Identification and mapping of ground water contamination site of district Sanghar

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Abstract

The purpose of this study was to assess the quality of ground water and conducted health risk assessment, then plot the map according to hazardous level. Our study area was Sanghar district, we collected 205 samples and analysed them. The result showed that 3 talukas were having arsenic content higher than WHO limit (10ug/l). While the TDS of sample ranged from 500 mg/l to 6700 mg/l. Taluka Jam Nawaz ali was having higher TDS (71%) as compared to other talukas. The Ph, Ec and fluoride of most samples were within WHO's limit. While nitrates ranged from 0 to 127mg/l with Khipro having higher percent of nitrate within sample. Taluka Shahdadpur was exceeding limits in every parameter as compared to others. The findings of carcinogenic health risk was in three talukas.

Keywords: *GIS; health risk; ground water quality; heavy metal indices*.

1. Introduction

We are in the era where many developed nations are racing for colonizing moon, but sadly in the same world, billions of people throughout the world lack safe drinking water. There are two main sources of drinking water, surface water and ground water. Glaciers, lakes, reservoirs and Rivers are the main source of surface and groundwater. These water bodies can be contaminated through unsafe anthropogenic practices such as: disposing of chemicals, pesticides, open solid waste dumping and untreated human waste. In some cases, naturally occurring substances also contaminate the water. To deal with the contaminations developed nations have centralized monitoring system, sadly, developing nations like Pakistan, Bangladesh, Mexico, India, and Chile lacks these types of systems. There is need of centralized system facilities for the treatment of raw water, along with that awareness campaign are needed regarding presence of contaminants and their impact on health.

1.1. Ground water contamination and its health effect

Among all contaminants, the Arsenic (As) is the most dangerous to human health. Presence of arsenic in ground water was first reported by Agricola in book De Re Metallica in 1556, during the mining of cobalt skins of workmen were damaged due to arsenic cobalt (Storm et al. 2016). Arsenic is toxicant, which is found everywhere, it is carcinogenic element, it is found in ground water which flow through arsenic-rich rocks. Long term exposure of this contaminant can cause cancer of skin, liver, kidney and lungs (Smith et al. 1992). Health issues caused by arsenic is reported in many part of world like Bangladesh, Taiwan, Vietnam and Mexico (Brinkel, Khan, and Kraemer 2009).Situation is worse in countries like Bangladesh and Pakistan where drinking has arsenic level more than prescribed limit of WHO. Soluble arsenic is absorbed in large intestine; studies have shown that continuous consumption for twenty years will cause cancer(Carlson-Lynch, Beck, and Boardman 1994). Apart from drinking water arsenic also found in crops which we grow through contaminated water(Bhattacharya et al. 2010).In 2007, the Government of Pakistan established National Action Plan for Arsenic Mitigation (2007–2011) with the aim to screen out areas with high (As) groundwater's, provide an alternate supply of safe drinking water and arsenic removal technologies, and continuous monitoring of the affected areas(Mushtaq et al. 2021).

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1.2. Drinking water quality in Pakistan

In Pakistan, other than urban areas most population use ground water for drinking purpose, mostly hand pumps and bore machines are used to pump out water from ground. Due to continuous pumping ground water the changes its quality, the concentration of minerals and toxic metal increases. Sometime the ground water gets polluted due to land pollution near industries and urban localities. According to PCRWR report (Soomro and , Dr. M. I. A. Khokhar 2011) and around 81,996 diseases were spread from drinking unhealthy water in northern Punjab. In Pakistan nearly 40% Patients in hospitals are suffering due to drinking of unhealthy water (UNICEF)

