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Research Article

Assessment of drinking water quality "Natural springs and surface water" and associated health risks in Gilgit-Baltistan Pakistan

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Abstract

Heavy metals in drinking water are not only detrimental to environment but also to human health. The study was carried out to investigate the quantification of heavy metals in selected springs and surface drinking water sources of Gilgit-Baltistan, Pakistan. Overall, 66 water samples were collected and analyzed. The concentration of heavy metals in 20% of the samples were beyond the National Standards for Drinking Water Quality (NSDWQ) and WHO guidelines. The concentration of heavy metals in 59% of the samples were within the permissible limits and only 21% of samples were free of heavy metals. The highest concentration of heavy metal beyond the permissible limit of NSDWQ was found in Skardu (23%), Nagar (15%), Hunza (15%) and 8% in Gilgit, Diamer and Ghizer respectively. The average concentration of heavy metals in drinking water sources were found in order of Al > B > Mn > Zn > Ba > Ni > Cr > Cu > As > Hg > Sb and > Se. Health risk index (HRI) and chronic daily intake (CDI) was calculated for both children and adults. CDI values detected were in order of Al > B > Mn > Zn > Ba > Cr > As > Ni > Cu > Hg > Sb > Se respectively. In addition, HRI values were in the sequence of Cr > Mn > Zn > Ni > Cu respectively. According to univariate and multivariate statistical analysis, geological activities taking place in the strata of the region were the possible source of HM in drinking water sources.

Keywords: Daily Chronic Intake; Health Risk Indexes; Heavy Metals; Reference Dose

Introduction

Access to safe drinking water is one of the most pressing challenges facing the world today. According to World Health Organization (WHO) 13.6% of total deaths (1386.4) in Pakistan are attributed to water, sanitation and hygiene **[1]**. In recent times, there has been an increasing health related concern associated with the quality of drinking water.

The water supply sector in Pakistan is characterized by extremely low level of coverage particularly in the rural areas; water supply coverage through piped network and hand pumps is around 66%. High arsenic found in major industrial cities of Punjab due to industrial and chemical waste discharge, elevated concentrations of iron reported in Khyber Pakhtunkhwa (KPK) while high level of turbidity was observed in Sindh [2].

GB is the water tower for rest of the country; its glaciers provide 50.5billion cubic meters of water to river Indus annually that corresponds to 70% of mean annual flow. Access to water is not an issue in GB, however quality of water has always been a concern in the region. Rapid population growth, economic advances, anthropogenic activities, lack of planning, capacities, and financial resources along with climate change are the fundamental factors for deterioration of water quality in GB.

The three main sources of drinking water in GB are springs, rivers and streams [3]. Surface water is the main source of water supply in urban areas of Gilgit-Baltistan. Usage of groundwater for domestic water supply is not common except in the low lying settlements of Gilgit city and a few riverside villages in Skardu, where people draw water from shallow wells. Quantity of water supply reduces in winter season due to reduced glacial melt in most of the urban areas.

Humans get exposed to heavy metals (HM) through inhalation and ingestion; long lasting bioaccumulation and toxicity of heavy metals (HM) have been found to be highly hazardous to human health and ecosystem [4, 5]. These chemicals enter water sources as a result of natural and anthropogenic activities like weathering, erosion of bed rocks; and industrial and agriculture practices respectively [6]. In mountainous area like GB, springs are formed due to water infiltration into cracks at higher elevations and oozes out at the other end at lower elevations through percolation under gravity. During this phenomena, flowing water erode the ground formation and take away minerals and heavy metals. The toxicity of metals to human depends on duration, concentration and route of exposure. Due to free radical formation, these metals can bio-accumulate in human body and cause various chronic disorders [7]. Exposure to these metals can lead to diseases such as Cancer, Kidney failure, Mental retardation, Muscular dystrophy, Parkinson's disease, Alzheimer's disease and Multiple sclerosis [8]. HM pose serious impacts on human such as Cd is a carcinogen and its exposure above 0.003 mg/L can cause severe damage to lungs, Irritates the stomach, leading to vomiting and diarrhea, kidney disease and fragile bones. Cu is also a toxic metal and its exposure above 1.5 mg/L can cause chronic anemia, Coronary heart diseases and high blood pressure while Mn is highly toxic to the human nervous system [9]. Exposure of Ni above 0.02 mg/L is very dangerous and can cause throat, nose, lungs and stomach cancer [10]. According to world health organization (WHO) exposure of Zn for a specific time above 3 mg/L can have adverse impacts on human health like vomiting, nausea, stomach pain, anemia, damage pancreas and decrease level of high-density lipoprotein cholesterol.

