Risk Assessment of Toxic Metals from Drinking Water of Taluka Ghorābāri, Sindh, Pakistan

Abdul Raheem Shar[1*], Ghulam Qadir Shar[1], Zulfiqar Ali Jumani[1], Aslam Khan Pathan[1], Zubeda Bhatti[1], Ali Raza Rind[2], and Ghulam Mujtaba Jogi[1]

[1]*Institute of Chemistry, Shah Abdul Latif University Khairpur, Sindh 66020, Pakistan*

[2]*Institute of Physics, University of Sindh, Jamshoro 76080, Sindh, Pakistan*

* ***Corresponding author:***

tel: +92-3063402926
email: araheem.shar@salu.edu.pk

Received: November 10, 2021
Accepted: January 10, 2022

DOI: 10.22146/ijc.70345

Abstract: *In the current study, the quality of groundwater used for drinking purposes was assessed in Taluka Ghorābāri, Sindh, Pakistan. Twenty-five sampling locations were selected for the collection of groundwater. Samples were analyzed for physicochemical and heavy metal analysis, followed by standard methods. Detection of heavy metals was conducted using Atomic Absorption Spectrophotometer. Heavy metals which exceeded the WHO safe limit included Cr (28%), Fe (16%), Mn (48%), and Ni (16%) from the drinking water of the study area. The Cu and Zn were found within the safe limit in all drinking water samples of the study area. The Daily Intake of heavy Metals (DIM) and Health Risk Indexes (HRI) Assessments were calculated to determine risk assessments; the order of mean DIM values was observed as Ni > Cu > Fe > Zn > Cr while HRI was observed in the order of Cu > Mn > Zn > Fe > Cr. The HRI values were observed less than one for both adults and children, which shows the lack of possible health hazards for the people of the study area.*

Keywords: *heavy metals; WHO; DIM; HRI; risk assessments*

■ INTRODUCTION

Water is essential for all kinds of life. On the earth, about 3% of fresh water is available, out of which only 0.01% can be utilized for the use of people. Anthropogenic and lithogenic activities severely affect this little amount of freshwater, like vehicular emission, mining, urbanization, rapid population growth, and invalid development in industries and agriculture [1]. Most people of urban and rural areas of developing countries are unable to know the quality of groundwater they use. According to an estimation made by the WHO, yearly deaths of 842,000 took place in developing countries due to various reasons such as unsafe hygiene, sanitation, and water supply. Meanwhile, about 780 million people from the globe do not have access to safe drinking water because of chemical and bacteriological pollutants [2]. Reports reveal that presence of heavy metals in groundwater has enhanced threats in the world because heavy metals may cause various types of diseases, including cancers.

So many drinking water sources are found, such as the accessibility of rivers, reservoirs, lakes, and aquifers. The severe natural disaster and health risk of people may arise from contamination of drinking water whose origin is found from geological variations and anthropogenic sources. Variation in water quality and contribution to water pollution arises mostly from the release of industrial wastewater [3]. The disease state and main health controlling factors are associated with water quality characteristics. Potentially toxic metals, physical, chemical, and biological parameters are included in water quality characteristics since heavy metals are more toxic because of their bio-accumulative, non-degradable and toxic nature. Non-essential or toxic and essential elements are included in heavy metals. Regular functioning of essential elements is extremely important in a particular quantity since their higher amount may cause destructive consequences. Heavy metals, for instance, Pb, Cd, As, and Hg, are highly detrimental for life, even at trace levels. Unfavorable effects of toxic metals include carcinogenesis, cardiovascular disease, nerve disease, anemia, mental stoppage, liver, kidney and brain problems, nausea, hypertension, irritability, vomiting, abdominal pain, and headache [4].

Supportive information is obtained for regular monitoring of water quality. Hence, various investigations from developed and developing countries focused on drinking water quality on a regular basis. The more severe problem of water contamination is observed in developing countries because of the high growth rate of population and less cost on treatment features. Pakistan is also facing severe drinking water problems in super cities like other developing neighboring countries [5]. There are different pathways by which extremely poisonous heavy metals accumulate in the water system, for instance, water drainage, industrial effluents, agricultural runoffs, range of bedrock, and environmental deposition [6]. Furthermore, the high content of toxic metals contaminates the groundwater and surface water, badly affecting water quality and human health. Toxic metals occur naturally in the crust of the earth since variation in their concentrations does not remain the same in different locations [7]. Although heavy metals have distinctive atmospheric toxicity, therefore, they cannot be converted into a non-toxic structure. Surface water contamination occurring due to the discharges and runoff of groundwater has been a matter of universal ecological distress since the liberation of heavy metals once into the atmosphere through food, water, and air or synthetic chemicals are taken into the human body by dermal absorption, ingestion, and inhalation. In the case of surface water conditions, ingestion and dermal absorptions are major sources of introduction [8].

