

## Assessment of drinking water quality and human health risks in the tehsils of Jamrud and Landikotal, Khyber Agency, Pakistan

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### Abstract

The concentrations of various pollutants in drinking water (surface and groundwater) were investigated for their contamination and associated health risk, if any, in the mountainous terrain of the Khyber Agency, Federally Administrated Tribal Areas (FATA) of Pakistan. Water samples were collected from different sources (tube wells and springs) used for drinking purposes, installed by Public Health Engineering Department (PHED) in the study area, composed of Tehsils of Jamrud and Landikotal in Khyber Agency. The physico-chemical parameters such as color, odor, taste, turbidity and pH, electrical conductivity (EC), total dissolved solids (TDS), nitrite (NO<sub>3</sub><sup>-</sup>), chloride (Cl<sup>-</sup>), sulfate (SO<sub>4</sub><sup>-</sup>), alkalinity, and hardness, sodium (Na) and potassium (K) were observed within their respective permissible limits when compared with the standards set by the WHO. However, the concentrations of calcium (Ca) and magnesium (Mg) exceeded the maximum permissible limits in some of the samples collected from Tehsil Landikotal and Jamrud. Heavy metals such as cobalt (Co), copper (Cu), lead (Pb) and arsenic (As) were below respective detection limits while the concentrations of zinc (Zn), iron (Fe) and chromium (Cr) were within the respective limits of WHO. However, the concentration of cadmium (Cd) was higher than the WHO limit in various water samples collected from Tehsil Landikotal. Daily chronic intake (CDI) and hazard quotient (HQ) indices were tabulated for heavy metals to measure the human health risks. The CDI values were in order of Zn > Fe > Cd > Cr. The HQ indices values were in order of Zn > Cd > Fe > Cr. The values of HQ were less than 1 which indicates no human health risks. The drinking water obtained from tube wells and springs of two tehsils (Jamrud and Landikotal) of Khyber Agency were found suitable for the drinking purpose as far as the chemical constituents are concerned.

**Keywords:** Drinking water quality; Heavy metals; Health hazards; FATA; Pakistan.

### 1. Introduction

Drinking water quality is a serious concern for humans of recent years. Drinking water contaminations have both natural (ore deposits and rocks weathering and erosion) and anthropogenic (industries, mining, agriculture activities and waste water) origins (Muhammad et al., 2010; Khan et al., 2013; Li et al., 2014). On the basis of toxicity, persistence and bio-accumulative nature in environment, the heavy metals are considered as severe pollutants (Pekey et al., 2004). The heavy metals like manganese, lead and cadmium can cause toxicity in aquatic and human life if ingested in very low concentration (Ouyang et al., 2002). Human health may be at greater risk from laxative effects of sulfates (WHO, 1996). An increase in dissolved solids also increases the concentration of Na and chloride. A more significant problem in developing countries is the effect of salts of mainly sulfates and chlorides which makes the water unpalatable and thus leading the people to use

surface water which is more likely to be bacteriologically polluted (Cairncross and Feachem, 1991).

Drinking water with excessive Zn has astringent taste and causes problems in digestive system i.e., vomiting, diarrhea, stomach cramps. It also causes kidney disorders, abdominal pain, nausea, dizziness, lethargy and lack of muscular coordination (Elinder, 1986; Parsad, 1987). In ground water mostly Fe is found in ferrous form (Read, 1970). It affects the color and flavor of water and food (Moore, 1973). The deficiency of Fe causes anemia while excessive intake of iron causes abdominal pain, constipation, nausea, intestinal infection and damage to heart and liver (Peter, 2000; Bhattacharjee, 2001). The absence of essential chemicals in water is not generally a problem because there are alternative sources of these chemicals in food (Cairncross and Feachem, 1991) but the excess of essential nutrients can also cause severe health problems (Aziziullah et al., 2010)

