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Analysis of drinking water quality and health risk assessment- A case study of Dir Pakistan

Muhammad Ilyas[1], Sardar Khan[1]*, Anwarzeb Khan[1]*, Rohul Amin[2], Asif Khan[1] and Muhammad Aamir[1]

[1]Department of Environmental Sciences, University of Peshawar
[2]Mathematics Department, University of Peshawar
**Corresponding authors' email: khan.anwarzeb@yahoo.com; sardar.khan2008@yahoo.com*
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Abstract

The current study was conducted to explore the physicochemical characteristics, light and heavy metal concentrations in drinking water of the selected area of Lower Dir, Pakistan. In the study area, no such study about the assessment of drinking water quality has been carried out. The people of Lower Dir are unaware about the quality of water and adverse impacts of contaminated water. The research work will provide base for the awareness campaign regarding the importance of pure and safe drinking water quality.. For this purposes, the water samples (n=22) were collected and analyzed for various parameters. Among the physical parameters the pH, dissolved oxygen (DO), electrical conductivity (EC), salinity and temperature, while in chemical parameters the alkalinity, total dissolved solids (TDS), hardness, chlorides (Cl^-), and sulfates were determined. Light metals such as magnesium (Mg^{+2}), calcium (Ca^{+2}), sodium (Na^+), and potassium (K^+) and heavy metals included lead (Pb), chromium (Cr), nickel (Ni), and zinc (Zn) were analyzed in the collected samples. The results showed that all the parameters were within the permissible limits set by World Health Organization (WHO) and Pakistan Environmental Protection Agency (Pak-EPA) except hardness (351.44 mg/L). The light metals were within the permissible limit except Mg^{+2} (308.60 mg/L) that exceeded the permissible limits of WHO and Pak-EPA, while Ca^{+2} (53.71 mg/L) exceeded the permissible limit of WHO. The heavy metal results showed that all the metals were within permissible limit except Cr (0.18 mg/L) and Pb (0.04 mg/L). The health risk assessment like Average Daily Dose (ADD) and Hazard Quotient (HQ) were calculated for heavy metals. All heavy metals in drinking water samples indicated no health risk (CDI and HQ<1).

Keywords: Water quality analysis; Health risks; Dir; Spring; Hardness; Electric conductivity.

1. Introduction

Drinking water is a vital component for human being and contamination of such vital resource due to intensive population growth, industrialization and urbanization is a serious health concern (Velea et al., 2009). Clean and safe drinking water is the key to good health (Tahir, 2004). In drinking water, there should be a balance in physical, chemical and biological ingredients (Rezaee et al., 2001). Human being use water for a variety of purposes in the homes, industries, agriculture and for recreation purposes (Shirley et al., 2000). House hold uses may include drinking, personal hygiene, cleaning and for food production (Cahill, 2000). Drinking water is contaminated from either geogenic (erosion, rocks weathering, and ore deposits) or anthropogenic (wastewater, agriculture activities, mining and industries) sources (khan et al., 2013a). The geology of the area and water-rock interaction has significant influence on the water quality. Previously, several studies have been conducted on water quality which showed that well water in areas with specific geological feature did not meet the required drinking water standard without anthropogenic influence (Edmunds and Smedley, 1996). Agriculture effluents discharge into aquatic systems pose serious threats to the community consuming such contaminated water (Alkarkhi et al., 2008). For safe and healthy life, drinking water must be free from pathogens and organic and inorganic pollutants (Kraemer et al., 2001). It should be free from all those impurities which affect the color, taste and odor of water. Once these impurities are removed water can be used for drinking purpose without any hesitation regarding adverse health effects (Greenstone and Hanna, 2011).

WHO (1993) and European Commission (EC, 1998) have recommended general drinking water quality guidelines. However, the term Maximum Allowable Concentration for heavy metals in drinking and spring water is still a subject of interest for scientists and researchers. Trace elements concentration in ground water is also a subject of interest (Giammanco et al., 1998). Similarly, the shifting of interest towards the need for clean drinking water and prevention of environmental pollution for healthy life leads to establish drinking water quality guidelines (WHO, 1993; WHO, 1995).