The steady increase of contaminants may take place in the human body if the accumulation and entering of these toxic metals occur faster as compared to the discard of the detoxification mechanisms. For toxicity in the body, higher content of toxins is not a requirement because in body tissues amassing heavy metals may be observed steady and eventually may get the concentration much more than the allowable level. It is, therefore, necessary to determine a risk assessment of daily human purpose. For this purpose, it is important to characterize physical situations, recognition of potential exposure populations and mechanisms, as well as assess the chemical intakes and exposure concentrations. Since heavy metals are major atmospheric contaminants and their toxic nature is a threat of enhancing consequence for atmospheric, nutritional, evolutionary, and ecological reasons [9]. Some important heavy metals at lesser content are supposed to be very important in the metabolic movements of living things; their long-term exposure may cause cancers, kidney, and liver problems and therefore are believed to be harmful to human health. Severe health problems may be caused to humans due to toxic metals and may possibly cause numerous diseases derived from the concentration and kind of metal concerned [10]. Overuse of copper is a casual issue for kidney damage, Alzheimer's disease, mental diseases, and gastrointestinal cancers. The main purpose of this study was to analyze physicochemical and chemical parameters from rural areas of Taluka Ghorābāri as well as to determine human health risk assessments. Our focus is to assess drinking water quality and to aware the people of the area under study because contaminated drinking water may cause various diseases, including different types of cancers, kidney, liver, and cardiovascular problems.

■ EXPERIMENTAL SECTION

Study Area

Ghorābāri is the study area situated in the coastal area of district Thatta, Sindh, Pakistan. Coordinates of Ghorābāri are 24° 13' 0" N, 67° 34' 0" E (Fig. 1). Its population is about 174,088 residing in scattered towns form and the Sindhi is the local language spoken in the area. The land of the villages consists of large ploughed fields. Ghorābāri is less developed since roads are unpaved and cob houses made by the residents. Health care centers and personal care clinics are less in the area. Education of the area is poor. Since for three centuries, inhabitants of Sindhi and some Baloch tribes are settled in Ghorābāri. It was observed in the present study that

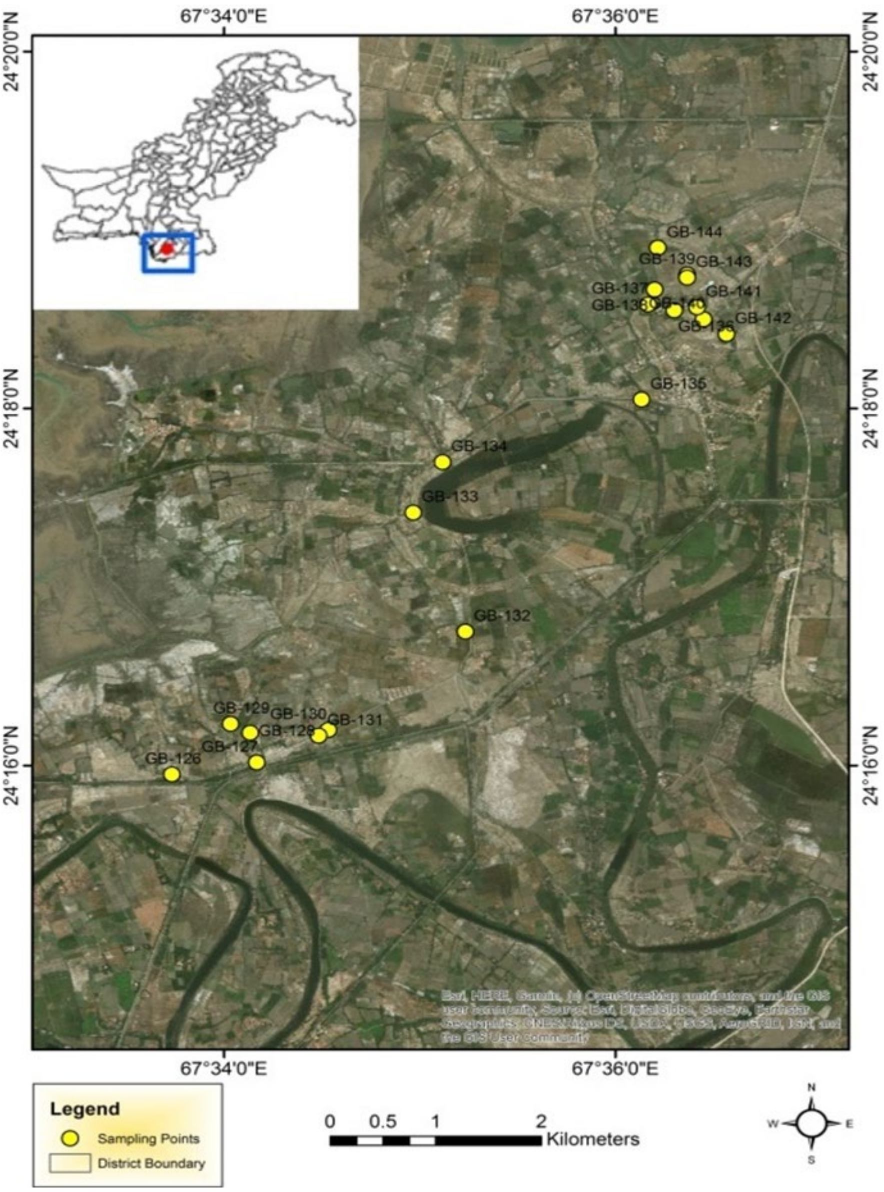

Fig 1. Sampling location map of the study area

people of the study area derived groundwater for drinking purposes from hand pumps situated mostly in rural areas of the Taluka Ghorābāri.