which include different kinds of cancer, kidney diseases, cardiovascular diseases and neuro-cognitive effects (Haq et al., 2005; Bola et al., 1992). Chromium is needed in a specific amount for normal body functions but liver, kidney diseases and cancer may be caused when consumed in higher quantity (Knight et al., 1997; Strachan, 2010). It is present in almost all foods in trace amounts which do not cause any harm to human health. It does not play any known role as food nutrient and is thus not required in our daily diet. Kidney damage, vomiting, diarrhea and nephro-toxic effects are associated with excessive Cd ingestion (Friberg et al., 1985; Barrento et al., 2009). In living organisms acute and chronic effects are caused by Cd exposure (Barbee and Prince, 1999). Skeletal damage, kidney damage, and itai-itai (ouch ouch) diseases are caused due to its chronic effects (Jarup et al., 2000; Nordberg et al., 2002). In humans it is experimentally proven that cancer may be caused by Cd exposure (IARC, 1993). The present study is aimed to evaluate the drinking water quality (tube wells and springs) of Jamrud and Landikotal tehsils of Khyber agency for physico-chemical and heavy metals

concentrations and the health risks associated with the ingestion of contaminated drinking water.

## 2. Materials and methods

### 2.1. Study area

The study area (Fig. 1) in the Khyber agency is an administrative unit of Federally Administrated Tribal Areas (FATA) of Pakistan. Khyber Agency is divided into three Tehsils namely Jamrud, Barra and Landikotal. A major part of this agency is composed of the closed and inaccessible areas of Tirah, Bazzar Zakha Khel and Choor. The agency lies between latitude,  $33^{\circ} 32'$  and  $34^{\circ} 51' N$  and between longitude,  $70^{\circ} 37'$  and  $77^{\circ} 56' E$ . It borders Peshawar to east, Afghanistan to west, Orakzai agency to south and Kurram agency to south-west. It has an area of 2,576 sq kms with a population of 8, 45,309 persons. The mineral deposits in Khyber Agency include soapstone, limestone, dolomite, silica sand, barite, mica, graphite and marble. Mullagori marble is one of the largest deposits in the world located in the study area. Soapstone is the second largest