The water of the earth is broadly categorized into two main categories, surface water which flow over the earth surface and ground water which found beneath the earth surface and in natural aquifers. As far as human uses are concerned, both of these water forms have been used for various purposes but it also then depend upon the specific area conditions and the quality of water being used (Eldon and Bradley, 2004). Best qualities of pure and clean drinking water, means free from any physical, chemical and biological contaminants. Any change in these parameters will affect the water quality, which have a negative impact on human health. Water having any change in color, taste or odor, is considered to be contaminated and cannot be used for drinking purposes (Kraemer et al., 2001). The surface water is more easily accessible and at the same time more exposed to be contaminated by the suspended dust particles and other microorganisms.

Besides, it depends upon various other factors such as environmental set up of that particular area, waste material mixed with water and discharge from the agricultural field and treatment plants. Rainfall and topography of the specific region also play an important role in determining the water quality (Greenstone and Hanna, 2011).

On the other hand, ground water is more safe compared to surface water, because it is free from any dust particles and any other harmful materials. Springs, wells and tube wells are the common sources of gourd water. Keeping in view, deep wells are less prone to contamination while shallow wells are more, which may cause numerous environmental and health problems. Mostly, the underground water is comprises of chemical constituents, which are of different kinds. The kinds of such chemical constituents depend on water movement, geo-chemical environment and source of underground water. The concentration of dissolved constituents is comparatively higher in underground water as compared to the surface water (Tahir, 2004). Heavy metals, metalloids and dissolved matter in drinking water pose serious human health hazards (Abbas et al., 2001).

Chemical contamination is one of the serious matters that affect the underground water through infiltration, leaks in pipelines and cross contamination between aquifers that can transmit the pollutants among the aquifers (Rapant and Krcmova, 2007). Heavy metals are toxic in nature and impair the quality of water and food, therefore, they are of global concern among environmental contaminants (Shah et al., 2012a). Improper and inadequate sanitation and chlorination and sewage flooding may result in waterborne diseases in human beings (Abu-Amr and Yassin, 2008). Similarly unhygienic living condition of poor societies is also the causing factor of water borne diseases (Lehloesa and Muyima, 2000) in most of the developing countries. According to United Nation Environmental Program (UNEP), five millions to ten millions deaths occur every year from the diseases caused by polluted water. A study carried out by the United Nation (UN) claimed that in 2025, most of the people will be suffering from the shortage of fresh water (Seckler et al., 1998).

Globally environmental researchers have a prime focus on health risk assessment of human through consumption of drinking water (Spayd et al., 2012). Pakistan is a developing country, facing serious crisis in safe and clean portable water supply in urban and rural areas. In the northern region of Pakistan, only few studies on the drinking water contamination have been reported in the past (Khan et al., 2013a; Shah et al., 2012a; Muhammad et al., 2011). The aim of the study was to investigate the current status of quality of drinking water and to assess the health risks of contaminated water to the people of Lower Dir. The people are unaware about the quality of water and adverse impacts of contaminated water. The research work will provide a base for the awareness campaign regarding the importance of pure and safe drinking water quality.

2. Experimental

2.1. Study area description

District Lower Dir is situated in the northern areas of Khyber Pakhtunkhwa, Pakistan having latitude 71°, 31' to 72°, 14' East and longitude 34°, 37' to 35°, 07' approximately 820 meter above sea level (Fig. 1). Lower Dir receives an annual precipitation of about 253.7 mm in March and 253.7mm in December (Ullah et al., 2014a). The total population of Lower Dir is about 767,409. The district is surrounded by Chitral in North, Swat in East, Afghanistan and Bajour in West (Ullah et al., 2014b) and in South-West its boundaries extended to FATA (Federally Administered Tribal Areas). The total area of Lower Dir is 1,582 km2 (611 sq mi). In the area, there are four seasons in a year namely winter, spring summer, and autumn. Most of the peoples are related with the profession of agriculture. No industrial sector exists in the study area. The source of drinking water includes wells and springs (Richard, 1985).