2. Literature Review

Many studies had been conducted on the ground water quality in Pakistan. A study was conducted on the Lahore on ground water quality and arsenic source identification, along with that Health risk assessment was done using agglomerative hierarchical cluster analysis. The result showed high variability in As concentration, it bounced between (<0.1 mg/L) and (655 mg/L). More than 85% samples exceeded the WHO limit (10 mg/L), 70% of sample cleared the national limit of 50mg/L(Mushtaq et al. 2021).In Punjab study was sponsored by the government community development department in which arsenic concentration of ground water studied. Around 5000 Samples were collected from hand pumps and wells from all over Punjab. Sample were analyzed using Atomic absorption spectrum technique. The result showed that quality of ground water varied from place to place. The results showed that average arsenic concentrations in eleven district ranged from 6 mg/L to 12mg/L. This average resided with the Who limit of 10mg/L(Toor and Tahir 2009). Another study was conducted in 4 provinces of Pakistan by Pakistan centre of advanced research in water and sample were collected from 21 cities. Ground water sample were analysed for physical, chemical and biological contaminations. All standard methods were used for collection and analysis. Majority of samples were found unfit for drinking water, there was microbiological contamination and arsenic contamination in samples. Iron concentration was found higher in Mardan district, turbidity was high in samples from Hyderabad and Sukkur(Soomro and , Dr. M. I. A. Khokhar 2011).Study was conducted on arsenic contamination and health risk assessment of ground water in Mardan district KPK. Sample were collected in acidified and un-acidified forms; anions were identified using spectrophotometer. HRA was carried out to understand the impact on health, Chronic risk levels were found by formula of hazard quotients and RfD (mg/kg-day). CR was calculated by CR ¼ ADD × CSF, ADD is average daily dose and CSF cancer slope factor. The results showed that average value of physical parameter were found within prescribed limits of WHO. Concentration of HCO3 was higher other anions were within limits and Hazard quotients was > 1. This study concluded that parameters found were within the guidelines of WHO(Gul et al. 2015).In Charsada district KPK study was conducted to investigate various physical, chemical and biological parameters of ground water. The drinking water quality parameters were analyzed using standard methods. In order to find out impact of water on human health the questioner based survey was conducted. The result showed that PH values ranged between 6.29 to 7 .2, EC was 0.28 to 0.91 mS/cm and salinity ranged from 0.01 to 0.02%, they were all within safe limits prescribed by PEA. SO4 and NO3 were within limits but somewhere they exceed USA-EPA limits. Urban water was found contaminated by PB, FE and Zn due to pipe leakages and solid waste leaching. In city somewhere coliform bacteria was also present(Khan et al. 2013). Study was conducted to determine the toxicology risk of metals in ground water on human health by using Hazard Quotient for arsenic for district Jamshoro, Sindh, Pakistan. A total of 67 samples were collected from Manchar lake, canals, rivers, water supply schemes and groundwater and were tested for arsenic concentration with HACH arsenic kit. The study showed that carcinogenic risk of arsenic was higher than 10-1 in ground as well as surface water which is a serious thread for the communities living in Jamshoro(Memon et al. 2016). Ali conducted a research to estimate the Arsenic concentration in ground water for 15 pre-urban site of district Vehari Pakistan. They collected 127 sample of groundwater and tested for Arsenic and physiochemical content by using hydride generation atomic absorption spectrophotometer. Their findings showed that the groundwater was not fit for drinking purpose due to the increased level of Arsenic whose mean was about 46.9 ug/L. the study also showed that 83% of the ground water sample of the area has Arsenic concentration greater than the WHO permissible level i.e., 10 ug/l(Shah et al. 2020). Study was conducted to assess the quality of drinking water and arsenic health risk assessment for the province of Sistan and Baluchistan, Iran. They collected groundwater sample and examined for physical parameters, anions, and heavy metals using the standard procedures. The results showed that concentration of sulfate, chlorine, MG, and Na exceeded the permissible level set by WHO and Institute of Standards and Industrial Research of Iran. Besides this, arsenic concentration was within the limit of Who and local regulations. Based on the excess lifetime cancer risk and indices of hazard quotient, the study suggested that the ground water in the study area has no adverse impact on consumer's health. However, the study showed that overuse of pesticide and fertilizers, unsuitable sludge and solid waste disposal, inappropriate sewerage system may lead to drinking water pollution(Radfard et al. 2019). Study was conducted by

Sardar khan from environmental science department of Peshawar university. Total 74 samples were analyzed from urban and rural parts, heavy metal such as (Cd, Co, Cr, Hg, As, Ni, Zn and Pb) were found using atomic absorption Spectrophotometer technique. Heavy metals were having high pollution index (PI), Pb and cd were higher than allowable limits of WHO: ($p<0.05$) and along with that here HQ was greater than 1(Khan et al. 2016).