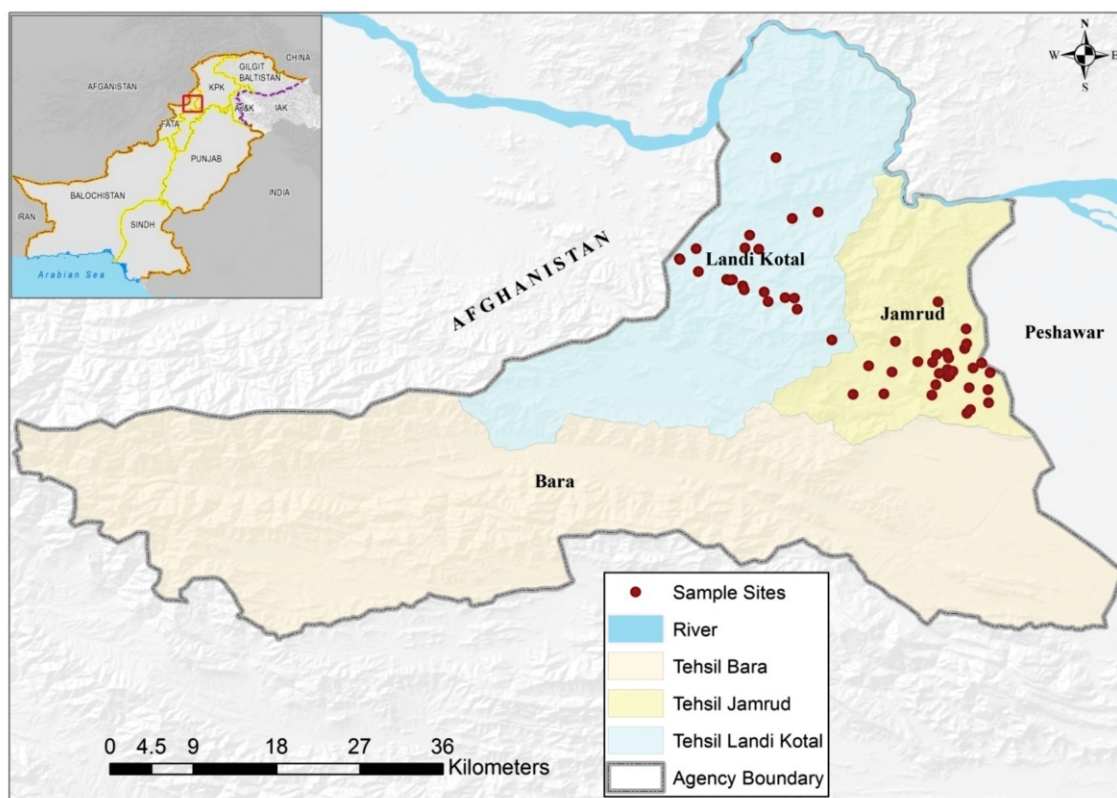


Fig. 1. Map showing location of the sampling sites in the study area in the tehsils of Jamrud and Landikotal, Khyber Agency.

mineral found in the area (Khan, 2001). Khyber Agency has a very low industrial base. The major industries of the area are ghee mills, cigarette factories, PVC pipes, steel mills and marble industries in Barra, Shakas Jamrud and Mullagori. There are other small silk processing units and ice factories in Barra and Jamrud respectively (Khan, 2001). Wheat, maize and sugarcane are the major crops of Khyber Agency (Khan, 2001). The principle sources of irrigation in Khyber Agency are canals and tube wells. Tube wells are the most important source of potable water. There are 241 Public Health Engineering Department (PHED) water supply schemes in which 179 are tube wells while 62 are gravity based schemes through which 73.18 % (6,18,584 people) of the population is served (PHED,2012).

## 2.2. Sampling

The drinking water samples (n=50) were collected from different sources including springs and tube wells in 2014 from Tehsils of Jamrud and Landikotal in Khyber Agency. Each sample was stored in clean polythene bottles in acidified form for the determination of heavy metals and in non-acidified form for the determination of physico-chemical parameters.

## 2.3. Analytical procedures

The pH was measured by Mettler Delta 320 pH meters while EC was determined by using conductivity meter model CM-4060 made by Jenway, UK. The bacteriological parameters (fecal coliforms and total coliforms bacteria) were measured in each sample by using Delagua Kit. Sulfate was measured by turbid metric method by using spectrophotometer (Hitachi, U-2900). The light metals Na and K were analyzed by using flame photometer (Jenway PFP-7). Heavy Metals and metalloids (Cd, Cr, Co, Cu, Fe, Pb, Zn and As) were analyzed using polarized Zeeman atomic absorption spectrophotometer (Hitachi Model Z-2000). In order to acquire the quality data the samples were analyzed carefully and standard solution and blank sample were run frequently to judge the reliability of the data. For the analysis of TDS, nitrite, alkalinity, chloride, hardness and light and heavy metals. Standard procedures were followed as mentioned in

Standard Methods for Water and Waste Water, 20th edition (APHA, 1998). All the acids and reagents used were of analytical grade. All the water samples were analyzed in Pakistan Council of Scientific and Industrial Research (PCSIR) laboratory in Peshawar, Pakistan.

## 2.4. Health risk assessment

Interviews were conducted from the inhabitants of the Khyber Agency via a questioner to know the adverse impacts of contaminated water on the public health. Questions regarding their age, body weight, smoking and non-smoking habit, education, occupational exposure, waterborne diseases, general body problems and monthly income were asked from the local inhabitants of the study area.