2.2. Water sampling

The sources from which the water samples were collected include springs (n=18) and wells (n=4). The samples were collected in clean polythene bottles and all precautions were taken. Samples were collected using standard procedure of Holinger et al. (2014b) and Giammanco et al. (1998) for surface and ground water respectively. Samples were collected separately for physicochemical analysis and heavy metals analysis. After transportation of samples to the laboratory acidified samples were used for light and heavy metals analysis.

2.3. Analytical procedures

The physiochemical parameters Water checker U-10 was used for basic parameters such as pH, EC,DO, temperature and salinity were measured on the spot using Hanna Instruments meter (HI9828, Hanna Instruments, Woonsocket, RI, USA) as described by Machado and Bordalo (2014). Alkalinity and chloride (Cl-) were determined using titration method as given by APHA (1992). The concentration of sulfate was determined by using electro thermal atomic ultraviolet spectrophotometer, HACH-2800 (APHA, 1992). However, heavy metals (Pb, Cr, Ni, and Zn) concentration in water samples were determined by using atomic absorption spectrophotometer (Perkins Elmer-650) equipped with HGA graphite furnace, in the Centralized Resource Laboratories (CRL), University of Peshawar.

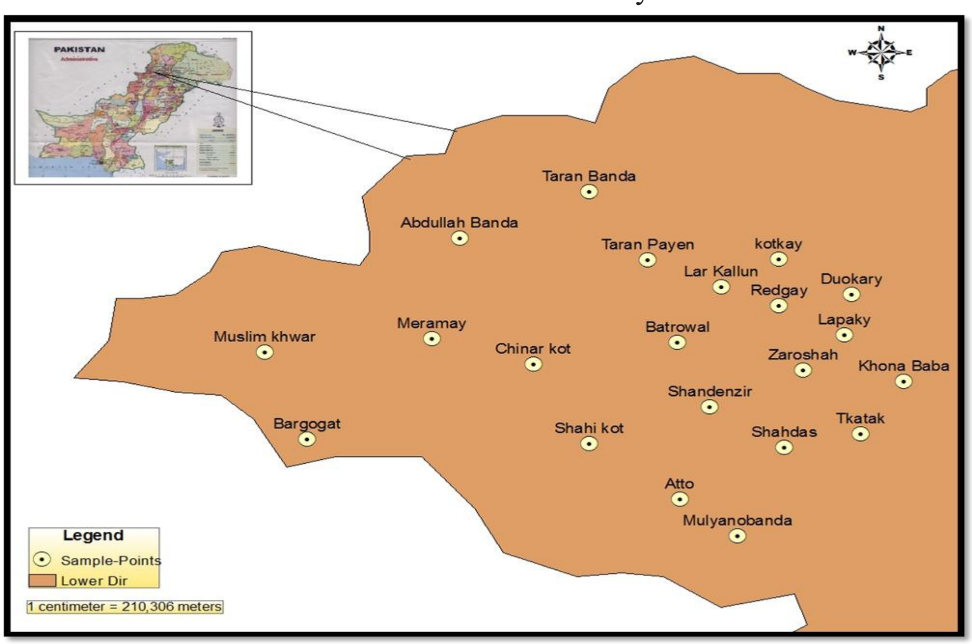

Fig. 1. Location map of the study area.

2.4. Health risk assessment

2.4.1. Average daily dose (ADD)

Several pathways through which heavy metals enter into human body include dermal contact, food chain and inhalation, but all others are negligible in comparison to oral intake (ATSDR, 2000). ADD through water intake was calculated according to the modified equation of US EPA (US EPA, 1998):

$$ADD = Cm \times IR / BW \quad (1)$$

Where, Cm, represent the metal concentrations in water (mg/L), IR represent water ingestion rate and BW represent body weight. The IR and BW were 2l/day and 70kg respectively (Muhammad et al., 2011).

2.4.2. Hazard Quotient (HQ)

The non-carcinogenic health risk (HQ) was calculated using equation (2) (US EPA, 1998):

$$HQ = ADD / RfD \quad (2)$$

Where, RfD is oral reference dose. According to US EPA database the oral toxicity reference dose values (RfD) are 0.02 mg/kg-day, 1.5 mg/kg-day, 0.3 mg/kg-day, and 0.036 mg/kg-day for Ni, Cr, Zn, and Pb, respectively (US EPA, 2005). When HQ<1, then the exposed population is assumed to be safe (Muhammad et al., 2011; Khan et al., 2008).