3. Research Materials and Methods

3.1. Study area description

Sanghar (Fig. 1) is situated in Sindh, Pakistan and it lies on coordinates 26.044418 N,68.953880 E. It lies at the center of Sindh and on east it borders with Rajasthan desert of India. It is one of the largest district of Sindh, it has an area of 9874 square kilometers with population of 1,453,028 and density of 190/km2 (DISTRICT WISE CENSUS RESULTS CENSUS 2017 n.d.). It is divided into six talukas: Jam Nawaz Ali, Sinjhoro, Shadadpur, Tando Adam khan, Sanghar and Khipro. This city is rich in cultural and social heritage, it has diverse ecosystem of arid and semi-arid regions along with vegetation less desert and one small reservoir Chotiyari with forest. Agriculture is the main profession here along with livestock, poultry and fish farms. Area is irrigated by Mitharho canal system, the ground water is recharged through seepage of irrigation water and rain water. Mostly the areas are water logged due to lack of proper drainage system, this causes rises in water and deteriorating of ground water quality due to leaching of salts into aquifers. Along with agriculture it has cotton processing industries, there is huge abundance of oil and gas in some talukas.

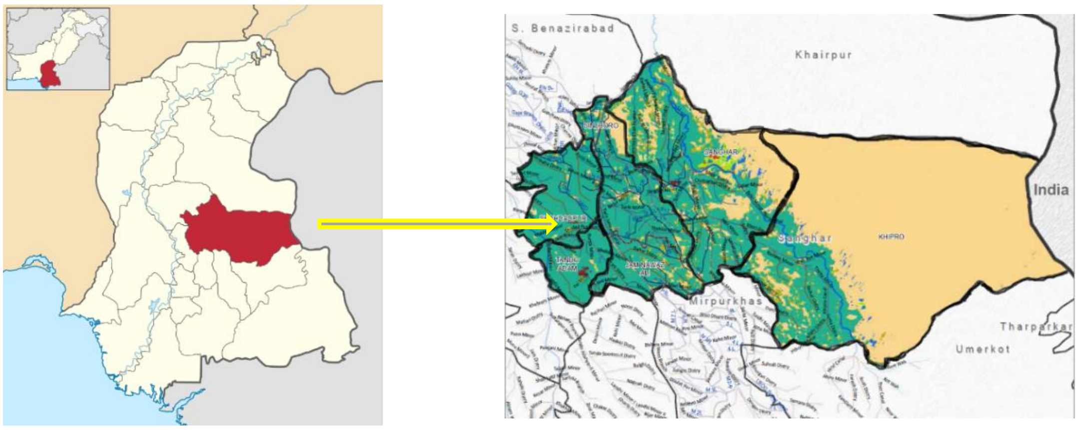

Fig. 1: Study Area (Sanghar District - Wikipedia" n.d.)

3.2. .Ground water Sampling

The 203 water samples were collected from the ground water hand pumps, from house hold and tube well from each taluka. The sampling exercise was conducted for one week. A summary of the samples collected is given in Fig. 1 and location of samples is marked in Fig. 2.