Health risk assessment was made according to the standard methods. The chronic daily intake indices were calculated through the modified equation of Muhammad et al., 2011.

$$CDI = C \times DI / BW \text{ (Eq 1)}$$

Where C is the concentrations ( $\mu\text{g/L}$ ) of heavy metal, DI is the daily intake in water (2 L/day) and BW (72 kg) is the body weight (Muhammad et al., 2011) whereas to calculate the hazard quotient (HQ) for non carcinogenic risk the following equation was used

$$HQ = CDI / RfD \text{ (Eq 2)}$$

Where CDI is the chronic daily intake and RfD is the reference dose. The RfD are  $3.0\text{E-}01$ ,  $5.0\text{E-}04$ ,  $7.0\text{E-}01$  and  $1.5 \text{ mg/kg-day}$  for Zn, Cd, Fe and Cr respectively (US EPA, 1999).

## 2.5. Statistical analysis

To find the mean, standard deviation and significance of raw data Statistical Package for the Social Sciences (SPSS Version 17.0) software was used.

# 3. Results and discussion

## 3.1. Water characteristics

Results of the water samples from tehsils



of Jamrud and Ladikotal in the Khyber Agency are given in tables 1 to 4. The color, odor and taste of drinking water of the study area were normal and nothing unpleasant was noticed. The pH, EC and chemical concentrations in drinking water samples are summarized in Table.1 which are collected from the surface (springs) and ground (tube wells) water of tehsils of Jamrud and Landikotal in the Khyber Agency.

In the tube well of Tehsil Jamrud, the pH ranged from 6.60 to 8.00 with the mean value of 7.46. In the spring's water, it ranged from 6.80 to 8.00 with the mean value of 7.27. The mean pH value at Tehsil Landikotal was found higher than that of the Tehsil Jamrud where the pH in tube wells water ranged from 7.30 to 8.10 with the mean value of 7.63 while in spring water it ranged from 7.20 to 8.20 with the mean value of 7.73 (Table 1). The highest pH value (8.20) was recorded in a spring of Gagra at Tehsil Landikotal while lowest pH (6.60) was recorded in Ghundi Abdal Khel village at Tehsil Jamrud. As the range of pH was found within the permissible limit of WHO (2008) and PAK EPA (2010).

Turbidity in water samples collected from Khyber Agency was found within the permissible limits. The mean turbidity values at tehsils of Jamrud and Landikotal were noticed as 2.62 and 2.66 NTU respectively. The maximum (5 NTU) turbidity 5 NTU was observed in Zahir shah village Wazir Dhund and Saidgi spring while the minimum (1 NTU) was found in drinking water of Aqal Jan Kaley Shakas, Khyali Khan Surkamar, Gul Rahman Kaley Dandoona, Ali Masjid of Tehsil Jamrud and Sardar Khan Kaley, Malik Sawab Khan Kaley of Tehsil Landikotal.

The range of TDS in tube wells water at Tehsil Jamrud was observed as 340-729 mg/l. The maximum value (729 mg/l) was noted at Wali Baba village with the mean value of 437.96 mg/l while in springs it ranged from 368 to 492 mg/l with the mean value of 457 mg/l. In Tehsil Landikotal, the TDS value in the water samples from tube wells ranged as 337-642 mg/l with the mean value of 433.73 mg/l whereas in springs it ranged as 354-601 mg/l with the mean of 464 mg/l. The mean

concentrations in spring water were found slightly higher than tube wells in both Tehsils (Table 1).

The hardness of the water samples collected from tube wells of Tehsil Jamrud ranged from 208 to 396 mg/l with the mean value is 269 mg/l while in spring's waters it ranged as 204-364 mg/l with the mean value of 343 mg/l. The maximum value (396 mg/l) was noticed in Wali Baba village at Tehsil Jamrud. In drinking water samples collected from tube wells of Tehsil Landikotal, it ranged from 160-360 mg/l with the mean value of 246.40 mg/l whereas in springs water of Tehsil Landikotal, it ranged from 316 to 368 mg/l with the mean value of 343.33 mg/l (Table 1). The spring's water of Tehsil Landikotal was having more hardness as compare to the rest of the samples collected and analyzed from Khyber Agency (Table 1).