2.4.3. Statistical analysis

All calculations (means, ranges and standard deviations) were conducted using Excel 2010 (Microsoft Office). Arc Geographic Information System was used to prepared location map.

3. Results and discussion

3.1. Physical parameters of drinking water

Physiochemical characteristics of different water sources like stream, spring, tube well and dug well provide a clear picture of the water quality. Drinking water quality has been affected by a number of physiochemical factors causing different environmental problems and health hazards (Mora et al., 2009).The physiochemical characteristics of the selected water sources elicit a considerable variation among different water sources. The results of physical parameters like pH, DO, EC, salinity and temperature of water samples are summarizes in Table 1. The pH values ranged from 6.61 to 7.7 with a mean value of 7.28 and were within the permissible limit set by Pak-EPA, WHO. The lowest value of 6.61 was noted for Shandienzar (spring) while the highest value of 7.7 was noted for Kotkay (spring). Among different physiochemical parameters pH is considered as the basic indicator for determining water quality and has an indirect effects on human health as it provide an ideal condition for microorganism to survive in and spreading fetal diseases (Ho et al., 2003). Machado and Bordalo (2014) reported a very acidic pH of dugwell water, which may be due to less depth, unhygienic condition and presence of waste in the study area. In this study the variation reported in pH values among different sampling points (spring and well water) is due to variation in depth and sources from where they are added to reservoir. Similarly, it is the indication of presence of trace metals in the study area which affect the pH. It is assumed that these contaminants may be geogenic in nature as the area is less affect by anthropogenic activities. The DO values ranged between 3.17-3.23 mg/L with a mean value of 3.21mg/L. The values were observed in such a manner that the minimum value was noted for Shadas (spring) and the maximum value was noted for Batrowal (well), Barjogat (spring) and Shahikot (well) and all the values were within permissible limits. DO is a key component in determining the degree of freshness of an aquatic system (Fakayode, 2005). The values of EC ranged between 135 to 678µS/cm with a mean value of 381.75 µS/cm. The minimum value was noted for Shandienzar (spring) and the maximum value was noted for Shahikot (well). EC of well water was in the range of 190-678 µS/cm, similar value was calculated by Giammanco et al. (1998) in the northern basin of Mount Etna, Italy. High value of EC in water may be due to the natural processes that occur in the aquifer, as previously reported by Neal et al. (2005). High

EC value can also be linked with high Ca+2, Mg^{+2}, (Table 3) Cr and Ni (Table 4) concentration in the study area. EC is a function of total salt dissolve in an aquatic media (Pradeep et al., 1998). Similarly, the salinity values ranged 0.01 to 0.02% with a mean value of 0.004%. The lowest value was noted for Meramay (spring), Abdullah Banda (spring), Batrowal (well), Shandienzer (spring), Shadas (spring), Zaroshah (spring) and the highest value was observed for Shahikot (well) 0.02% and there was no great variation in the values of salinity detected in drinking water samples. Geological factors have strong influence on geochemical behavior of light and trace elements in solution (Giammanco et al., 1998) that may affect the physical and chemical behavior of drinking water.

Table 1. Range and mean (standard deviation) concentrations of physical parameters in drinking water samples.

	Springs		Wells			
Parameters	Range	Mean±SD	Range	Mean±SD	Pak-EPA[a]	WHO[b]
pH	6.61-7.7	7.28±0.30	7.15-7.61	7.35±0.21	6.5-8.5	6.5-8.5
DO (mg/L)	3.17-3.23	3.21±0.03	3.22-3.23	3.22±0.01	4	4
EC (μs/cm)	135-678	381.7±133.68	190-678	433.25±280.31	1500	1500
Salinity (%)	BDL*-0.02	0.004±0.005	BDL-0.02	0.008±0.009	-	-
Temperature (^{o}C)	1-17	12.33±2.09	12-17	14.25±2.22	-	-

[a]Pakistan Environmental Protection Agency (Pak-EPA, 2008)

[b]World Health Organization (WHO, 2008)

*BDL: Below Detection Limit

SD: standard deviation

Table 2. Range and mean (standard deviation) concentrations (mg/L) of chemical parameters in drinking water samples.