Materials

The spectroscopic purity of reagents and chemicals used in this study was about 99.9% (Merck Darmstadt, Germany). Standard solutions of all six heavy metals were prepared by successive dilution method from 1000 mg/L certified standard solution of corresponding heavy metals (FlukaKamica, Buchs, Switzerland).

Instrumentation

Heavy metals from drinking water samples were determined by standard methods. Atomic Absorption Spectrophotometer (Analytic Jena) was used to determine heavy metals such as chromium, nickel, copper, iron, manganese, and zinc under standard conditions. Prepared samples were transported to the Laboratory of Pakistan Council of Research in Water Resources (PCRWR) Government of Pakistan Ministry of Science & Technology National Water Quality Laboratory, Islamabad, for heavy metal analyses.

Procedure

Sampling

The 25 groundwater samples used for drinking purposes were collected from hand pumps fitted by the people of the rural areas of Taluka Ghorabari. Drinking water samples were collected after running the water sources for five minutes or till fresh water. Sampling bottles were labeled as GB-01 to GB-25. Most rural areas of the Taluka Ghorābāri were selected for sampling purposes. For heavy metals determination, water collected in sampling bottles was acidified with nitric acid. Samples were quickly shifted to the Shah Abdul Latif University Khairpur for further analytical processes and stored at 4 °C.

Health risk assessment for humans

The health risk for humans through consumption of heavy metals found in infected drinking water was assessed with the help of formulas for health risks like DIM and HRI.

Daily intake of metals (DIM)

There are various pathways through which heavy metals contact the human body, for instance, oral intake, ingestion, inhalation, food chain, and dermal interaction since the most important role is played by oral ingestion in amassing of heavy metals in humans. The following equation was used to calculate the DIM adapted from [11].

$$\mathrm{DIM} = \frac{\mathrm{Cm} \times \mathrm{DIw}}{\mathrm{BW}} \quad (1)$$

where Cm, DIw, and BW are the concentration of heavy metals in water, average daily intake of water (2 L per day for adults and 1 L per day for children) [12], and average body weight (72.0 and 23.7 kg for adult and children respectively).

Health risk indexes (HRIs) of heavy metals

Eq. (2) given below was used for the calculation of HRIs of toxic metals by ingestion of water [13].

$$\mathrm{HRI} = \frac{\mathrm{DIM}}{\mathrm{RfD}} \quad (2)$$

where, DIM and RfD are average daily intake and toxicity oral reference dose of heavy metals. TheRfD values of heavy metals were represented as; Cr (1.5 mg/kgbw/d), Ni (0.02 mg/kgbw/d), Cu (0.04 mg/kgbw/d), Mn (0.033 mg/kgbw/d), Fe (0.7 mg/kgbw/d) and Zn (0.30 mg/kgbw/d). The level of selected metals is considered safe when HRIs are less than 1 [14].

■ RESULTS AND DISCUSSION

Little quantities of Cr(III) is present in food, wine, and water, whereas inhaled Cr(VI) is very toxic. Stomach tumors and allergic contact dermatitis may be caused when Cr(VI) is ingested through water [15]. The WHO guideline of Cr for potable water is 0.05 mg/L, since Cr was measured from 0.028 to 0.057 mg/L. The average content of Cr from potable water of the study area was determined as 0.044 mg/L. The higher limit of Cr as compared to prescribed limit was measured in samples GB-01 (0.055 mg/L), GB-03 (0.057 mg/L), GB-10 (0.055 mg/L), GB-16 (0.056 mg/L), GB-21 (0.055 mg/L), GB-24 (0.051 mg/L), and GB-25 (0.055 mg/L) (Table 1).

The dietary intake of Ni with a concentration of approximately 70–100 µg/day was prescribed with less than 10% may release in urine. Relatively high Ni content is observed above than assessed average intake due to stainless steel may release into food [16]. The concentration of Ni greater than allowable level of 0.02 mg/L was observed in potable water labelled as, G-08 (0.021 mg/L), G-19 (0.021 mg/L), G-20 (0.026 mg/L), and G-22 (0.024 mg/L). The minimum and maximum concentration of Ni was found as 0.010 and 0.026 mg/L, respectively, with a mean concentration of 0.017 mg/L (Table 1).