The Ca concentrations ranged from 96-200 mg/l in drinking water samples collected from tube wells of Tehsil Jamrud with mean value of 140.16 mg/l while in spring's water it ranged from 108-204 mg/l with the mean value of 142 mg/l. In Tehsil Landikotal, it ranged from 116-316 mg/l in water samples collected from tube wells with the mean concentration value is 165 mg/l. The maximum concentration (316 mg/l) was found in Loy Shalman area of Tehsil Landikotal. Ca concentrations also exceeded the maximum permissible limit in Gudar Spring at Tehsil Jamrud and LandiKhana Spring, Saidgi Spring, Gagra Spring and ChingiKhel in Tehsil Landikotal while in the water samples of springs, it ranged from 176-284 mg/l with the mean value of 225 mg/l (Table 1).

Mg is mainly contributed to the natural water by the rocks like gypsum and dolomite and mafic and ultramafic rocks which are rich in Mg. The Mg ranged from 72-196 mg/l with the mean value of 129 mg/l in the drinking water samples collected from tube wells of Tehsil Jamrud. Maximum concentration of 196 mg/l was recorded in Wali Baba village at Tehsil Jamrud while the minimum concentration of 37 mg/l was recorded in the Gagra Spring water of Tehsil Landikotal. The concentrations of Mg were found higher than

Table 1. Physico-chemical parameters of drinking water of the study area.

Parameters	Statistics	Tehsil Jamrud		Tehsil Landikotal		WHO, 2008	Pak EPA, 2010
		Tube Wells (n=25)	Springs (n=04)	Tube Wells (n=15)	Springs (n=06)		
Total Hardness (mg/l)	Range	208-396	204.-364	160-360	316-368	<500	<500
	Mean	269.20	268	246.40	343.33		
	Std d <sup>b</sup>	47.52	68.19	44.20	23.10		
Ca (mg/l)	Range	96-200	108-204	116-316	176-284	200	NG <sup>a</sup> -
	Mean	140.16	142	165.06	225.33		
	Std d	29.60	42.39	46.16	41.85		
Mg (mg/l)	Range	72-196	96-160	40-112	37-188	150	NG <sup>a</sup>
	Mean	129.04	126	81.33	117.50		
	Std d	32.92	27.03	23.45	59.63		
Alkalinity (mg/l)	Range	148-432	184-288	156-376	196-272	<500	<500
	Mean	212.16	233	202.66	239.33		
	Std d	64.95	54.68	51.12	26.94		
Nitrites (mg/l)	Range	0.00-1.60	0.00-0.26	0.00-1.60	BDL <sup>c</sup>	3	NG <sup>a</sup>
	Mean	0.31	0.06	0.16			
	Std d	0.58	0.13	0.41			
Chlorides (mg/l)	Range	12-90	20-36	12-56	16-40	250	250
	Mean	24.40	28.00	25.86	27.33		
	Std d	17.56	7.30	11.52	10.55		
Sulfates (mg/l)	Range	22-56	28-56	16-105	15-32	250	250
	Mean	35.46	38.35	35.54	24.15		
	Std d	8.76	13.10	23.39	6.96		
TDS (mg/l)	Range	340-729	368-492	337-642	354-601	<1000	<1000
	Mean	437.96	457.00	433.73	464.00		
	Std d	104.22	59.72	85.28	87.45		
pH	Range	6.60-8.00	6.80-8.00	7.30-8.10	7.20-8.20	6.5-8.5	6.5-8.5
	Mean	7.46	7.27	7.63	7.73		
	Std d <sup>b</sup>	0.444	0.585	0.249	0.377		
K (mg/l)	Range	1.10-5.70	0.60-4.20	1.40-5.70	0.80-5.40	12	12
	Mean	3.64	2.62	2.86	2.78		
	Std d	1.05	1.58	1.50	1.68		
Na (mg/l)	Range	24-102	28-80	14-98	12-80	200	NG <sup>a</sup>
	Mean	35.02	44.10	30.18	31.68		
	Std d	19.57	24.36	19.82	24.67		
Cd (mg/l)	Range	BDL <sup>c</sup>	BDL	BDL-0.01	BDL-0.01	0.003	0.01
	Mean			0.0027	0.0067		
	Std d			0.0045	0.0051		
Cr (mg/l)	Range	0.00-0.02	BDL	BDL	BDL	0.05	0.05
	Mean	0.0008					
	Std d	0.004					
Zn (mg/l)	Range	0.01-0.85	0.00-0.01	0.01-3.0	0.01-1.40	3	5
	Mean	0.11	0.002	0.478	0.521		
	Std d	0.168	0.005	0.748	0.522		
Fe (mg/l)	Range	0.00-0.08	BDL	BDL	BDL	0.3	NG <sup>a</sup>
	Mean	0.030					
	Std d	0.025					