	Springs		Wells		
Parameters	Range	Mean±SD	Range	Mean±SD	Pak-EPA[a]
Alkalinity	69.3-265.65	131.27±60.40	111.85-183	153.96±35.19	500
TDS	305-843	478.17±144.23	505-740	619.50±98.78	1000
Hardness	132.8-798.8	351.44±100.69	212.4-481	372.05±116.73	500
Chloride	9.58-34.7	20.55±7.36	19.17-28.75	25.34±4.54	250
Sulfate	33.5-145.5	92.31±33.06	33.5-125	92.13±43.39	1000

[a]Pakistan Environmental Protection Agency (Pak-EPA, 2008)

3.2. *Chemical parameters of drinking water*

The concentration of chemical parameters determined in the drinking water samples are given in Table 2. Alkalinity value ranged between 69.30 to 265.65 mg/L with a mean value of 131.27 mg/L. The minimum value was noted for Taran Payen (spring) and the maximum value was noted for Abdullah Banda (spring). There is no guideline value (permissible limit) available, however, US EPA use 500 mg/L as the upper allowable limit, beyond which water will be considered unsafe of household activities. Similarly, TDS value ranged between 305 to 843 mg/L L with a mean value of 478.17 mg/L. The minimum value of 305 mg/L was noted for Chinarkot (spring) and the maximum value of 843 mg/L was noted for Abdullah Banda (spring). Most of the samples have TDS values within the permissible limits, with few exceptions where the TDS exceed the permissible limit. Higher concentration of TDS is harmful for aquatic biota and human beings and excessive use of such contaminated water can cause kidney disease. TDS in drinking-water originate from natural sources, sewage, urban run-off, industrial wastewater, and chemicals used in the water treatment process, and the nature of the piping or hardware used to convey the water, i.e., the plumbing (Pradeep et al., 1998). Hardness showed a result in a range of 132.8 to 798.8 mg/L with mean value of 351.44 mg/L as $CaCO_3$ hardness. Where the minimum value of 132.8 mg/L was noted for Taran Payen (spring), Chinarkot (spring) and maximum value of 798.8 mg/L was noted for Mulyanobanda (well). Eight Samples out of 22 have hardness above the permissible limit set by WHO (250-300 mg/L). The value of hardness of Taran Payan was in agreement with the findings of Ullah et al., (Jain et al., 2003) at Konhaye Stream Lower Dir (131 mg/L). Similarly chloride value range between 9.58 to 34.7 mg/L with mean value of 20.55 mg/L. The results showed that the minimum value of 9.58 mg/L was noted for Zaroshah (spring) and the maximum value of 34.7 mg/L was noted for Chinarkot (spring).The obtained results were all within the limits set by Pak-EPA (250 mg/L). Similarly the values of sulfate show the result in a range of 33.5 to 145.5 mg/L with 92.31 mg/L as mean value. The maximum value of 145.5 mg/L was observed for Kotkay (spring) and the minimum value of 33.5 mg/L was observed for Batrowal (well). The obtained results of sulfate were within the permissible limits. Sulfate values of spring Kotkay were similar with the previous research work done in the same area on Konhaye stream (Ullah et al., 2014c).