Copper is essential for the human being. The consequences of high Cu exposure on the well-being of people are most probably not known. Toxic effects of copper are recognized for high, acute Cu contact containing acute indications such as vomiting, nausea, and cramping in the gastrointestinal tract [17]. The concentration of Cu greater than 30 mg/L when utilized by polluted beverages or water causes copper-related diseases. The concentration of Cu > 1, when ingested by an adult, may cause acute toxemia and finally death. The WHO guideline of Cu in potable water is recommended as 2.0 mg/L, although all water samples showed the Cu

Table 1. Heavy metal contents in water collected from the area under study

Sample ID	Cr ±SD	Cu ±SD	Fe ±SD	Mn ±SD	Ni ±SD	Zn ±SD
G–1	0.055±0.001	0.900±0.003	0.150±0.002	0.020±0.002	0.018±0.002	0.190±0.005
G–2	0.040±0.001	0.040±0.001	0.110±0.002	0.050±0.002	0.016±0.001	0.064±0.004
G–3	0.057±0.002	0.110±0.005	0.060±0.002	0.040±0.003	0.017±0.001	0.066±0.005
G–4	0.045±0.001	0.140±0.005	0.370±0.003	0.030±0.003	0.011±0.001	0.064±0.006
G–5	0.039±0.001	0.120±0.005	0.090±0.002	0.310±0.005	0.014±0.001	0.060±0.003
G–6	0.046±0.001	0.800±0.005	0.170±0.001	0.040±0.003	0.020±0.000	0.210±0.005
G–7	0.028±0.002	0.740±0.008	0.140±0.002	0.060±0.003	0.020±0.000	0.061±0.005
G–8	0.04±0.0010	0.042±0.003	0.190±0.003	0.030±0.001	0.021±0.003	0.062±0.003
G–9	0.036±0.001	0.041±0.002	0.120±0.005	0.040±0.003	0.015±0.001	0.071±0.007
G–10	0.055±0.002	0.048±0.003	0.320±0.003	0.050±0.004	0.017±0.001	0.066±0.007
G–11	0.048±0.002	0.800±0.004	0.180±0.003	0.030±0.002	0.010±0.001	0.270±0.004
G–12	0.034±0.002	0.670±0.005	0.090±0.003	0.030±0.001	0.015±0.002	0.061±0.003
G–13	0.039±0.001	0.050±0.003	0.280±0.003	0.060±0.003	0.017±0.001	0.063±0.005
G–14	0.040±0.002	0.044±0.004	0.110±0.004	0.060±0.002	0.015±0.001	0.068±0.004
G–15	0.036±0.002	0.042±0.004	0.360±0.003	0.100±0.003	0.017±0.001	0.060±0.005
G–16	0.056±0.001	0.600±0.007	0.050±0.001	0.050±0.003	0.012±0.002	0.260±0.005
G–17	0.046±0.002	0.049±0.003	0.080±0.002	0.020±0.003	0.018±0.001	0.060±0.005
G–18	0.032±0.001	0.050±0.003	0.130±0.001	0.160±0.004	0.016±0.001	0.060±0.006
G–19	0.036±0.001	0.038±0.002	0.170±0.003	0.060±0.007	0.021±0.002	0.003±0.001
G–20	0.043±0.001	0.050±0.006	0.310±0.002	0.110±0.003	0.026±0.002	0.061±0.000
G–21	0.055±0.001	1.000±0.012	0.020±0.003	0.080±0.003	0.016±0.002	0.220±0.005
G–22	0.036±0.000	0.048±0.003	0.120±0.001	0.160±0.002	0.024±0.001	0.077±0.004
G–23	0.043±0.000	0.067±0.002	0.160±0.003	0.080±0.006	0.015±0.002	0.061±0.002
G–24	0.051±0.003	0.050±0.003	0.080±0.004	0.090±0.002	0.017±0.002	0.061±0.004
G–25	0.055±0.001	0.045±0.003	0.150±0.002	0.050±0.003	0.014±0.001	0.059±0.005

concentration below the prescribed limit. Since the range was observed as 0.040 to 1.000 mg/L, the mean Cu content of 0.239 mg/L was found in potable water samples of the study area (Table 1).

Iron is very important for life. The Nitrogenase enzyme is included in repetitive iron-sulfur clusters for the biological fixation of nitrogen. Iron-containing proteins carry out the use, transport, and storage of oxygen [18]. The concentration range of Fe from potable water was measured as 0.020 to 0.370 mg/L with an average content of 0.160 mg/L. The WHO allowable level of Fe is recommended as 0.3 mg/L, since samples in which higher Fe content was found comprise; GB-04 (0.37 mg/L), GB-10 (0.32 mg/L), GB-15 (0.36 mg/L), and GB-20 (0.31 mg/L) (Table1).

Manganese is believed to be important for growth and human health, metabolism as well as antioxidant system. The neurogenerative disorder known as Parkinson's disease is observed due to ingestion of an excessive amount of Mn [19]. The permissible WHO limit of Mn is recommended as 0.05 mg/L, however, samples in which Mn content greater than allowable limit was found include; GB-05, G-07, G-13, G-14, G-15, G-18, G-19, G-20, G-21, G-22, G-23, and G-24 as; 0.31, 0.06, 0.06, 0.06, 0.10, 0.16, 0.06, 0.11, 0.08, 0.16, 0.08, and 0.09 mg/L, respectively (Table 1).