Being a developing country, Pakistan needs to address the problems related to safe drinking water and its availability [11]. Majority of the rural and urban population in Pakistan has no access to clean drinking water [12] which results in high incidence of water and sanitation related diseases in Pakistan. The country lacks proper drinking water quality and sanitation monitoring system [13]. In Pakistan, 50% of all diseases and 40% of all deaths are due to poor water quality [14].

Contamination of aquatic ecosystems by heavy metals (HM) is the prime concern of the world during the last decade [15]. HM contaminate the surface and ground water resulting in deterioration of drinking water quality [16]. Several studies have documented direct and indirect effects of heavy metals like zinc (Zn), lead (Pb), nickel (Ni), manganese (Mn), copper (Cu), chromium (Cr) and cadmium (Cd) in drinking water on human health. HM cause severe ecological threat when enter into the food chain through bioaccumulation and have long term exposures and adverse effects on human health **[17]**.

Rapid increase in human population from the last three decades has excelled altered the process of contamination of surface water through different anthropogenic activities **[18, 19]**.

According to an estimate in 2004-05, 62% of households had access to tap water inside or within a reasonable distance from their homes via storage and partial treatment at Water Supply Complexes-the highest rate in Pakistan **[20]**.

This study was conducted in selected areas to identify concentration of different chemicals and heavy metals in springs and surface drinking water sources of GB to point out sources of HMs contamination using multivariate statistical analysis, and to measure health risks in the study region. The finding of the study would provide a way forward to plan and implement water supply projects keeping in view the hazards posed by HM to human health and their occurrence in natural spring and streams, once considered safe across GB.

Materials and Methods

Study area

Gilgit-Baltistan is situated in the northern part of Pakistan, sharing its international borders with China in the north, Afghanistan in the northwest and India in the east and southeast. GB comprise on ten districts: Gilgit, Hunza, Nagar, Ghizer, Diamer, Astore, Skardu, Shigar, Kharmang and Ghanche lies between latitude 30° N to 37° N and longitude 72° E to77° E (Fig. 1) **[21]**. It covers almost an area of 72,496 km^{-2}. GB is one of the mountainous landscapes in the world; here the three mightiest mountain ranges of the world – Karakoram, Hindukush and N. W. Himalaya, intersect near Bunji at the confluence of Gilgit and Indus rivers. The longest glaciers outside polar region is located here. Pristine valleys and elegant peaks are the home of vast species of wildlife. Physiography of the region varies in accordance with the elevation, rain, snowfall and sunlight. Indus the Lion River is fed by Shayok, Shigar, Hunza, Astore and Gilgit rivers. Hundreds of other tributaries also join it on its way down. Geologically, this region is unstable. Geologists say, two deep level regional thrusts-main mantle thrust (MMT) across South while main Karakoram thrust (MKT) at the north, almost horizontally run across these mountain ranges. The region is meeting point of Indo Pak. and Asiatic plates. Due to collision of these plates, the area is moving and bulging northwards by 5 centimeters, annually. By virtue of this, Nanga parbat is gaining an average height by 7mm annually **[21]**.

Sampling

Total 66 water samples were collected using simple random sampling method. Samples were selected on basis of their use for drinking purpose by nearby communities or by visitors from across GB. Oneliter sample was collected form each representative sample. Water specimen gathered in contaminant free plastic bottles sterilized with 20% diluted nitric acid and transported in ice box to maintain the temperature.

Chemical analysis

GB-EPA procured equipment Metalyser HM2000 serial No. MY-011-006 made in the United Kingdom to test cadmium (Cd), mercury (Hg), arsenic (As), and zinc (Zn) while Metalometer HM2000 serial No.MM005-007 made in the United Kingdom was used to detect aluminium (Al), boron (B), iron (Fe), copper (Cu), manganese (Mn), chromium (Cr), and nickel (Ni) on site. The samples were then sent to Pakistan Institute of Nuclear Sciences and Technology (PINSTEC), Islamabad for further detailed analysis. Equipment and techniques used for analysis of metals at PINSTEC are shown in (Table 1).