3.3. *Light metals concentration in drinking water*

Table 3 summarized the results of light metals. Mg^{+2} when analyzed for different water sources of District Lower Dir, showed a result in range of 76.4 to 655.08 mg/L with 308.596 mg/L as mean concentration. Most of the samples have very high Mg values. Similarly, Ca+2 were found in concentration range from 21.25 to 120 mg/L with mean concentration of 53.71 mg/L. Most of the samples were within the permissible limit and only 3 samples have value exceed the permissible limit. Similar results were found by Khan et al. (2015) in drinking water of Nowshera, Khyber Pakhtunkhwa. The data were compared with the previous work done in other regions of the world, the data showed that the concentration of Ca^{+2} in the spring and well water of Kotkay were will related with the findings of Avino et al. (2011), Jung et al. (2007) and Collivignarelli et al. (2007) with calculated values of 91.6 mg/L, 92.2 mg/L and 40.3 mg/L, respectively. Na+1 showed a result in a range of 1 to 5 mg/L with 1.5 mg/L as mean concentration. All the values were within the permissible limit. Similarly K^{+1} when analyzed for different water sources showed a result in a range of 1 to 5 mg/L with mean concentration of 1.66 mg/L. The minimum value was noted for most of the samples and the maximum value was noted for Kotkay (spring). All the samples were within the permissible limit. These finding were in agreement with the findings of Avino et al. (2011) (1.55 mg/L). The low concentration of K^{+1} in the water samples may be due to the fact that K^{+1} mineral normally resist the weathering of rock. These findings were similar to the previous research work done on drinking water (Avino et al., 2011; Sansoni et al., 1988). The presence of high concentration of Ca^{+2} and Mg^{+2} in water may be associated with leaching of these elements from the parent rocks (Giammanco et al., 1998).

3.4. Heavy metals concentrations in drinking water

The heavy metal concentrations in different sources of drinking water of the study area are summarizes in Table 4. The concentrations of Pb in drinking water samples were ranged from of 0.002 to 0.071 mg/L with a mean concentration of 0.04 mg/L. 23% of the samples have Pb above the permissible limits. The use of plumbing materials and substandard pipes is one of the professed reasons for Pb contamination. Cr showed a result of 0.039 to 0.349 mg/L with mean concentration of 0.18 mg/L, all the samples were having Cr above the permissible limit of Pak-EPA (Pak-EPA, 2008) and WHO (WHO, 2008). However, these values were well below the concentration of Cr in drinking water of Mingora as noted previously (Khan et al., 2013b). Ni showed a range of 0.026 to 0.090 mg/L with 0.06 mg/L as mean concentration. The minimum value was noted for Kotkay (spring) and the maximum value was noted for Shadas (spring). The concentrations of Ni were above the permissible limit set by Pak-EPA (Pak-EPA, 2008) and WHO (WHO, 2008). These results were in agreement with the findings of Khan et al. (Khan et al., 2015; Khan et al., 2013b). High concentration of Ni is ground and surface water of the study area may be due to the erosion of the parent rocks (Shah et al., 2012b). Similarly, Zn concentrations were in the range of 0.02 to 2.40 mg/L with 0.69 mg/L as mean concentration. The minimum value was noted for Abdullah Banda (spring) and the maximum value was noted for Tkatak (spring). This variation is obvious as the spring flow from Abdullah Banda to Tkatak trace metals may be dissolved in it either from various sources including bedrocks and aerial deposition. The permissible limit set by Pak-EPA and by US-EPA which is 5 mg/L. All the observed values were well within the limits set by the above mentioned agencies. Trace metals have a significant role in human life by determining human health and literature showed a positive correlation between heavy metals and human disease (Ahmad et al., 1998; Avino et al., 2000). In the present study higher heavy metals concentration in well water is an indication poor quality well water and a threat to general health of the consuming population.

Table 3. Range and mean (standard deviation) concentrations (mg/L) of light metals in drinking water samples.

Parameters	Springs Range	Springs Mean±SD	Wells Range	Wells Mean±SD	WHO[a]
Mg	76.4-655.08	308. 59±137.46	109.66-367.63	278.21±195.6	50
Ca	21.25-120	53.71±31.47	61.23-113.7	93.84±46.15	100
Na	BDL-5	1.5±0.95	BDL-1	0.75±0.45	200
K	BDL-5	1.66 ± 0.71	1-2	1.25±0.45	12

[a]World Health Organization (WHO, 2008).

Table 4. Range and mean (standard deviation) concentrations (mg/L) of heavy metals in drinking water samples.

Parameter	Springs Range	Springs Mean±SD	Wells Range	Wells Mean±SD	Pak-EPA[a]	WHO[b]
Pb	0.002-0.071	0.04±0.31	0.01-0.02	0.01± 0.02	0.05	0.01
Cr	0.039-0.349	0.18± 0.04	0.13-0.19	0.16±0.05	0.05	0.05
Ni	0.026- 0.090	0.06±0.02	0.04-0.08	0.06±0.02	0.02	0.07
Zn	0.020-2.400	0.69± 0.84	0.05-2.38	0.62± 1.00	5.00	3.00

[a]Pakistan Environmental Protection Agency (Pak-EPA, 2008).