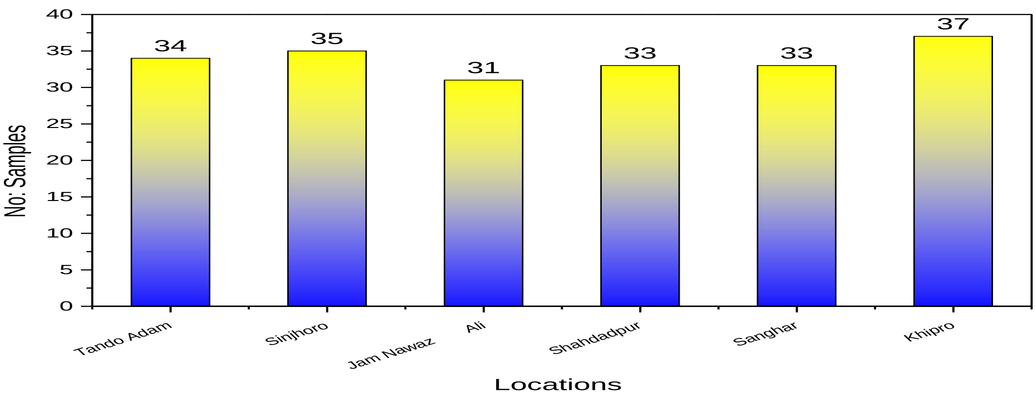

Fig. 2: Number of samples collection and locations

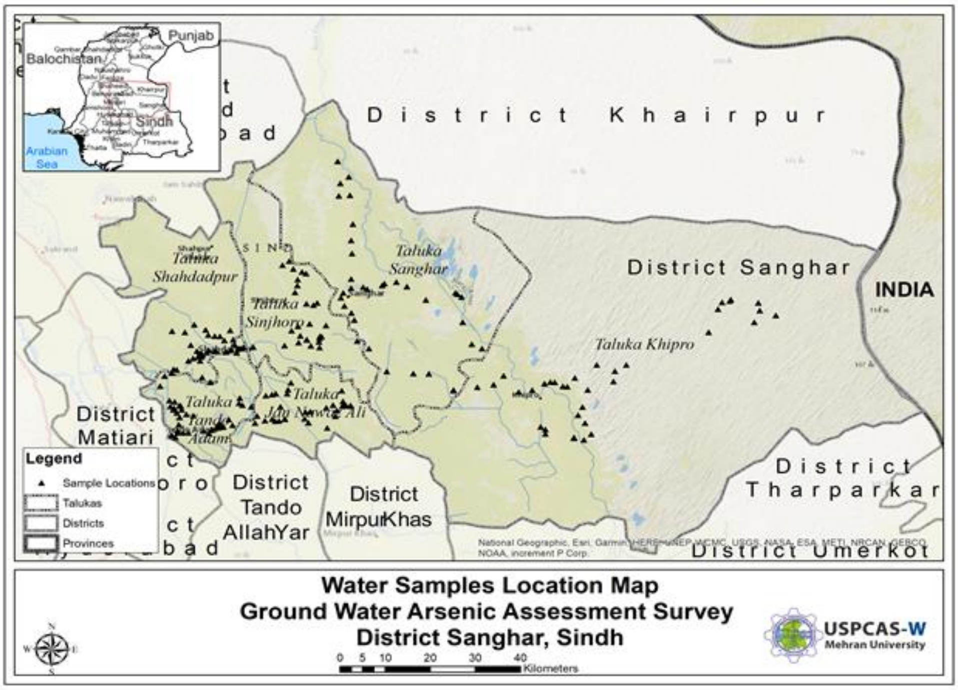

Fig. 3: Ground water samples location

3.3. Analysis of Water Quality Parameters

Water analysis was performed at the lab following the standard operating procedures and methods by APHA and using standard equipment available at USPCASW, MUET. The following parameters were analysed as mentioned in Table 1.

Table 1. Water Assessment Parameters & Procedures

S. No.	Parameter	Measurement unit	Instrument used	Standard method used
1	Color	Pt-Co	DR900 Portable Spectrophotometer	US-EPA Method Platinum-Cobalt Standard Method (Method 8025)
2	Turbidity	NTU	HI 93703 HANNA Portable Turbidity Meter	APHA Standard Method 2130 turbidity
3	pH	--	HI 8424 pH meter, Hanna.	Electrode Method
4	TDS	mg/L	HI 8734, Hanna.	Electrode Method
5	EC	µS/cm	HI 8734, Hanna.	APHA 2510 CONDUCTIVITY
6	Arsenic (As)	µg/L	NexION 350 ICP-MS, PerkinELmer	APHA 3125 B. Inductively coupled Plasma-Mass Spectrometry (IC-PMS) Method
7	Chloride	mg/L	N/A	APHA 4500-Cl– B. Argentometric Method
8	Hardness	mg/L	N/A	APHA 2340 C. EDTA Titrimetric Method
9	Fluoride	mg/L	DR1900 Portable Spectrophotometer	APHA 4500-F- SPADNS method
10	Nitrate	mg/L	Lambda 365, UV/Vis spectrophotometer (PerkinElmer)	US-EPA Method 352.1 Nitrate Colorimetric Brucine method.

3.4. Health risk assessment of heavy metals
3.4.1. Chronic daily intake (CDI)

Eq. (1) was used to estimate the chronic daily intake (CDI) it is given by USEPA. In above equation Cm is heavy metal concentration in water (in mg/l), DI is the average daily intake rate (which is 2L/day for child and 1L/day for adult), ABS is dermal adsorption factor, EF is Exposure frequency in year, ED is exposure duration in years, BW is average body weight, and AT is the period over which exposure is averaged. The input parameter and standards used for CDI calculation are mentioned in Table 2(Ahmed et al. 2021).

