Articles

Groundwater quality and associated health risks in flood affected public schools: A case study of district Sanghar, Pakistan

Calidad del agua subterránea y riesgos de salud asociados en las escuelas públicas afectadas por inundaciones: un estudio de caso del distrito Sanghar, Pakistán

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Abstract

Drinking water quality is of vital importance for the healthy life of a community especially if consumer is a teenager. In order to compare groundwater profile of flooded area (FA) and non-flooded area (NFA) of district Sanghar, 120 water samples from public schools were collected and investigated for physico-chemical parameters, essential metals, trace elements and microbiological indicators. Analysis data revealed that 47% samples in FA were contaminated with *faecal coliform* bacteria as compared to only 8.3% in NFA. On the other hand, chemical indicators like TDS, Ca, Na, K, SO_4, Mg and hardness were higher in FA. Comparison of trace elements content with WHO guidelines revealed that concentration of Fe, As and Zn was higher in 66.7%, 31.7% and 13.3% water samples, respectively in FA whereas content of these elements was also on higher side in 3.3%, 23.3% and 1.7% samples in NFA, respectively. Health risk assessment due to high concentration of Fe, As and Zn showed that As HRI>1, for children in 35 and 23% water samples in FA and NFA, respectively.

Keywords: Contamination, potable water, risk assessment, Sindh, trace metals.

Resumen

La calidad del agua potable es de vital importancia para la vida saludable de una comunidad, especialmente si el consumidor es un adolescente. Para comparar el perfil de las aguas subterráneas del área inundada (FA) y el área no inundada (NFA) del distrito de Sanghar, se recolectaron e investigaron 120 muestras de agua de escuelas públicas para determinar parámetros fisicoquímicos, metales esenciales, oligoelementos e indicadores microbiológicos. Los datos del análisis

revelaron que 47% de las muestras en FA estaba contaminada con bacterias coliformes fecales en comparación con sólo 8.3% en NFA. Por otro lado, los indicadores químicos como TDS, Ca, Na, K, SO4, Mg y dureza fueron más altos en FA. La comparación del contenido de elementos traza con las pautas de la OMS reveló que la concentración de Fe, As y Zn fue mayor en 66.7, 31.7 y 13.3% de muestras de agua, respectivamente, en FA, mientras que el contenido de estos elementos también estuvo en el lado superior en 3.3, 23.3 y 1.7% de muestras en NFA, respectivamente. La evaluación del riesgo para la salud debido a la alta concentración de Fe, As y Zn mostró que As HRI > 1, para niños en 35 y 23% de muestras de agua en FA y NFA, respectivamente.

Palabras clave: contaminación, agua portátil, evaluación de riesgos, Sindh, trazas de metales.

Introduction

According to an estimate, about 70% of people rely on groundwater for their drinking and other household use in Pakistan (Malik, Azam, & Saboor, 2010). In general, quality of groundwater varies from one place

to another, sometimes depending upon seasonal changes, the nature of soil, rocks and surfaces through which water flows (Thivya, Chidambaram, Thilagavathi, Nepolian, & Adithya, 2014). During flood or rainy season, surface water carrying various types of wastes, chemicals, minerals and other pollutants makes its way to groundwater. This mixing or seepage of polluted surface water into groundwater causes contamination of groundwater sources and aquifer. Consumption of this polluted water contribute to about 80% of waterborne diseases such as hepatitis, diarrhea, dental caries, oral hygiene and anemia in children (Memon, Soomro, Akhtar, & Memon, 2011). A study conducted by Djaouda *et al*. (2014) showed possible contamination of well water by human wastes from the traditional latrines system, and animal manure. A number of other studies have also been documented on severe contamination of drinking water sources with hazardous pathogenic bacteria like *Shigella sp*., *V. cholerae*, *P. aeruginosa*, *Salmonella*, and *S. aureus* in different areas of Pakistan caused by recent floods, which have resulted diseases like diarrhea, typhoid fever, cholera, dysentery, food poisoning, gastroenteritis, and other serious infections (Baig, Xu, & Khan, 2012; Khan, Ali, Ullah, & Ayaz, 2013; Saeed & Attaullah, 2014). Women and children are more prone to waterborne diseases and it is estimated that in developing countries, 1.7 million deaths per year which include 90% children are attributed to diarrheal disease due to lack of safe drinking water (WHO, 2004). A study conducted in Charsadda district of KPK, Pakistan revealed that faecal contamination of drinking water was the reason behind the occurrence of a number of waterborne diseases in the region (Khan *et al*., 2013).