[b]World Health Organization (WHO, 2008).

3.5. Average daily dose (ADD) indices and Hazard Quotient (HQ)

Table 5 summarized the calculated ADD and HQ values for consumption of drinking water in different water sources. The ADD values ranged from 0.00 to 0.002 µg/kg.day, 0.001–0.007 µg/kg.day, 0.001–0.002 µg/kg.day, and 0.00–0.07 µg/kg-day for Pb, Cr, Ni, and Zn respectively for spring water and 0.00-0.00 µg/kg.day, 0.004-0.004 µg/kg.day, 0.001-0.002 µg/kg.day, and 0.002-0.07µg/kg-day for Pb, Cr, Ni, and Zn respectively for well water. Similarly the calculated HQ values for consumption of drinking water ranged from 0.00 to 0.05 , 0.001 to 0.004 µg/kg.day, 0.10to 0.05 µg/kg.day and 0.00 to 0.023 µg/kg.day for Pb, Cr, Ni, and Zn respectively, for spring water while the HQ values calculated for well water are 0.00-0.00 µg/kg.day, 0.002 to .001 µg/kg.day, 0.05 to 0.1 µg/kg.day and 0.006 to 0.023 µg/kg.day for Pb, Cr, Ni, and Zn respectively. All heavy metals in drinking water samples indicated no health risk (HQ<1). All the values were within the acceptable limits for drinking water quality parameters.

4. Conclusion

Results revealed that the physiochemical parameters were within permissible limit, except hardness that exceed the permissible limits of WHO and Pak-EPA in 36% of samples, Mg exceed WHO limits in 100% samples, Ca found above safe limit of WHO in 14%, Pb exceed Pak-EPA limits in 23% and Ni exceed the safe limit of WHO and Pak-EPA in 100% of samples. All heavy metals in drinking water samples indicate no health risk (HQ <1) when compared with US-EPA (2005). It is concluded that the distribution network of drinking water is damaged and causing the contamination of drinking water with heavy metals. It is assumed that there is potential for local population, including potentially high risk groups such as young children and health deprived persons, to be exposed to drinking water that contain possible hazardous contaminants such as Pb and Ni. It is concluded that the water quality of the study area does not fulfill the public health criteria of Pak EPA, US EPA and WHO. Therefore, strict policy measured must be adopted and implemented in the study area to insure excess to safe drinking water, for the purpose governments and non government organizations must be actively involved in improving water quality. Similarly, public awareness programs must be carried out to aware the local community about drinking water quality and its importance.

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Table 5. Average daily dose (ADD) and hazard quotient (HQ) of heavy metals through drinking water in mg/kg-day.

Chromic risk assessment	Parameter	Springs		Wells	
		Range	Mean	Range	Mean
ADD[c]	Pb	0.00-0.002	0.001	ND[*]	ND
	Cr	0.001-0.007	0.005	0.004-0.004	0.004
	Ni	0.001-0.002	0.0015	0.001-0.002	0.0015
	Zn	0.00-0.07	0.02	0.002-0.07	0.036
HQ[d]	Pb	0.00- 0.5	0.105	ND	ND
	Cr	0.001-0.004	0.00291	0.002-0.001	0.002
	Ni	0.1-0.05	0.076	0.05-0.100	0.075
	Zn	0.00-0.230	0.046	0.006-0.023	0.012

[c]Average daily dose
[d]Hazard Quotient
[*]ND; Not Detected

Authors' contribution

Muhammad Ilyas did data collection, sample analyses, and write up. Sardar Khan did work in sample analyses and critically reviewed the manuscript. Anwarzeb Khan provided guidelines and helped in drafting and reviewing the manuscript. The statistical calculation were conducted by Rohul Amin. Asif Khan checked the statistics and critically reviewed the manuscript. Muhammad Aamir prepared geological map for the manuscript.

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