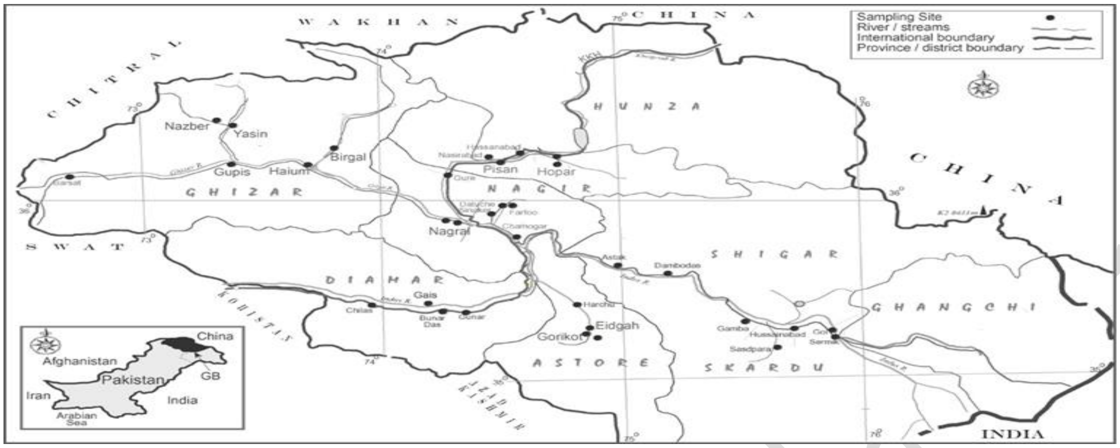

Figure 1. The location of the sampling stations depicted on the image in Gilgit-Baltistan Pakistan

Table 1. Equipment used for detailed chemical analysis at PINSTEC Islamabad

Metals	Equipment used to detect HM
Al, B, Ba, Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, SO_4, Si, Sr, Zn	Inductively coupled plasma optical emission spectrometry 6500 (ICP-OES)
AS, Cd, Hg, Cr, Cu, Pb, Sb, Se	Graphite furnace atomic absorption (GFAAS) Hydride generation atomic absorption spectrometry (HGAAS)

Methods for evaluating health risks

Chronic daily intakes (CDI) of metals

HM take different pathways to enter human body which are during inhalation, skin contact and food intake. All the routes are deemed insignificant in relation to oral ingestion. The following equation was used to compute CDI (mg/(kg-day)) of HMs from water intake;

$$\mathbf{CDI} = \frac{C_m - I_w}{W_b} \quad \mathbf{(1)}$$

where, C*m* (mg/L) is the HM content in water; I*w* (L/day) is the water intake per day (supposed to be be 2L/day for adults and 1 L/day for children) (US EPA, 2011); while W*b* (kg) is the averagely body weight (supposed to be 72 kg for adult and 32.7 kg for child).

Health risk indexes (HRIs) of metals

Estimation of prolonged healthiness hazards, HRIs was measure through the following equation.

$$\mathbf{HRI} = \frac{CDI}{RfD} \quad \mathbf{(2)}$$

The (RfD, mg/(kg·day)) represents the verbal harmfulness level for Cr, Cu, Mn, Ni, and Zn observed as 1.5, 0.037, 0.14, 0.02 and 0.3 respectively. The HRI level lower than 1 is harmless for the users.

Statistical analysis

All the calculations and statistical analysis were performed in MS Office 2013 and SPSS 20 respectively. A one-way factorial ANOVA was used to evaluate any remarkable differences in HMs contents between different places. The Pearson relationship assessment was used to see whether there was any conceivable relationship between the factors that were being assessed. One-mode factor ANOVA was used to test significance difference in HM among sites. Pearson relationship employed to find out any correlation between tested factors.