Although major ions and elements present in drinking water are essential nutrients for humans, however, beyond certain limit these

pose serious health hazards. Higher concentrations of SO_4 with Mg and Na impair water taste and have a laxative effect. Similarly, it has been investigated that high concentrations of Na may increase blood pressure (Azizullah, Khattak, Richter, & Häder, 2011). Trace elements if ingested in excess can cause serious health implications depending upon nature and quantity of the metal ingested. Therefore, it is important to investigate potential health impacts associated with various water contaminants. Estimation of heavy metals concentration and health risk assessment have been carried out in various studies which revealed that overall all of these metals in excess concentration are toxic (Venkatramanan, Chung, Kim, Prasanna, & Hamm, 2015). About 200 million people around the world are at the health risk of As poisoning due to intake of As rich water (Rahman, Naidu, & Bhattacharya, 2009a). A large number of other investigations have also been carried out to evaluate physicochemical and microbiological quality of drinking water and possible health risks. Most of water samples analyzed in these studies were found unfit for human consumption on grounds of either chemical and/or microbiological contamination (Oyem, Oyem, & Usese, 2015; Alamgir, Khan, Schilling, Shaukat, & Shahab, 2016; Mohsin, Safdar, Asghar, & Jamal, 2013; Sarfraz, Sultana, Jamil, & Ashraf, 2016; Sarfraz, Sultana, & Jamil, 2018a; Sarfraz, Sultana, & Tariq, 2018b).

Rain and flood water carry out and mix human and animal's faecal wastes to groundwater which may carry pathogens and ultimately contaminates the water sources in the region. Besides this, pollutants from fertilizers, industrial wastes, metallic elements due to corrosion or decay of metallic infrastructure and other chemical constitutes make their route to groundwater. All these occurrences cause contamination of groundwater sources with different types of

pollutants. Hence, we have designed our project to evaluate potable groundwater quality in flooded area (FA) and non-flooded area (NFA) of district Sanghar, Pakistan, by performing physico-chemical and microbial investigations. Health risk assessment of all water samples collected from 120 public schools situated in rural areas of both FA and NFA locations was also carried out to understand risks associated with human consumption of this water.

Materials and methods

Study area

Sanghar, one of the largest district of Sindh province is located at 26° 02' 00" N and 71° 11' 36'' E. This district is almost located in the centre of Sindh and is bounded by India on east side. Heavy rains in 2016 and overflowing water of river Sindh flooded a large area of Sanghar, Pakistan, causing damage to infrastructure, agricultural land and farmland in rural areas of this district. In rural areas of the district Sanghar, drinking water in public schools is available directly from various groundwater sources including hand pumps and motor pumps without any further water treatment. Water samples from available groundwater sources of public schools located in 120 villages (60 FA

and 60 NFA) were collected and analyzed for various water quality parameters. From each site, three water samples were collected in clean poly propylene bottles (600 ml) for evaluation of physico-chemical, trace elements and aesthetic parameters whereas water samples for microbiological analysis were collected in sterilized bottles (250 ml) and stored in ice box. Water samples for As and NO_3 were preserved with HNO_3 and boric acid solutions respectively.

Physico-chemical analysis

Aesthetic and physical parameters like color, taste, electrical conductivity (EC), turbidity and pH were recorded at the sampling site using respective field testing instrument. All other water quality

parameters were recorded in laboratory. Briefly, titrimetric analysis was carried out against ethylene diamine tetraacetate (EDTA) for estimation of Ca, Mg and hardness, silver nitrate ($AgNO_3$) for chloride determination and HCl solution for estimation of alkalinity. UV-VIS spectrophotometer was used for analysis of NO_3 and SO_4 by taking absorbance at 220 and 450 nm respectively. Analysis of Na and K was achieved by using flame photometer and other trace elements like Fe, Zn and As were analyzed on atomic absorption spectrophotometer (AAS). APHA standard methods for examination of water and wastewater were employed to conduct analysis and calculation of results after proper calibration and standardization of instruments (APHA, 2005).