Standard deviation, c below detection limit, NGa Not Given

the permissible limit (150 mg/l) of WHO (1996) in Zahir Shah Kaley, Wazir Dhund, Rahed Khan Spera, Shazad Gul Gudar, Malik Atta Ullah Ghundi, Mahboob Lalma, Mania Khel, Gudar spring at Tehsil Jamrud and Charbagh and Landikhana spring of Tehsil Landikotal. In the water samples collected from springs Mg ranged from 96 to 160 mg/l with the mean value of 126 mg/l. In drinking water samples of Tehsil Landikotal collected from tube wells it ranged from 40 to 112 mg/l with the mean value of 81.33 mg/l while in springs water it ranged from 37 to 188 mg/l with the mean value of 118 mg/l (Table 1). The mean concentration of Mg, though within the permissible limit, was found relatively higher in the water samples of springs in Tehsil Landikotal as compared to that of tube wells.

In water samples collected from tube wells of Tehsil Jamrud, alkalinity ranged from 148 to 432 mg/l. Its maximum concentration (432mg/l) was noted in Shoukat Chinar Kaley at Tehsil Jamrud with the mean value of 212 mg/l whereas in spring's water it ranged from 184 to 288 mg/l with the mean value of 233 mg/l. In tube well's water of Tehsil Landikotal it ranged from 156-376 mg/l with the mean concentrations of 203 mg/l whereas in drinking water samples collected from springs the alkalinity ranged from 196 to 272 mg/l with the mean concentration of 239 mg/l. Alkalinity was slightly higher in springs water than the water samples collected from tube wells in both the tehsils of Khyber Agency (Table 1).

In drinking water of tube wells in Tehsil Jamrud nitrite is ranged between 0.00-1.60 mg/l. The maximum nitrite content (1.60 mg/l) was noticed in NikiKhel village of Tehsil Landikotal and Kharkai, Wali Baba and Zahir Shah Village of Tehsil Jamrud. The concentration of nitrite in spring water of Tehsil Jamrud ranged from 0.00-0.26 mg/l with the mean concentration of 0.06 mg/l. However, its concentration in the water samples collected from springs of Landikotal was found below detection limit (Table 1).

The concentrations of chloride in drinking water samples collected from tube wells of Tehsil Jamrud ranged from 12 to 90 mg/l (mean: 24.4 mg/l). The maximum

concentration of 90 mg/l was found in Shazad Gul Guddar village while in water samples of springs, it ranged from 20 to 36 mg/l (mean: 28.0 mg/l). Chloride contents in drinking water samples collected from the tube wells of Tehsil Landikotal ranged between 12-56 mg/l (mean: 25.9 mg/l) while in samples collected from springs it ranged between 16-40 mg/l (mean: 27.3 mg/l) (Table 1).

Sulfates ranged from 22 to 56 mg/l (mean: 35.46 mg/l) in drinking water samples collected from tube wells of Tehsil Jamrud while in spring's water samples its concentration ranged between 28-56 mg/l (mean: 38.4 mg/l). In water samples collected from tube wells of Tehsil Landikotal it ranged from 16 to 105 mg/l. The maximum level of sulfate in drinking water was found as 105 mg/l in Loy Shalmanarea and the minimum value of 15.7mg/l was found in ChingiKhel at Tehsil Landikotal. In the water samples collected from springs the sulfates concentration ranged from 15 to 32 mg/l (mean: 24.2 mg/l). The concentrations of sulfate were found in relatively lesser amount in springs of Tehsil Landikotal (Table 1).