Zinc is extremely important for animals, humans, plants, microorganisms, and animals. Zinc is obligatory for the function of >300 enzymes and 1000 transcription factors that are transported and collected in metallothioneins. Zinc is 2nd most abundant trace metal after Fe in humans; zinc is present in approximately entire enzymes [20]. The WHO guideline of Zn for potable water is set as 3.0 mg/L, since all potable water samples declared a safe limit of Zn from the area under study. The range was determined as 0.003 to 0.270 mg/L with mean Zn content of 0.094 mg/L (Table 1).

Daily Intake (DIM) of Heavy Metals

The DIM range of Cr in the drinking water of the study area was observed for adults as 0.0008–0.0016 mg/kgbw/d. For children, it was found as 0.0009–0.0017 mg/kgbw/d, while the mean DIM concentration of Cr for adults and children was determined as 0.0012 and 0.0013 mg/kgbw/d, respectively. For Ni, the DIM range was found for adults and children as; 0.2800–0.7200 and 0.3100–0.8000 mg/kgbw/d, respectively. Since the average DIM values were observed for adults and children as 0.4688 and 0.5168 mg/kgbw/d, respectively. For Cu DIM values for adults and children were measured as 0.0010 to 0.0280 mg/kgbw/d and 0.0010 to 0.0310 mg/kgbw/d, respectively with average level of Adult (0.0072 mg/kgbw/d) and Children (0.0080 mg/kgbw/d). The DIM values of Mn for adults and children were measured as; for Adult (0.0006–0.0086 mg/kgbw/d) and for children (0.0008–0.0131 mg/kgbw/d) with mean content of 0.0020 and 0.0031 mg/kgbw/d for adults and children, respectively. The minimum and maximum DIM values of Fe for adults and children were determined as; 0.0006–0.0103 mg/kgbw/d and 0.0006–0.0113 mg/kgbw/d, respectively, since the average DIM values for both adults and children were found as 0.0045 and 0.0049 mg/kgbw/d, respectively. Minimum, maximum and mean DIM values of Zn for adults and children were measured as; 0.0001, 0.0075 and 0.0026 mg/kgbw/d, and 0.0001, 0.0083 and 0.0029 mg/kgbw/d, respectively (Table 2-5).

Health Risk Indexes of (HRIs) Heavy Metals

The minimum, maximum and mean HRI of Cr for adults and children were observed as 0.0005, 0.0011 and 0.0008; and 0.0006, 0.0012 and 0.0009, respectively. HRI

Table 2. The mean daily intakes (mg/kgbw/d) and Health risk indexes of Heavy Metals via absorption of polluted potable water

Sample ID	Cr				Ni			
	Adult		Children		Adult		Children	
	DIM	HRI	DIM	HRI	DIM	HRI	DIM	HRI
G–1	0.0015	0.0010	0.0017	0.0011	0.50	0.03	0.55	0.03
G–2	0.0011	0.0007	0.0012	0.0008	0.44	0.02	0.49	0.02
G–3	0.0016	0.0011	0.0017	0.0012	0.47	0.02	0.52	0.03
G–4	0.0013	0.0008	0.0014	0.0009	0.31	0.02	0.34	0.02
G–5	0.0011	0.0007	0.0012	0.0008	0.39	0.02	0.43	0.02
G–6	0.0013	0.0009	0.0014	0.0009	0.56	0.03	0.61	0.03
G–7	0.0008	0.0005	0.0009	0.0006	0.56	0.03	0.61	0.03
G–8	0.0013	0.0008	0.0014	0.0009	0.58	0.03	0.64	0.03
G–9	0.0010	0.0007	0.0011	0.0007	0.42	0.02	0.46	0.02
G–10	0.0015	0.0010	0.0017	0.0011	0.47	0.02	0.52	0.03
G–11	0.0013	0.0009	0.0015	0.0010	0.28	0.01	0.31	0.02
G–12	0.0009	0.0006	0.0010	0.0007	0.42	0.02	0.46	0.02
G–13	0.0011	0.0007	0.0012	0.0008	0.47	0.02	0.52	0.03
G–14	0.0011	0.0007	0.0012	0.0008	0.42	0.02	0.46	0.02
G–15	0.0010	0.0007	0.0011	0.0007	0.47	0.02	0.52	0.03
G–16	0.0016	0.0010	0.0017	0.0011	0.33	0.02	0.37	0.02
G–17	0.0013	0.0009	0.0014	0.0009	0.50	0.03	0.55	0.03
G–18	0.0009	0.0006	0.0010	0.0007	0.44	0.02	0.49	0.02
G–19	0.0010	0.0007	0.0011	0.0007	0.58	0.03	0.64	0.03
G–20	0.0012	0.0008	0.0013	0.0009	0.72	0.04	0.80	0.04

Table 3. The mean daily intakes (mg/kgbw/d) and Health risk indexes of Heavy Metals via absorption of polluted potable water (*Continued*)