$$CDI=\frac{CM\times DI\times ABS\times ED\times EF}{AT\times BW} \quad (1)$$

Table 2: Input parameters and assumptions for exposure assessment of heavy metal

Parameters	Unit	Values
Daily average intake (DI)	L/day	1L
Heavy metal concentration (Cm)	µg/day	From collected data
Exposure frequency (EF)	Days/year	365 Days
Exposure Time (ET)	Hours/ Events	Varying
Body Weight (BW)	kg	Age group based
Exposure Duration (ED)	Years	6-10 Years
Average time for carcinogens (AT)	Days	25550 Days
Average time for noncarcinogens (AT)	Days	1368 Days

3.4.2. Chronic health risk (non-carcinogenic) assessment using hazard quotient index

The chronic health risk assessment of non-carcinogenic was found by using equation below.

$$Hazard\ Quotient\ (HQ) = \frac{CDI}{RFD} \quad (2)$$

In the Eq. (2) RFD refers to oral reference dose, it is in (mg/kg/day) and CDI is the chronic daily intake of trace metal in drinking water source for non-carcinogenic elements in (mg/kg/day). The reference values of RFD are given in Table 3. If HQ value is greater than one, there is non-carcinogenic health risk, while if HQ is less than or equal to one there are no harmful effects.

Table 3. The oral reference dose (RFD) for toxicity responses to heavy metals

Heavy Metals	Oral (RFD) mg/kg/day	Cancer Slope factor
Ar	0.000814	1.5
Pb	1.4	8.5

3.4.3. Chronic health risk (carcinogenic) assessment using ILCR

ILCR is abbreviated as Incremental Lifetime Cancer Risk, it measures that estimate of someone getting cancer over lifetime due to exposure carcinogenic elements for years. It is estimated by equation below.

$$ILCR = CDI \times CSF \quad (3)$$

In the Eq. (3) CSF is cancer slope factor and it is defined as risk generated by lifetime average amount of one mg /kg /day of carcinogen chemical. The ILCR will be analysed for Pb and Ar and permissible limit was considered 10^{-4} for study.

3.5. Mapping through Global information system software

During the collection of samples, the coordinates of each collection site were recorded during field work. Then those coordinates were plotted on Arc(Gis). The coordinate files of longitude and latitude was generated on excel. In the end hazardous base map was generated on Arc(Gis).

4. Result and discussion

Map on Fig. 4 shows the arsenic contamination sites, the red areas are hotspots where arsenic in the water is crossing WHO's permissible limit (10µg/L). The red areas comprise of Sanghar, Shadadpur and Khipro. Among these three talukas Sanghar is most dangerous because 30% of its area is exceeding the WHO's limit.

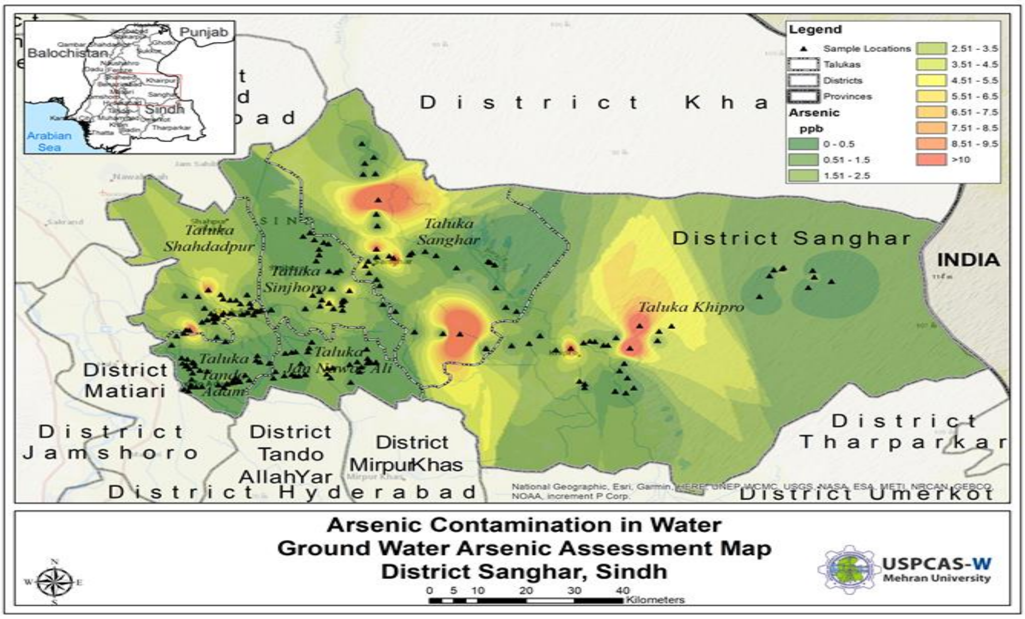

Fig. 4: Arsenic contamination sites

4.1. Tando Adam

The 33 groundwater samples were collected from different location of Tando Adam, majority of samples were higher TDS concentration (67%) and higher the total hardness (57%) Nitrate (3%), However, the pH, fluoride and arsenic concentration were found within the permissible limit as shown in Fig. 5.