Microbiological analysis

Water samples were subject to analysis of total *coliforms* and *faecal coliform* by using membrane filtration method (USEPA, 2002). Each water sample (100 ml) was filtered using 0.45 μm paper filters and these filters were placed on mENDO and mFC agar and plates were incubated aerobically. Typical *coliform* colonies having pink to dark red color with metallic sheen and *faecal coliform* colonies having blue color were counted after incubation for 24 h at 35 ^{0}C and 45 ^{0}C, respectively.

Reagent and instrumentation

All chemicals and reagent used for the study were of analytical grade and calibration of all instruments was done prior to analysis. Instruments and methods employed for evaluation of chemical parameters includes Jenway, 350 pH meter EU, HANNA HI 99300 Italy EC meter, Louibond PC_H63739 Germany turbidity meter, Ca, Mg, Cl, alkalinity and hardness by titration method. Na and K on Flame Photometer Italy, Analysis of SO_4, Fe and NO_3 were performed on Optizen 2120 UV Plus Spectrophotometer, Mecasy Co. Ltd. Korea. Atomic absorption spectrophotometer was used for analysis of As and Zn. TDS was calculated by addition of cations and anions and c*oliform* and *faecal coliform* by membrane filtration assembly.

Health risk assessment

Chronic daily intake (CDI) and health risk index (HRI) of trace metals was calculated by using the equation given below (Shah, Ara, Muhammad, Khan, & Tariq, 2012):

$$ChronicDailyIntake\ (CDI) = \frac{Mc \times Lw}{Wb}$$

where Mc (µg/l) is the metal concentration in water while Lw (l/day) is daily water intake that is considered as 1 L/day and 2 L/day for child and adult respectively, and Wb (kg) is body weight that is assumed as 32.7 kg for child and 72 kg for adult (Khan, Rehman, Khan, Khan, & Shah, 2010). To address chronic health problems, the health risk index was calculated by using below equation:

$$\text{Health Risk Index (HRI)} = \frac{CDI}{RfD} \times 0.001$$

where CDI is chronic daily intake; RfD is the reference dose for oral toxicity which is 0.0003, 0.7 and 0.3 mg.kg^{-1}·day^{-1} for As, Fe and Zn respectively and HRI is measured health risk index, and 0.001 is the conversion factor for downscaling the reference dose (RfD) from mg to µg. HRI < 1 will be the limit for safe mode of water consumption.

Results and discussion

Water samples from 120 public schools were subject to investigation for physico-chemical water quality parameters (color, odor, pH, EC, turbidity, Cl, alkalinity, NO_3, SO_4 and TDS), essential metals (Ca, Mg, Na and K) and trace elements (Fe, Zn and As) in comparison to WHO

guidelines. Analysis results of all water samples are presented in Table 1, Table 2, and Figure 1 and Figure 2. Microbiological analysis of all water samples was also carried out to assess *coliform* and *faecal coliform* organisms.

Table 1. Presentation of chemical parameters in FA and NFA samples.

Parameters		Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	Fe (mg/l)	As (mg/l)	Zn (mg/l)
	Min.	8	12.15	26	1	0.1	0.7	0.3
FA	Max.	416	315.9	1000	55	2	18.5	4.2
	Mean	116.2	84.3	275.5	10.1	0.5	7.5	1.69
	Min.	8	9.72	27	3	0.1	0.45	0.3
NFA	Max.	176	97.2	410	68	0.4	22.5	3.2
	Mean	63.1	35.3	124.9	7.5	0.2	5.7	1.26

Table 2. Presentation of metallic elements in FA and NFA samples.