Sample ID	Cr				Ni			
	Adult		Children		Adult		Children	
	DIM	HRI	DIM	HRI	DIM	HRI	DIM	HRI
G–21	0.0015	0.0010	0.0017	0.0011	0.44	0.02	0.49	0.02
G–22	0.0010	0.0007	0.0011	0.0007	0.67	0.03	0.73	0.04
G–23	0.0012	0.0008	0.0013	0.0009	0.42	0.02	0.46	0.02
G–24	0.0014	0.0009	0.0016	0.0010	0.47	0.02	0.52	0.03
G–25	0.0015	0.0010	0.0017	0.0011	0.39	0.02	0.43	0.02

Table 4. The mean daily intakes (mg/kgbw/d) and Health risk indexes of Heavy Metals via absorption of polluted potable water

Sample ID	Cu				Mn			
	Adult		Children		Adult		Children	
	DIM	HRI	DIM	HRI	DIM	HRI	DIM	HRI
G–1	0.025	0.625	0.028	0.688	0.0006	0.0168	0.0008	0.0256
G–2	0.001	0.028	0.001	0.031	0.0014	0.0421	0.0021	0.0639
G–3	0.003	0.076	0.003	0.084	0.0011	0.0337	0.0017	0.0511
G–4	0.004	0.097	0.004	0.107	0.0008	0.0253	0.0013	0.0384
G–5	0.003	0.083	0.004	0.092	0.0086	0.2609	0.0131	0.3964
G–6	0.022	0.556	0.024	0.612	0.0011	0.0337	0.0017	0.0511
G–7	0.021	0.514	0.023	0.566	0.0017	0.0505	0.0025	0.0767
G–8	0.001	0.029	0.001	0.032	0.0008	0.0253	0.0013	0.0384
G–9	0.001	0.028	0.001	0.031	0.0011	0.0337	0.0017	0.0511
G–10	0.001	0.033	0.001	0.037	0.0014	0.0421	0.0021	0.0639
G–11	0.022	0.556	0.024	0.612	0.0008	0.0253	0.0013	0.0384
G–12	0.019	0.465	0.020	0.512	0.0008	0.0253	0.0013	0.0384
G–13	0.001	0.035	0.002	0.038	0.0017	0.0505	0.0025	0.0767
G–14	0.001	0.031	0.001	0.034	0.0017	0.0505	0.0025	0.0767
G–15	0.001	0.029	0.001	0.032	0.0028	0.0842	0.0042	0.1279
G–16	0.017	0.417	0.018	0.459	0.0014	0.0421	0.0021	0.0639
G–17	0.001	0.034	0.001	0.037	0.0006	0.0168	0.0008	0.0256
G–18	0.001	0.035	0.002	0.038	0.0044	0.1347	0.0068	0.2046
G–19	0.001	0.026	0.001	0.029	0.0017	0.0505	0.0025	0.0767
G–20	0.001	0.035	0.002	0.038	0.0031	0.0926	0.0046	0.1406
G–21	0.028	0.694	0.031	0.765	0.0022	0.0673	0.0034	0.1023
G–22	0.001	0.033	0.001	0.037	0.0044	0.1347	0.0068	0.2046
G–23	0.002	0.047	0.002	0.051	0.0022	0.0673	0.0034	0.1023
G–24	0.001	0.035	0.002	0.038	0.0025	0.0758	0.0038	0.1151
G–25	0.001	0.031	0.001	0.034	0.0014	0.0421	0.0021	0.0639

values of Ni like minimum, maximum and mean for adults and children were found as; 0.0100, 0.0400 and 0.0232; and 0.0200, 0.0400 and 0.0260 respectively in the potable water of the area under study. The range of HRI of Cu for adults and children in the study area were determined as 0.0260–0.6940 and 0.0290–0.7650, respectively, while the mean HRI value for adults and children was found as 0.1829 and 0.2014, respectively.

Table 5. The mean daily intakes (mg/kgbw/d) and Health risk indexes of Heavy Metals via absorption of polluted potable water