In the tube wells of Tehsil Jamrud the concentrations of K in drinking water ranged from 1.10 to 5.50 mg/l (mean: 3.64 mg/l) while in the samples collected from springs it ranged as 0.60-4.20 mg/l (mean: 2.62 mg/l). The concentrations of K in drinking water samples collected from tube wells of Tehsil Landikotal ranged as 1.40-5.70 mg/l (mean: 2.86 mg/l) while in springs waters it ranged from 0.80 to 5.40 mg/l (mean: 2.78 mg/l) (Table 1). The maximum concentration (5.70 mg/l) was found in the water samples collected from Madukhel Ghundi area of Tehsil Jamrud and Loy Shalman area of Tehsil Landikotal.

In the drinking water samples collected from the tube wells of Tehsil Jamrud, the concentrations of Na ranged from 24-102 mg/l (mean: 35.02 mg/l) while in springs water it ranged from 28-80 mg/l (mean: 44.10 mg/l). In the water samples collected from the tube wells of Tehsil Landikotal, the concentration of Na ranged from 14-98 mg/l (mean: 30.18 mg/l) while in water samples collected from springs of Tehsil Landikotal it ranged between 12-80

mg/l (31.68 mg/l) (Table 1). The maximum concentration (102 mg/l) was found in Haji Shazad Gul Gudar village of Tehsil Jamrud and minimum concentration (12 mg/l) was noticed in spring water of Gagra village at Tehsil Landikotal.

Drinking water of Khyber Agency was analyzed for heavy metals and metalloids (Cd, Cr, Co, Cu, Fe, Zn, Pb and As). The detection limits of the instrument for Cd, Cr, Fe, Co, Cu, Zn, Pb and As reported are as 0.002 mg/l, 0.02 mg/l, 0.02 mg/l, 0.03 mg/l, 0.01 mg/l, 0.005 mg/l, 0.05 mg/l and 0.001 mg/l, respectively. The concentrations of Co, Cu, Pb and As were found below detection limit (BDL) in almost all the samples and are, therefore, not given in Table 1.

The concentrations of Cd in drinking water samples collected from tube wells of Tehsil Landikotal ranged from BDL-0.01 mg/l (mean: 0.0027 mg/l) while in springs water it ranged between 0.00-0.01 mg/l (mean: 0.0067 mg/l). The concentration of Cd was found below detection limit in the water samples of both springs and tube wells of Tehsil Jamrud (Table 1). The maximum concentration 0.01 mg/l was found in drinking water of Malik Younas Kaley, Mirdad Khel, Kam Shalman, Loyshalman and in the spring water of Ragha Kamshalman, Gagra spring, Landikhana spring and Chingikhel area of Tehsil Landikotal. However, concentration of Cd was found below detection limit in all the samples collected from Tehsil Jamrud (Table 1).

The concentration of Cr ranged from 0.00 to 0.02 mg/l (mean: 0.0004 mg/l) in drinking water of Khyber Agency. The maximum concentration of 0.02 mg/l was noticed in only one water sample collected from Bismillah Jan Ibrahim khel Shakas village of Tehsil Jamrud and it was below detection limit in rest of the samples collected from Khyber Agency (Table 1).

The Zn concentrations in drinking water samples collected from tube wells of Tehsil Jamrud ranged from 0.01 to 0.85 mg/l (mean: 0.11 mg/l) while a very low concentration (0.01 mg/l) was found in the spring water of Qadam and rest of the samples collected from the

springs of Tehsil Jamrud were found below the detection limit. In the water samples collected from the tube wells of Landikotal, it ranged from 0.01 to 3.0 mg/l (mean: 0.478 mg/l) while in springs water, it ranged from 0.01 to 1.40 mg/l (mean: 0.521 mg/l) (Table 1). Maximum concentration of 3 mg/l was found in drinking water of Major Dost Muhammad village of Tehsil Landikotal while it was below detection level in spring water of Jabba, Rikaley and Gudar village of Tehsil Jamrud.