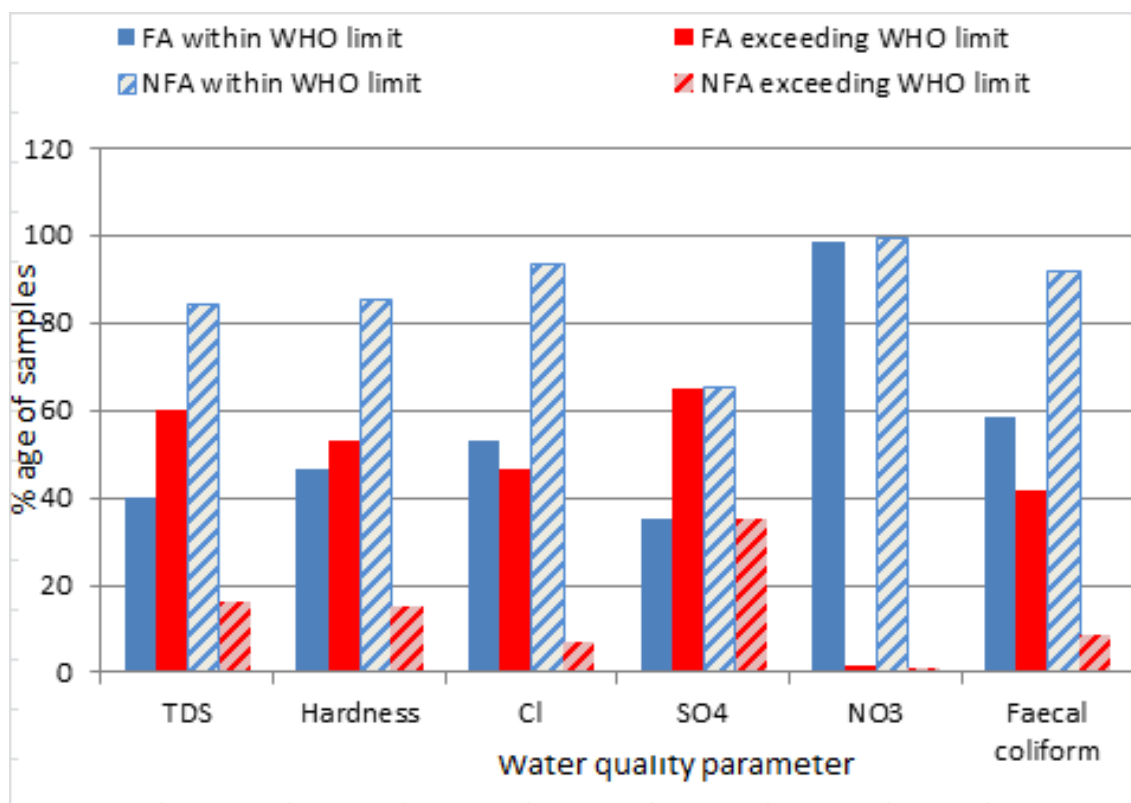| Parameters		Ec (µS/cm)	Hard. (mg/l)	TDS (mg/l)	SO_4 (mg/l)	NO_3 (mg/l)	Cl (mg/l)	Alkal. (mg/l)
	Min.	478	80	242.1	28	0.0	31.5	110
FA	Max.	6 335	2 100	3 996.7	1 230	10.5	1 575	560
	Mean	2 324.8	638	1 473.1	397.2	1.2	406.7	295.5
	Min.	391	60	232.6	26	0.0	24.5	100
NFA	Max.	5152	760	1 500.4	542	4.9	427	420
	Mean	1 410.3	304.9	699.5	211.5	0.5	105.8	248.9