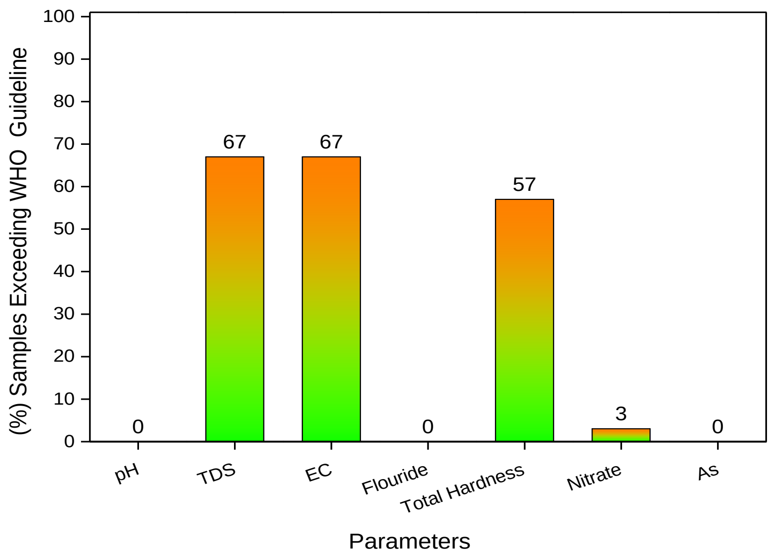

Fig. 5: Percent samples exceeding the permissible limit in Tando Adam

4.2. Jam Nawaz Ali

Around 31 groundwater samples were collected from different locations including household, schools and mosques. 71% of samples have higher TDS concentration whereas 58% have higher total hardness concentration. However, Arsenic, fluoride, nitrate and pH were within the permissible limit as shown in Fig. 6.

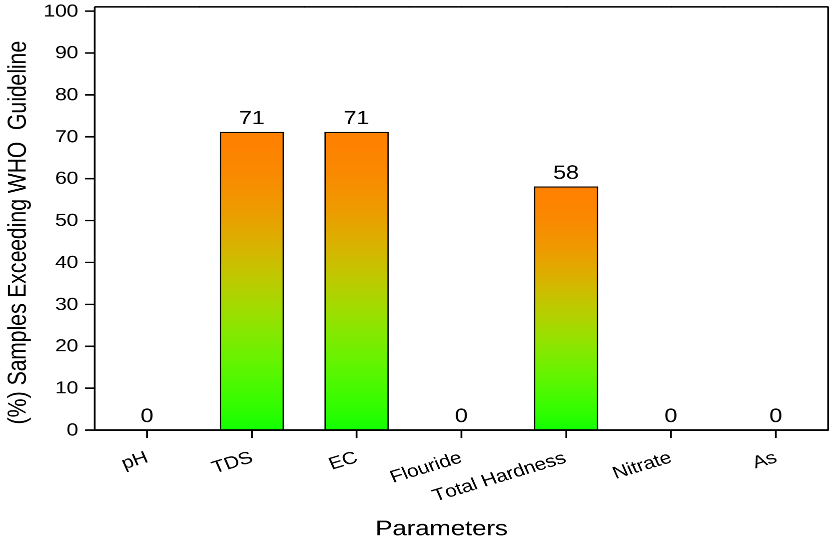

Fig. 6: Percent samples exceeding the permissible limit in Jam Nawaz Ali

4.3. Sinjhoro

Total 37 groundwater samples were collected from different locations including household, schools and mosques. 43% of samples have higher TDS concentration whereas 46% have higher total hardness concentration and 11% samples were found higher concentration of fluoride contamination, arsenic (3%), nitrate (3%) were exceeding the permissible limit as shown in Fig. 7.