Sample ID	Fe				Zn			
	Adult		Children		Adult		Children	
	DIM	HRI	DIM	HRI	DIM	HRI	DIM	HRI
G–1	0.00417	0.005952	0.004587	0.006553	0.00528	0.017593	0.005810	0.019368
G–2	0.00306	0.004365	0.003364	0.004806	0.00178	0.005926	0.001957	0.006524
G–3	0.00167	0.002381	0.001835	0.002621	0.00183	0.006111	0.002018	0.006728
G–4	0.01028	0.014683	0.011315	0.016164	0.00178	0.005926	0.001957	0.006524
G–5	0.00250	0.003571	0.002752	0.003932	0.00167	0.005556	0.001835	0.006116
G–6	0.00472	0.006746	0.005199	0.007427	0.00583	0.019444	0.006422	0.021407
G–7	0.00389	0.005556	0.004281	0.006116	0.00169	0.005648	0.001865	0.006218
G–8	0.00528	0.00754	0.005810	0.008301	0.00172	0.005741	0.001896	0.006320
G–9	0.00333	0.004762	0.003670	0.005243	0.00197	0.006574	0.002171	0.007238
G–10	0.00889	0.012698	0.009786	0.01398	0.00183	0.006111	0.002018	0.006728
G–11	0.00500	0.007143	0.005505	0.007864	0.00750	0.025000	0.008257	0.027523
G–12	0.00250	0.003571	0.002752	0.003932	0.00169	0.005648	0.001865	0.006218
G–13	0.00778	0.011111	0.008563	0.012232	0.00175	0.005833	0.001927	0.006422
G–14	0.00306	0.004365	0.003364	0.004806	0.00189	0.006296	0.002080	0.006932
G–15	0.01000	0.014286	0.011009	0.015727	0.00167	0.005556	0.001835	0.006116
G–16	0.00139	0.001984	0.001529	0.002184	0.00722	0.024074	0.007951	0.026504
G–17	0.00222	0.003175	0.002446	0.003495	0.00167	0.005556	0.001835	0.006116
G–18	0.00361	0.005159	0.003976	0.005679	0.00167	0.005556	0.001835	0.006116
G–19	0.00472	0.006746	0.005199	0.007427	8.3E-05	0.000278	9.17E-05	0.000306
G–20	0.00861	0.012302	0.009480	0.013543	0.00169	0.005648	0.001865	0.006218
G–21	0.00056	0.000794	0.000612	0.000874	0.00611	0.020370	0.006728	0.022426
G–22	0.00333	0.004762	0.003670	0.005243	0.00214	0.007130	0.002355	0.007849
G–23	0.00444	0.006349	0.004893	0.006990	0.00169	0.005648	0.001865	0.006218
G–24	0.00222	0.003175	0.002446	0.003495	0.00169	0.005648	0.001865	0.006218
G–25	0.00417	0.005952	0.004587	0.006553	0.00164	0.005463	0.001804	0.006014

Table 6. Statistics with reference to daily intake and health risk indexes of heavy metals of potable water of area under study

	Daily Intake of Heavy Metals (DIM)											
	Cr		Ni		Cu		Mn		Fe		Zn	
	Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children
Min:	0.0008	0.0009	0.2800	0.3100	0.0010	0.0010	0.0006	0.0008	0.0006	0.0006	0.0001	0.0001
Max:	0.0016	0.0017	0.7200	0.8000	0.0280	0.0310	0.0086	0.0131	0.0103	0.0113	0.0075	0.0083
Mean	0.0012	0.0013	0.4688	0.5168	0.0072	0.0080	0.0020	0.0031	0.0045	0.0049	0.0026	0.0029
	Health Risk Indexes of Heavy Metals (HRIs)											
	Cr		Ni		Cu		Mn		Fe		Zn	
	Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children
Min:	0.0005	0.0006	0.0100	0.0200	0.0260	0.0290	0.0168	0.0256	0.0008	0.0009	0.0003	0.0003
Max:	0.0011	0.0012	0.0400	0.0400	0.6940	0.7650	0.2609	0.3964	0.0147	0.0162	0.0250	0.0275
Mean	0.0008	0.0009	0.0232	0.0260	0.1829	0.2014	0.0610	0.0926	0.0008	0.0070	0.0087	0.0096

The HRI range of Mn for adults and children was observed as; 0.0168–0.2609 and 0.0256–0.3964, respectively. Though, the average HRI value for adults and children was measured as 0.0610 and 0.0926, respectively. Minimum, maximum, and mean HRI values of Fe for adults and children were measured as 0.0008, 0.0147, and 0.006; and 0.0009, 0.0162, and 0.0070, respectively. For Zn, the minimum, maximum and mean HRI values for adults and children were determined as 0.0003, 0.0250, and 0.0087; and 0.0003, 0.0275, and 0.0096, respectively (Table 5).

CONCLUSION

The level of Cu and Zn were within the safe limit of the WHO, while Cr, Ni, Fe, Mn showed alarming levels in the drinking water of the study area. The DIM and HRI of heavy metals were measured for adults and children since the HRI values for all metals were < 1, which shows the lack of possible health hazards for the people of the study area. Finally, it can be concluded that groundwater used for drinking purposes must be treated before use. Otherwise, it may cause various diseases, for instance, heart disease, kidney failure, liver disease, blood pressure, hypertension, etc. it is, therefore, the responsibility of the government of Pakistan to provide either clean drinking water or to install reverse osmosis (RO) plants to clean drinking water before use for the people of the study area.

ACKNOWLEDGMENTS

The authors are highly thankful to the Pakistan Council of Research in Water Resources (PCRWR) Government of Pakistan Ministry of Science & Technology National Water Quality Laboratory, Islamabad, to analyze water samples for heavy metals.

AUTHOR CONTRIBUTIONS

Abdul Raheem Shar conducted the experiment, Ghulam Qadir Shar supervised the whole work, statistics of the data was carried out by Zulfiqar Jumani, Aslam Khan Pathan, Zubeda Bhatti corrected the grammatical mistakes, whereas Ali Raza Rind and Ghulam Mujtaba Jogi helped prepare the manuscript draft. All authors agreed to the final version of this manuscript.