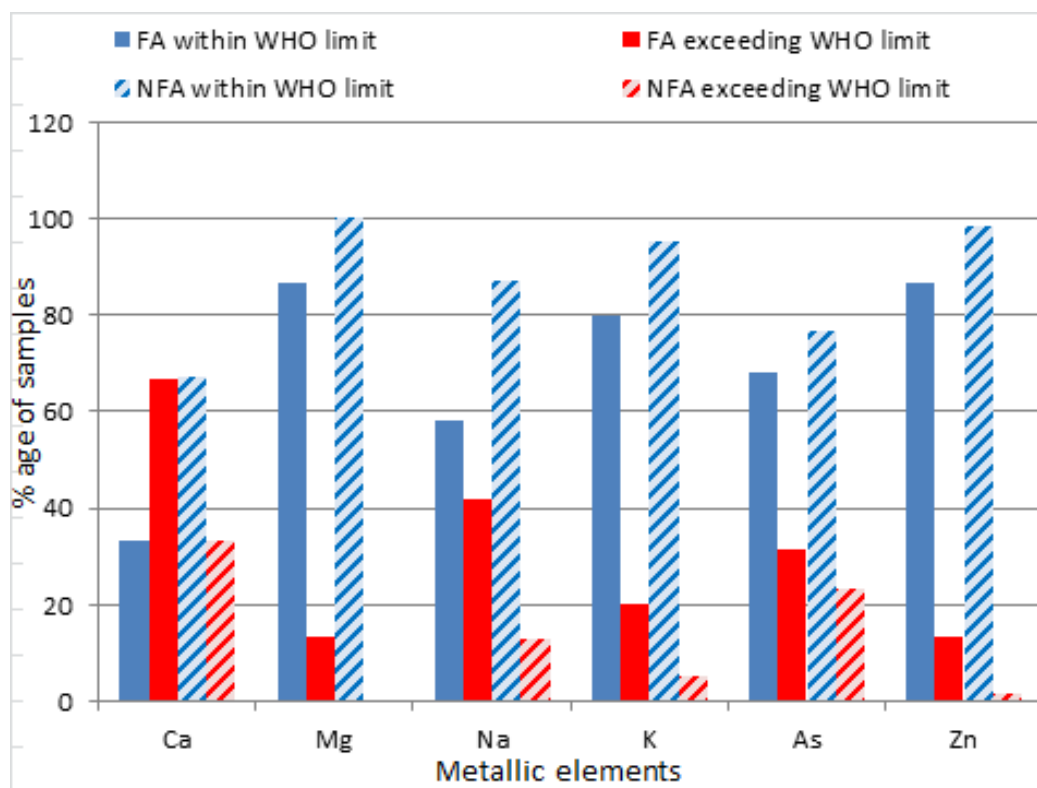**Figure 1**. Comparison of water samples results in FA and NFA.

Figure 2. Comparison of water quality indicators in FA and NFA.

Physico-chemical investigation

Physical and aesthetic parameters including color, taste and turbidity of most of the water samples were not objectionable with the exception of a few having saline taste. Turbidity of water samples ranged from 0.2-3.5 NTU which was in agreement to WHO permissible limit of 5 NTU. Measurement of pH value (7.02-8.37) was also within WHO permissible limits of 6.5-8.5.

EC is the measure of ions concentration, their mobility in water

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and is an indication of dissolved ionizable solids. In present study EC ranged from 478-6335 µS/cm in FA and 391-5152 µS/cm in NFA samples which indicated that FA have higher level of ionic concentration due to excessive dissolve solids. Alkalinity is also an important parameter of water quality. Mean value of alkalinity in FA and NFA samples was 295.5 and 248.9 mg/l, respectively. Chloride are present naturally in water, but higher content may incorporate saline taste, create problems in throat and digestive system along with causing corrosion (Khan *et al*., 2000). Chloride varied from 31.5-1575 and 24.5-427 mg/l in FA and NFA samples, respectively.

In FA, SO_4 varied from 28 to 1230 mg/l and overall 65% water samples were having high concentration of SO_4 as compared to WHO permissible limit whereas in NFA 35% samples were having SO_4 content on higher side. Total hardness is combination of Ca, Mg, Fe, Cl and SO_4 concentrations and its high level may instigate heart diseases in residents (Jamshidzadeh & Mirbagheri, 2011). Analysis data revealed that 53 and 15% sites in FA and NFA, respectively carried hardness higher than WHO guideline value of 500 mg/l. Total dissolved solids (TDS) indicate the ability of water to dissolve a wide range of minerals and salts such as salts of Na, K, Ca, Cl, SO_4, NO_3, Mg and bicarbonates etc. Findings of the present study showed that 60 and 16% water samples in FA and NFA, respectively have high value of TDS than WHO permissible limit of 1000 mg/l. Taste, hardness, corrosion properties and tendency to incrustation are associated with high TDS values in drinking water (WHO, 2004).