Results and Discussion

Concentration of heavy metals in drinking water sources

Heavy metals content in consumable water representatives gathered from seven districts (Skardu, Hunza, Nagar, Astore, Gilgit, Ghizer and Diamer) of Gilgit Baltistan is summarized in (Table 2). Long lasting bioaccumulation and toxicity of heavy metals has demonstrated a great threat for human health and environment. Humans get exposed to the metals through inhalation and ingestion. These chemicals enter water sources through natural phenomena as well as anthropogenic activities. The average concentration of HMs in drinking water sources were observed in sequence of Al > B > Mn > Zn > Ba > Ni > Cr > Cu > As > Hg > Sb and > Se. Mean concentrations of Al, Ni and Hg were higher as compared to the corresponding allowable boundaries set by WHO and Pak-EPA **[22, 23]**. The concentration of all other metals i.e. Ba, As, B, Zn, Mn, Cr, Cu, Sb and Se were within limits.

The mean concentration of Ba in drinking water samples from Skardu, Hunza, Gilgit, Ghizer, Diamer, Nagar and Astore were (0.017143 ± 0.0081), (0.007 ± 0.004), (0.0044 ± 0.001), (0.006 ± 0.0022), (0.0125 ± 0.0063), (0.122 ± 0.02) and (0.01 ± 001) mg/l respectively. In nature Barium is found in sedimentary and igneous rocks as a trace element. Drinking water gets mixed with Barium when it seeps from mountain top through sedimentary and igneous rocks. Barium can cause muscle weakness, blood pressure, diarrhea, difficulties in breathing, vomiting and abdominal cramps on short term exposure. Intake of larger amount can cause paralysis, high blood pressure and heart problems **[24]**.

The mean concentration of As was (0.019 ± 0.0054), (0.004 ± 0.002), (0.0005 ± 0.00036), (0.0015 ± 0.001), (0.007 ± 0.005), (0.0044 ± 0.0011) and (0.0007425 ± 0.00043) mg/l in same locations respectively. Arsenic is the 29th most abundant element and most important metal causing anxiety from both individual and ecological perspectives. Naturally it exists in the deposition of salts and oxides of iron, calcium, sodium, and copper **[25]**. The inorganic forms like arsenate and arsenide are toxic for human health and environment. Beside from its natural occurrence it is released in a large quantity from volcanic activity, forest fires, rocks erosion and anthropogenic activities. Arsenic is carcinogen and can affect skin, liver and lungs. Primarily it influences sulfhydryl cluster of tissues resulting in disorder of cell enzymes, and mitosis **[26]**.

The mean concentration of B in tested samples were (0.033 ± 0.012), (0.003 ± 0.001), (0.53 ± 0.4) and (0.004 ± 0.001) mg/l in Skardu, Hunza, Nagar and Gilgit respectively. The samples collected from Ghizer, Diamer and Astore were free of Boron contamination. The existence of boron suggests the occurrence of boron-containing minerals such as kernite, borax and colemanite as well as loam-rich rocks genesis and rocksalt. A high level of boron in the body produces queasiness, vomiting, diarrhea and blood coagulation **[27]**.

Hg was found in the samples collected from Skardu, Gilgit, Ghizer, Nagar and Astore. The concentration of Hg in Skardu and Astore was found above the permissible limits. Hg concentrations were (0.0094 ± 0.0004), (0.0002 ± 0.0001), (0.000074 ± 0.000012), (0.00067 ± 0.00021) and (0.0025 ± 0.001) mg/l respectively. Mercury is exceedingly bio-accumulative and toxic for human. Naturally, Hg is present in the structures of metallic component inorganic salts and organic substances. It also reacts with other elements to form inorganic and organic forms. Microorganisms in soil and water converts mercury into methylmercury which is a bio-accumulating toxin and cause mental retardation. Mercury is likely to known as carcinogen. All forms of mercury damage nervous system. High level of exposure can damage kidneys, developing fetuses and brain. Impacts on brain functioning may result in form of shyness, memory loss, irritability, vision and hearing disorders.

