than phase 1, when doors were closed of Manchar Regulators even MNVD. In Lake, Arsenic amount was less but surface water sources like river and water supply schemes shows more amount of arsenic but when Manchar Lake's all outlets becomes open. Arsenic in lake itself increased due to open MNVD but less found in river and water supply schemes which may shows that floods water was more contaminated with arsenic concentration. Ground water samples also found contaminated especially those was closer to lake and river which may be due to its seepage and other samples as well which may be due to nature of aquifer or soil. As Health concerns increased in phase 1 reflects its contamination which may be due to lack of fresh water flow in river. Carcinogenic Risk As Health Quotient found beyond the normal range in all the samples than Vietnam, Bangladesh and Kohistan studies which is awakening finding of this study. Bangladesh, Vietnam and Kohistan (Pakistan), CR index of study area was found lower than those reported by this study, which also reflects the area wise burden of contamination. In our study, ADD of As was found lower than in Vietnam, Bangladesh and more than Kohistan region northern Pakistan.

Abbreviations

ADD: Average Daily Dose

HQ: Hazard Quotient

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