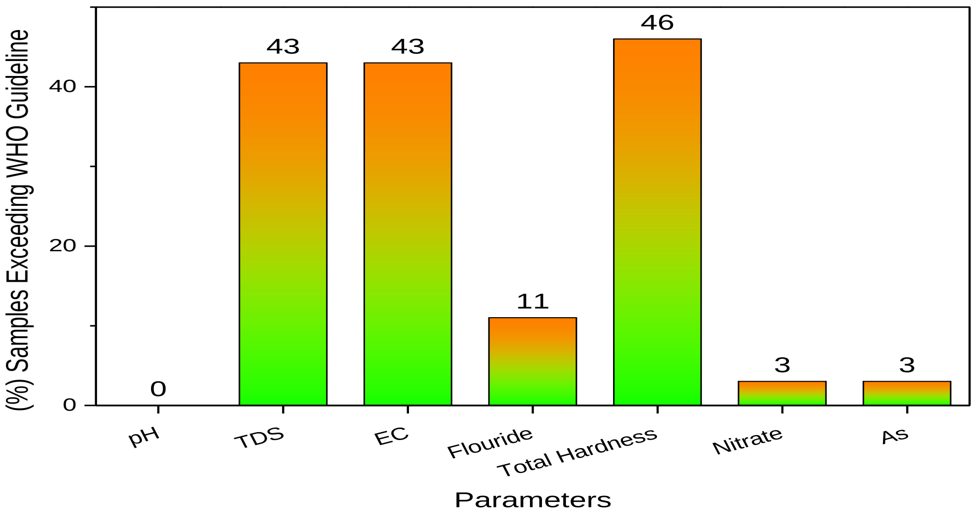

Fig. 7: Percent samples exceeding the permissible limit in Sinjhoro

4.4. Shahdadpur

Total 33 groundwater samples were collected from different locations including household, schools and mosques. 54% of samples have higher TDS concentration where as 48% have higher total hardness concentration and 30% samples were found higher concentration of fluoride contamination, arsenic (9%), nitrate (9%) were exceeding the permissible limit as shown in Fig. 8.

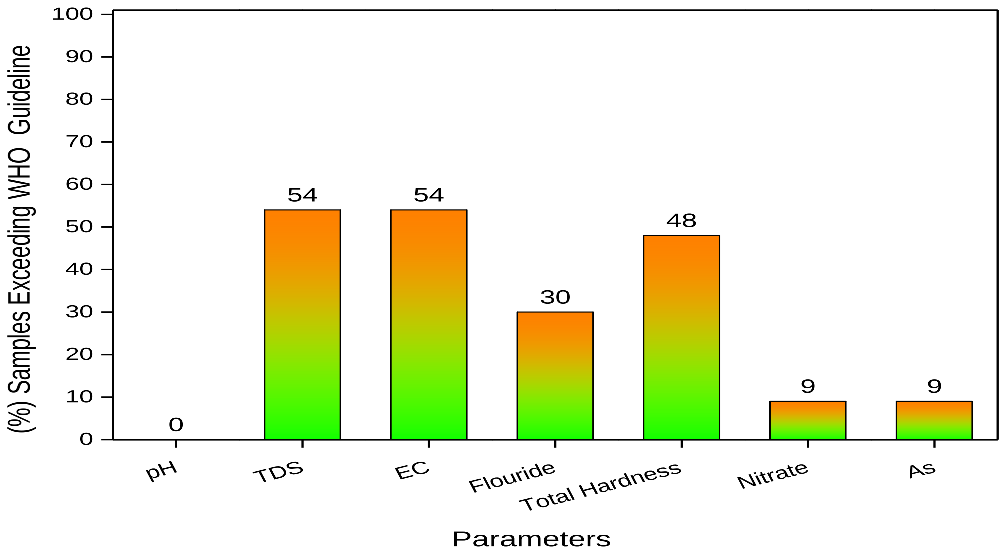

Fig. 8: Percent samples exceeding the permissible limit in Shahdadpur

4.5. Sanghar

Total 33 groundwater samples were collected from different locations including household, schools and mosques. 33% of samples have higher TDS concentration whereas 27% have higher total hardness concentration and 30% samples were found higher concentration of fluoride contamination, arsenic (12%), nitrate (6%) were exceeding the permissible limit as shown in Fig. 9.