The concentration of Manganese was (0.19 ± 0.01), (0.07 ± 0.02) and (0.086 ± 0.03) mg/l in Nagar, Gilgit and Ghizer respectively. Manganese is neurotoxic and damage nerve cells. Manganese usually occurs with iron and is found in ores of more than 100 deposits whereas it is also found in mixture of elemental components [28]. Only one sample from Nagar was contaminated by Al (16.65 ± 0.05) mg/L. It has been reported the 3rd highest substance on earth crust and present naturally in water, soil and air [29]. Recent research has reviled that aluminium can cause a major threat to human health [30]. The toxicity of aluminium is majorly influenced by organic matter content and pH of water. High concentration of aluminium is very toxic and harmful to nervous, osseous and hemopoietic cells [30]. Aluminium is nonessential and has no biological role. Aluminium may disturb cellular growth, intercellular communication and secretory functions. Aluminium is neuro toxic and cause neuronal atrophy.

Chromium was detected in two samples from Diamer and Nagar in a concentration of (0.0155 ± 0.001) and (0.033 ± 0.001) mg/l respectively. Cr is the 7th most abundant element on the crust. Cr can be found in many oxidation states but most occurring toxic forms are trivalent and hexavalent. Chromium(VI) in oxidized condition is greatly solvable in water and has toxic effects on human and environment. Chromium (III) which is not toxic in nature reacts with the oxygen in the environment and converts into Chromium (VI) which is known to be toxic for human [31]. Compounds of Chromium are toxins and cause cancer, whereas it is also a vital nutrient in a trace amount. Chromium can damage kidney, liver, nerve tissues and cause skin irritation on long term exposure.

Copper and Nickel was found in only one sample from Nagar in a concentration of (0.015 ± 0.001) (0.025 ± 0.002) mg/l. Nickel enters body through drinking water and food. Over exposure to Nickel can cause cancer of throat, nose, stomach, and lungs. High level of copper in drinking water may cause chronic anaemia. Ingestion of copper through food and water may also lead to coronary heart diseases and high blood pressure [32].

Samples from Skardu and Astore were found contaminated with Antimony in concentrations (0.00013 ± 0.00003) and (0.0045 ± 0.0021) mg/l respectively. Human gets exposed to Antimony through food, water, inhalation and occupational exposure. High exposure may cause irritation in respiration, genotoxic, and pneumoconiosis and antimony spot on the skin.Selenium was found only in Gilgit in a concentration (0.00022 ± 0.000146) mg/l. Trace amount of selenium is necessary for cellular metabolism and needed in thyroid glands functioning.

Health risk assessments

Chronic daily intakes of heavy metals

Chronic daily intake level of HM in selected areas of GB are summarized in (Table 3). The CDI values of HM detected in sequence Al > B > Mn > Zn > Ba > Cr > As > Ni > Cu > Hg > Sb > Se. The highest CDI value of Al (0.462 mg/(kg.day) was detected in Nagar. The mean CDI values of B ranged from 0.00008 to 0.14 mg/(kg.day) in adults and 0.000091 to 0.0161 mg/(kg.day) in children. In Nagar, the highest CDI value of "B" in adults and children were 0.14 and 0.0161 mg kg^{-1} day^{-} respectively. Whereas, the mean CDI value of Mn ranged from 0.002 to 0.005 mg/(kg.day) in adults and 0.0022 to 0.0057 mg/(kg.day) in children. The highest CDI values of Mn in adults and children were detected in Nagar and lowest in Gilgit. Zn ranged from 0.00027 to 0.0049 mg/(kg.day)

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in adults and 0.003 to 0.005 mg/(kg.day) in children. The highest CDI values of Zn were detected in Nagar and lowest in Skardu for both in adults and children. CDI values of Hg ranged from 0.00000205 to 0.000258 mg/(kg.day) and 0.00000226 to 0.0028 $mgKg^{-1}day^{-1}$/(kg.day) in adults and children respectively. The highest CDI value of mercury was observed in Skardu and lowest in Ghizer. CDI values for Al, Ni and Cu were only detected in Nagar which were 0.046, 0.00069 and 0.00041 mg/(kg.day) for adults and 0.5,0.0076, and 0.00043 mg/(kg.day) for children, respectively. Cr CDI values 0.00043 and 0.0155 mg/(kg.day) for adults and 0.001 and 0.00047 mg/(kg.day) for children were found in Nagar and Diamer respectively. CDI value for Se in Gilgit were 0.0000061 and 0.000067 mg/(kg.day) in adults and children respectively.