Essential metals

Present data indicated that 20 and 5% water samples possessed K concentration higher than WHO guideline limit in FA and NFA, respectively. Potassium is an important micronutrient for living organisms which plays an important role in the metabolism process of animals. But, excess amount of K in the drinking water may lead towards nervous and digestive systems disorder. In FA samples Na ranged from 26-1 000 mg/l whereas in NFA samples it varied from 27 to 410 mg/l. Overall 42 and 13% water samples in FA and NFA, respectively were having high Na content. The high concentration of Na impart taste to the water and make it unfit for drinking purpose and leads to cardiovascular diseases, hypertension and high blood pressure (Azizullah *et al*., 2011). Calcium being the basic structural component of teeth, bones and soft tissues is involved in different metabolic processes of the body. Calcium content in analyzed samples varied from very low (8 mg/l) to very high (416 mg/l) and in total 66.3 and 33% water samples have high level of Ca in FA and NFA, respectively. Magnesium is also an important essential element required by body for cardiac and vascular functions. Analysis data showed that Mg in only 13% FA water samples was higher than guideline value.

Trace elements

It is believed that due to interactions of hydrological cycle and the biosphere and geosphere, the groundwater sources used for drinking purpose generally contain natural organic matter (NOM) but during rainy season and floods its amount increases much more in surface and groundwater which changes organoleptic characteristics of water like taste, smell and color. Due to presence of NOM in water, oxidation of iron is inhibited by reducing it from Fe^{+3} to Fe^{+2}, and as a result iron content in water is increased. Furthermore, literature supported the increase in concentration of iron due to anthropogenic activities and land run off, as elevated concentration of iron was observed during monsoon and rainy seasons (Idoko, 2010). Present study showed high level of iron in FA as 66.7% water samples were having Fe value greater than permissible limit (Figure 3).
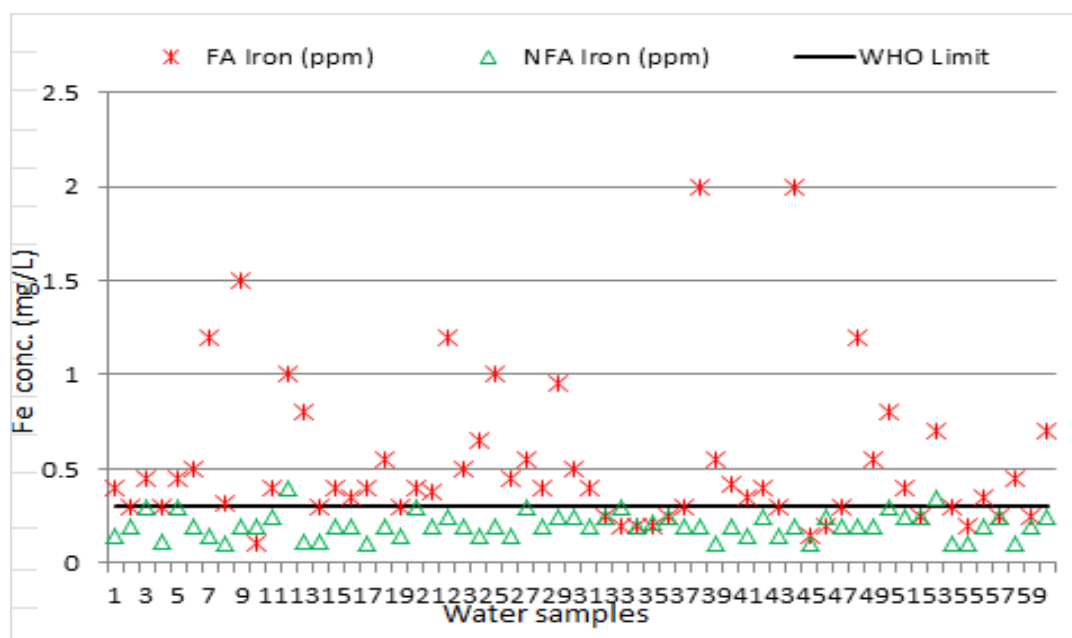

Figure 3. Comparison of Fe content in FA and NFA with WHO GVs.