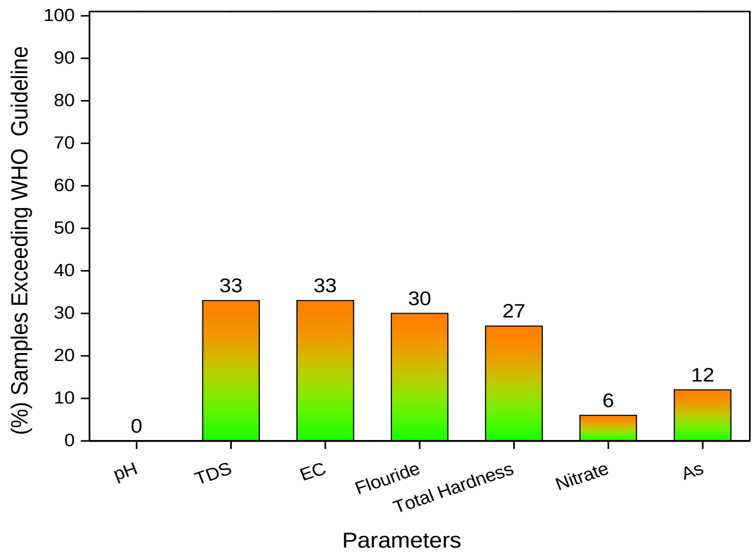

Fig. 9: Percent samples exceeding the permissible limit in Sanghar

4.6. Khipro

Total 33 groundwater samples were collected from different locations including household, schools and mosques. 51% of samples have higher TDS concentration whereas 27% have higher total hardness concentration and 11% samples were found higher concentration of fluoride contamination, arsenic (8%), nitrate (56%) were exceeding the permissible limit as shown in Fig. 9.

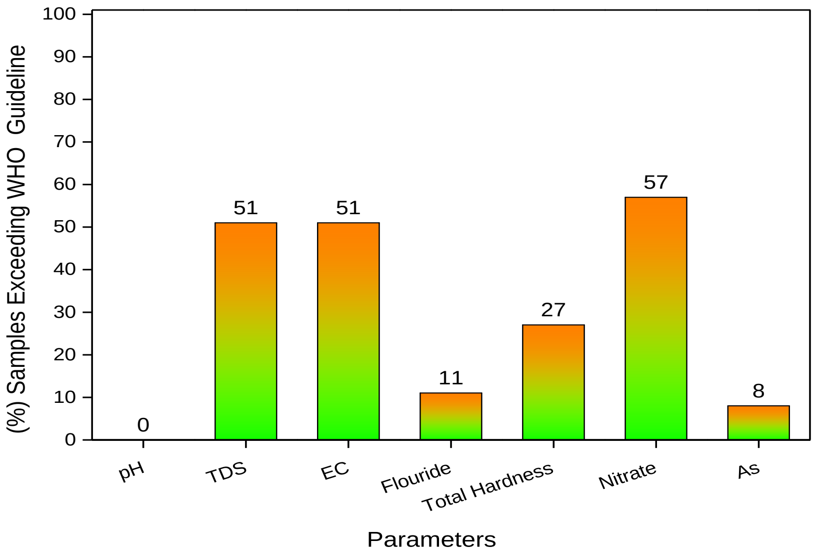

Fig. 9: Percent samples exceeding the permissible limit in Khipro

Total 203 groundwater samples were collected from different locations (Tando Adam, Jam Nawaz Ali, Sinjhoro, Shahdadpur, Sanghar and Khipro) of Sanghar. Form analysis, it was observed that groundwater samples have higher concentration of TDS. However, the other drinking water quality parameters were exceeding the permissible limit. Furthermore, the arsenic contamination in groundwater were observed in three taluka Shahdadpur (9%), Khipro (8%) and Sanghar (12%).

5. Conclusion

The groundwater quality was compared with WHO guidelines; from analysis it was identified that three talukas of Sanghar district contaminated with arsenic. Presence of arsenic metal contamination is considered the hazardous impact on the human health. Groundwater is considered the main source of arsenic contamination. Arsenic hotspots are located mainly in three talukas of Sanghar and arsenic has carcinogenic effect through consumption of arsenic contaminated water. Peoples and specially children from these areas at carcinogenic risk.

Acknowledgements

This research was supported/partially supported by Research Development Foundation. We thank our colleagues from Mehran University of Engineering Technology, Jamshoro, Sindh, Pakistan who provided insight and expertise that greatly assisted the research, although they may not agree with all of the interpretations of this paper.

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