Health risk indexes (HRI) of heavy metals

HRIs values based on drinking water quality are detected in the sequence of Cr > Mn > Zn > Ni > Cu. The HRIs values for Cr found in Nagar and Diamer were (0.000618, 0.00062) and (0.00029, 0.00032) for mature and adolescent respectively. For adults HRIs of Zn were 0.0093, 0.0163, 0.0013 and 0.0015 in Skardu, Nagar Gilgit and Ghizer respectively. In children the HRIs of Zn were 0.00102, 0.018, 0.0014 and 0.0017 one to one. The HRI value of Mn in in adults were 0.037, 0.014 and 0.017, whereas in children it was 0.04, 0.016 and 0.018 in Nagar, Gilgit and Ghizer respectively. In Nagar HRIs values of Ni and Cu were (0.034, 0.038) and (0.011, 0.012) for adults and children correspondingly (Table 4).

Principal component analysis (PCA)

PCA with three factors was applied to evaluate the qualitative behaviors of clustering. The component matrix and rotated component matrix for drinking water is summarized in (Table 5). The total cumulative variance revealed by the PCA for three factors was 82.089 %, within which 50.125 % was contributed by factor-1 to the total variance with a high loading on Cr (r = 0.997), Mn (r = 0.997), Al (r = 0.997), Cu (r = 0.997), Ni (r = 0.997) and Zn (r = 0.997) as shown in (Table 5). The levels of Mn, Cr, Al, Cu, Ni and Zn might be because of weathering of igneous and extreme igneous rocks. Total 17.72% was contributed by factor-2 which showed total alteration with greater loading on Zn (r = 0.988), As (r = 0.715) and Hg (r = 0.606). Factor-3 contributed 14.72% to the total variance with a high loading on Ba (r = 0.908) and B (r = 0.355). In mountainous area like GB, springs are formed due to water infiltration into cracks at higher elevations and oozes out at the other end at lower elevations through percolation under gravity. During this phenomena, flowing water erode the ground formation and take away minerals and heavy metals which could be the reason for contamination of these spring sources.

Correlation within selected HM

Inter metal correlation summarized in (Table 6) showed a positive correlation of Zn with Ba (r = 0.985212) and B (r = 0.993471), Hg with As (r = 0.857217), Mn with Ba (r = 0.809938), B(r = 0.840744) and Zn (r = 0.896735), Al with Ba (r = 0.994859), B (r = 0.998209) and Zn (r = 0.993756), Cr with Ba (r = 0.904836), B (r = 0.887121), Zn (r = 0.868609), Mn (r = 0.688509), Ni with Ba (r = 0.994859), B (r = 0.998209), Zn (r = 0.993756), Mn (r = 0.851009), Cr (r = 0.895494), and Cu with Ba (r = 0.994859), B (r = 0.998209), Zn (r = 0.993756), Mn (r = 0.851009), Cr (r = 0.895494). Except with Hg, As showed a weak negative correlation with all other metals.

Table 2. HM concentration in drinking water samples (mg/l)

Parameter	Statistics	Skardu	Hunza	Nagar	Astore	Gilgit	Ghizer	Diamer
		n=6	n=6	n=6	n=6	n=6	n=6	n=6
Ba	Range	0-0.06	0-0.04	0-0.72	0-0.01	0-0.04	0-0.02	0-0.03
	Mean	0.017	0.007	0.121	0.01	0.004	0.006	0.0125
	Stnd.Er	0.008	0.003	0.119	0	0.004	0.0022	0.006291529
As	Range	0-0.11	0-0.017	0.0012-0.0071	0-0.0015	0-0.0026	0-0.012	0-0.023
	Mean	0.018	0.004	0.004	0.00074	0.000544	0.0015	0.007
	Stnd.Er	0.015	0.001	0.001	0.00042	0.000361	0.0012	0.00546199
Zn	Range	0-0.04		0-1.02		0-0.04	0-0.12	
	Mean	0.01	ND	0.176	ND	0.0144	0.017	ND
	Stnd.Er	0.006		0.168		0.0058	0.012	
Hg	Range	0-0.06		0-0.004	0-0.01	0-0.002	0-0.0074	
	Mean	0.009	ND	0.00066	0.0025	0.0002	0.000074	ND
	Stnd.Er	0.008		0.00066	0.0025	0.0002	0.000074	
B	Range	0-0.23	0-0.03	0-2.33				
	Mean	0.032	0.003	0.528	ND	ND	ND	ND
	Stnd.Er	0.032	0.003	0.384				
Sb	Range	0-0.009			0-0.009			
	Mean	0.0001	ND	ND	0.0045	ND	ND	ND
	Stnd.Er	0.0001			0.0021			
Mn	Range			0-1.13		0-0.66	0-0.86	
	Mean	ND	ND	0.188	ND	0.0733	0.086	ND
	Stnd.Er			0.188		0.0733	0.086	
Al	Range			0-99.92				
	Mean	ND	ND	16.653	ND	ND	ND	ND
	Stnd.Er			16.653				
Cr	Range			0-0.2				0-0.062
	Mean	ND	ND	0.033	ND	ND	ND	0.0155
	Stnd.Er			0.033				0.0155
Ni	Range			0-0.15				
	Mean	ND	ND	0.025	ND	ND	ND	ND
	Stnd.Er			0.025				
Cu	Range			0-0.09				
	Mean	ND	ND	0.015	ND	ND	ND	ND
	Stnd.Er			0.015				
Se	Range					0-0.001		
	Mean	ND	ND	ND	ND	0.00022	ND	ND
	Stnd.Er					0.00014		