REFERENCES

[1] Cherfi, A., Achour, M., Cherfi, M., Otmani, S., and Morsli, A., 2015, Health risk assessment of heavy metals through consumption of vegetables irrigated with reclaimed urban wastewater in Algeria, *Process Saf. Environ. Prot.*, 98, 245–252.

[2] Matta, G., and Kumar, A., 2017, Health risk, water hygiene, science and communication, *Essence*, 8 (1), 179–186.

[3] Patel, P., Raju, N.J., Reddy, B.C.S.R., Suresh, U., Sankar, D.B., and Reddy, T.V.K., 2018, Heavy metal contamination in river water and sediments of the Swarnamukhi River Basin, India: Risk assessment and environmental implications, *Environ. Geochem. Health*, 40 (2), 609–623.

[4] Riaz, A., Khan, S., Muhammad, S., Liu, C., Shah, M.T., and Tariq, M., 2018, Mercury contamination in selected foodstuffs and potential health risk assessment along the artisanal gold mining, Gilgit-Baltistan, Pakistan, *Environ. Geochem. Health*, 40 (2), 625–635.

[5] Moynihan, M., 2016, Role of Diet in Heavy Metal Exposure and Toxicity during Prenatal and Peripubertal Periods, *Thesis*, University of Michigan, US.

[6] Daud, M., Nafees, M., Ali, S., Rizwan, M., Bajwa, R.A., Shakoor, M.B., Arshad, M.U., Chatha, S.A.S., Deeba, F., Murad, W., Malook, I., and Zhu, S.J., 2017, Drinking water quality status and contamination in Pakistan, *BioMed. Res. Int.*, 2017, 7908183.

[7] Khan, A., Khan, S., Khan, M.A., Qamar, Z., and Waqas, M., 2015, The uptake and bioaccumulation of heavy metals by food plants, their effects on plants nutrients, and associated health risk: A review, *Environ. Sci. Pollut. Res.*, 22 (18), 13772–13799.

[8] Rezapour, M., Rezapour, H.A., Chegeni, M., and Khanjani, N., 2021, Exposure to cadmium and head and neck cancers: A meta-analysis of observational studies, *Rev. Environ. Health*, 36 (4), 577–584.

[9] US-EPA, 2015, *Guidelines for Carcinogen Risk Assessment*, US Environmental Protection Agency, EPA/630/P-03/001F, Washington, DC.

[10] Jaishankar, M., Mathew, B.B., Shah, M.S., Krishna Murthy, T.P., and Sangeetha Gowda, K.R., 2014, Biosorption of few heavy metal ions using agricultural wastes, *J. Environ. Pollut. Hum. Health*, 2 (1), 1–6.

[11] Mehmood, A., Mirza, M.A., Choudhary, M.A., Kim, K.H., Raza, W., Raza, N., Lee, S.S., Zhang, M., Lee, J.H., and Sarfraz, M., 2019, Spatial distribution of heavy metals in crops in a wastewater irrigated zone and health risk assessment, *Environ. Res.*, 168, 382–388.

[12] Muhammad, S., Shah, M.T., and Khan, S., 2011, Health risk assessment of heavy metals and their source apportionment in drinking water of Kohistan region, northern Pakistan, *Microchem. J.*, 98 (2), 334–343.

[13] US-EPA, 2011, *Exposure Factors Handbook 2011 Edition (Final Report)*, US Environmental Protection Agency, EPA/600/R-09/052F, Washington, DC.

[14] Nawab, J., Ali, S., Rauf, A., Ur Rehman, U., Khan, A.A., Sajjad, M., and Khan, W., 2015, Health risk associated with heavy metals via consumption of surface and groundwater in district Shangla, Pakistan, *J. Himalayan Earth Sci.*, 48 (2), 62–73.

[15] Shekhawat, K., Chatterjee, S., and Joshi, B., 2015, Chromium toxicity and its health hazards, *Int. J Adv. Res.*, 3 (7), 167–172.

[16] Vincent, J.B., 2015, Is the pharmacological mode of action of chromium (III) as a second messenger?, *Biol. Trace Elem. Res.*, 166 (1), 7–12.

[17] Kamerud, K.L., Hobbie, K.A., and Anderson, K.A., 2013, Stainless steel leaches nickel and chromium into foods during cooking, *J. Agric. Food Chem.*, 61 (39), 9495–9501.

[18] Seetharaman, J., and Sarma, M.S., 2021, Chelation therapy in liver diseases of childhood: Current status and response, *World J. Hepatol.*, 13 (11), 1552–1567.

[19] Greenwood, N.N., and Earnshaw, A., 2012, *Chemistry of the Elements*, 2nd Ed., Elsevier, Oxford, Massachusetts, US.

[20] Erikson, K.M., and Aschner, M., 2019, Manganese: Its Role in Disease and Health, in *Therapeutic Use and Toxicity of Metal Ions in the Clinic*, De Gruyter, Berlin.