Normally, drinking water seldom contains Zn above 0.1 mg/L.

Concentration of Zn higher than 3 mg/l (as $ZnSO_4$) can impart an undesirable astringent taste to water. In present study, Zn content was higher in 13.3 and 1.7% water samples in FA and NFA, respectively. High concentration of Zn may be attributed to galvanized plumbing material usually used for boring purpose. Arsenic contamination of drinking water is a severe public health issue for Pakistan like other South Asian countries. Present study showed that 31.7 and 23.3% water samples possessed higher As in FA and NFA, respectively. It is well documented that dermatological symptoms such as melanosis (change pigmentation) and keratosis (rough, dry, papular skin lesions) have been identified in people who are exposed to chronic As poisoning through drinking water (Rahman, Ng, & Naidu 2009b).

Microbiological monitoring

Microbial analysis data revealed that 41.7 and 8.3% water samples in FA and NFA, respectively have been contaminated with *faecal coliform* micro-organism which shows high level of contamination in FA schools (Figure 1). Saeed and Attaullah (2014) reported that drinking water was highly polluted with *total colifoms* and *fecal coliforms* in flood-affected areas of Charsadda and Nowshera (Saeed & Attaullah, 2014).

Health risk assessment

Chronic daily intake (CDI) and health risk index (HRI) (chronic and carcinogenic effects) is calculated on the basis of As and other trace elements' concentration in drinking water (Kavcar, Sofuoglu, & Sofuoglu, 2009). In present study, health risk assessment due to high concentration of As, Fe and Zn in groundwater was carried out by measuring CDI and HRI values as shown in Table 3.

Table 3. Presentation of metallic elements in FA and NFA samples.

		As		Fe		Zn	
		FA	NFA	FA	NFA	FA	NFA
	Mean	0.116	0.089	0.008	0.003	0.026	0.019
CDI	**Min.**	0.021	0.014	0.003	0.003	0.009	0.009
	Max.	0.566	0.688	0.061	0.012	0.128	0.098
	Mean	0.388	0.297	1.17E-05	4.51E-06	8.68E-05	6.45E-05
HRI	**Min.**	0.071	0.046	4.37E-06	4.37E-06	3.06E-05	3.06E-05
	Max.	1.886	2.294	8.74E-05	1.75E-05	4.28E-04	3.26E-04

Calculated CDI value for As, Fe and Zn in FA and NFA samples ranged from 0.021-0.566 & 0.014-0.688, 0.003-0.061 & 0.003-0.012 and 0.009-0.128 & 0.009-0.098 $\mu g \cdot kg^{-1} \cdot day^{-1}$, respectively. HRI value for As ranged from 0.071-1.886 and 0.046-2.294 for FA and NFA, respectively and overall 35% water samples in FA and 23% in NFA have HRI > 1. HRI for Fe and Zn were less than 1 in both FA and NFA samples. HRI calculations showed that trace elements in groundwater of public schools of district Sanghar were found in order of As > Zn > Fe.

Groundwater samples having HRI > 1 highlight future consumer's health risk associated with intake of this water for drinking purpose. Literature shows high to very high carcinogenic and non-carcinogenic health risk for adults and children associated with elevated As concentration in drinking water and its correlation with Fe and other heavy metals (Van Halem *et al*., 2010).

Conclusion

Physico-chemical and microbiological analysis revealed that there was high level of microbial contamination in public schools of District Sanghar as 47% water samples were loaded with *faecal coliform* bacteria which may pose serious health threat to the healthy lives of young students. The study also showed that a large number of sampling sites were polluted with physico-chemical parameters like Ca, hardness, Na, K, Cl, SO_4, As, Fe and TDS. Net result of present study is that most of the waterborne diseases prevailing in the flooded region are due to consumption of contaminated water. A concrete policy should be devised to address post-flood environmental effects on life and human health so that safety from hazardous effects associated with bacterial contamination and elevated concentration of toxic components may be ensured.

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Conflict of interest

There is no conflict of interest among the authors.

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