*ND: Not Detectable

Table 3. Chronic Daily Intakes (CDIs, mg/(kg-day) of heavy metals in drinking water samples

Parameter	Individuals	Skardu n=16	Hunza n=16	Nagar n=16	Astore n=16	Gilgit n=16	Ghizer n=16	Diamer n=16
Ba	Adults Children	0.00047619 0.000524246	0.000194444 0.000214067	0.00337963 0.003720693	0.000277778 0.00030581	0.000123457 0.000135916	0.000166667 0.000183486	0.000347222 0.000382263
As	Adults Children	0.000519841 0.000572302	0.000111111 0.000214067	0.000121204 0.000133435	0.000020625 2.27064	1.51235E-05 1.66497	4.1667E-05 4.58716E-05	0.000194444 0.000214067
Zn	Adults Children	0.000277778 0.00030581	ND	0.004907407 0.00540265	ND	0.000401235 0.000441726	0.000472222 0.000519878	ND
Hg	Adults Children	0.000258333 0.000284404	ND	1.85185E-05 2.03874E-05	6.94444E-05 7.64526E-05	6.17284E-06 6.79579E-06	2.056E-06 2.263E-06	ND
B	Adults Children	0.000912698 0.001004806	8.33333E-05 9.17431E-05	0.014675926 0.016156983	ND	ND	ND	ND
Sb	Adults Children	3.33333E-06 3.66972E-06	ND	ND	0.000125 0.000137615	ND	ND	ND
Mn	Adults Children	ND	ND	0.005231481 0.005759429	ND	0.002037037 0.00224261	0.002388889 0.002629969	ND
Al	Adults Children	ND	ND	0.462592593 0.509276249	ND	ND	ND	ND
Cr	Adults Children	ND	ND	0.000430556 0.001019368	ND	ND	ND	0.00043056 0.000474006
Ni	Adults Children	ND	ND	0.000694444 0.000764526	ND	ND	ND	ND
Cu	Adults Children	ND	ND	0.000416667 0.000458716	ND	ND	ND	ND
Se	Adults Children	ND	ND	ND	ND	6.17284E-06 6.79579	ND	ND

*ND: Not detectable

Table 4. Health Risk Indexes (HRIs) of heavy metals through drinking water consumption

Parameter	Individuals	Skardu n=16	Hunza n=16	Nagar n=16	Astore n=16	Gilgit n=16	Ghizer n=16	Diamer n=16
Ba	Adults Children	NC	NC	NC	NC	NC	NC	NC
As	Adults Children	NC	NC	NC	NC	NC	NC	NC
Zn	Adults Children	0.0093 0.00102		0.01636 0.01801		0.00134 0.00147	0.00157 0.00173	
Hg	Adults Children	NC	NC	NC	NC	NC	NC	NC
B	Adults Children	NC	NC	NC	NC	NC	NC	NC
Sb	Adults Children	NC	NC	NC	NC	NC	NC	NC
Mn	Adults Children			0.03737 0.04114		0.01455 0.01602	0.01706 0.01879	
Al	Adults Children	NC	NC	NC	NC	NC	NC	NC
Cr	Adults Children	NC	NC	0.00062 0.00068	NC	NC	NC	0.00029 0.00032
Ni	Adults Children	NC	NC	0.03472 0.03822	NC	NC	NC	NC
Cu	Adults Children	NC	NC	0.01126 0.0124	NC	NC	NC	NC
Se	Adults Children	NC	NC		NC	NC	NC	NC

*NC: Not calculated

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Table 5. Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization

	Component Matrix			Rotated Component Matrix		
	Factor 1	**Factor 2**	**Factor 3**	**Factor 1**	**Factor 2**	**Factor 3**
Cr	.996	.073	.021	**.997**	-.069	.028
Mn	.996	.073	.021	**.997**	-.069	.028
Cu	.996	.073	.021	**.997**	-.069	.028
Al	.996	.073	.021	**.997**	-.069	.028
Ni	.996	.073	.021	**.997**	-.069	.028
Zn	-.167	.965	-.085	-.004	**.899**	.143
As	-.129	.783	.447	-.067	**.715**	.672
Hg	-.107	.495	-.767	-.143	**.606**	-.231
Ba	-.226	.307	.544	-.118	-.080	**.908**
B	-.084	-.245	.259	-.088	-.016	**-.355**
Variance (%)	50.788	19.696	11.604	50.125	17.172	14.792
Cumulative (%)	50.788	70.485	82.089	50.125	67.297	82.089

Table 6. Correlation matrixes of selected heavy metals

	Ba	**As**	**B**	**Zn**	**Hg**	**Mn**	**Al**	**Cr**	**Ni**	**Cu**	**Sb**	**Se**
Ba	1											
As	0.027431	1										
B	0.997445	-0.00796	1									
Zn	0.985212	-0.06377	0.993471	1								
Hg	-0.06752	0.857217	-0.09341	-0.1379	1							
Mn	0.809938	-0.30613	0.840744	0.896735	-0.3299	1						
Al	0.994859	-0.06254	0.998209	0.993756	-0.14935	0.851009	1					
Cr	0.904836	-0.00651	0.887121	0.868609	-0.25125	0.688509	0.895494	1				
Ni	0.994859	-0.06254	0.998209	0.993756	-0.14935	0.851009	1	0.895494	1			
Cu	0.994859	-0.06254	0.998209	0.993756	-0.14935	0.851009	1	0.895494	1	1		
Sb	-0.16377	-0.28967	-0.185	-0.21755	0.113596	-0.31422	-0.17182	-0.24434	-0.17182	-0.17182	1	
Se	-0.25183	-0.40503	-0.20798	-0.1553	-0.19565	0.100568	-0.2	-0.28867	-0.2	-0.2	-0.2	1

Conclusion

This research concludes that most of the drinking water sources in GB are contaminated with heavy metals, which are attributed to the natural geogenic processes taking place in the strata of this region, these metals are potential environmental contaminants and hazardous to human health, thus there is dire need to reduce the risk of exposure. Presence of these chemicals in springs and surface water sources are the main cause of the health issues in the region. Water supply is a specialized subject of Public Health Engineering being dealt in the region through conventional methods and practices. A water supply system in GB is meant to take water from the source and store in a tank for subsequent supply to the command area without any treatment, keeping in view the water quality and its demand for making it safe. The treatment system to remove chemical contamination from drinking water is highly technical and expensive. It is better option to avoid the source contaminated with chemicals. Keeping in view the above it is highly recommended that future planning of water supply systems shall consider the nature and concentration of the pollutants in the water source and provision of appropriate treatment system.

Authors' contributions

Conceptualization: SW Hussain, Conceived and designed the study: K Hussain, SW Hussain & S Liaqat, Laboratory work: SJ Hussain, SW Hussain, Q Zehra & A Ali, Assembly of data, data analysis and interpretation: SW Husssain, B Hussain & Y Abbas, Formal analysis: SW Hussain, B Hussain, Y Abbas & A Ali, Experimental work supported: SW Hussain, K Hussain & S Liaqat, Methodology: SW Hussain, B Hussain & Y Abbas, Writing original draft preparation: SW Hussain, Funding Acquisition: K Hussain.

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