The concentrations of Fe in drinking water samples collected from tube wells ranged from 0.00 to 0.08 mg/l (mean: 0.030 mg/l) while it was found below detection limit in all samples collected from springs of Tehsil Jamrud. The maximum concentration (0.08 mg/l) was noticed in the drinking water of Zahir Shah Wazir Dhund village and Kharki Abad village of Tehsil Jamrud.

### *3.2. Health risk assessment*

During the present research work, mainly the tube wells and springs were the sources of drinking water for the inhabitant of the study area. Therefore, these two sources were selected for the heavy metals related health risk assessment like chronic daily intake and Hazard Quotient.

#### *3.2.1. Chronic daily intake (CDI)*

This study revealed that in Tehsil Jamrud, where the inhabitants were mainly using tube well water for drinking purpose, there the Chronic daily intake values ranged as 0.27-23.61, 0.00-2.22 and 0.00-0.55  $\mu\text{g/kg-day}$  for Zn, Fe and Cr respectively (Table 2) whereas CDI was found below the limit for Fe and Cr and 0.00 to 0.27  $\mu\text{g/kg-day}$  for Zn in those areas of Tehsil Jamrud where the people were using springs water for drinking purpose. In Tehsil Landikotal where the people consumed tube well water there the CDI values ranged from 0.27-83.3 and 0.00-0.27  $\mu\text{g/kg-day}$  for Zn and Cd respectively while it was found below the limit for Cr and Fe in these areas (Table 2). On the other hand the people who consumed springs water in Tehsil Landikotal, the chronic daily intake value was found in the range of 0.27-38.9 and 0.00-0.27

µg/kg-day for Zn and Cd respectively while it was found below the limit for Cr and Fe (Table 2). Thus CDI indices in Khyber agency showed that Zn > Fe > Cd > Cr. However, CDI indices for Co, Cu, Pb and As were found below the limit in all samples collected from Khyber Agency.

### 3.2.2. Hazard quotient (HQ)

The non-cancer risk known as Hazard Quotient (HQ) indices for heavy metals consumption via drinking water by residents of Khyber Agency were calculated according to the US-EPA (2000, 2004) and are given in Table 3. In tube wells of Tehsil Jamrud the mean HQ index value for Zn, Fe and Cr were found as

1.06E-02, 1.19E-03 and 4.0E-04 respectively while in spring's water it was noticed as 9.00E-04 for Zn. Similarly, in tube wells of Tehsil Landikotal the mean HQ index values were found as 1.49E-01 and 4.43E-02 for Cd and Zn respectively. In spring water of Tehsil Landikotal the mean HQ index values were recorded as 3.73E-01 and 4.84E-02 for Cd and Zn respectively (Table 3). The HQ indices in Khyber Agency were found in order of Zn > Cd > Fe > Cr. The Hazard Quotient indices for the heavy metals indicate that there is no health related risk to local residents of study area when these are compared with US EPA (1999), Khan et al. (2008), Muhammad et al. (2011) and Jabeen et al. (2014).

Table 2. Chronic daily Intake indices for heavy metals (µg/kg-day) in the drinking water of the study area.

Parameter	Statistics	Tehsil Jamrud		Tehsil Landikotal	
		Tube Wells <i>n</i> =25	Springs <i>n</i> =04	Tube wells <i>n</i> =15	Springs <i>n</i> =06
Cd	Range	BL <sup>b</sup>	BL	0.00-0.27	0.00-0.27
	Mean			0.074	0.185
	Std d <sup>c</sup>			0.1272	0.1435
Cr	Range	0.00-0.55	BL	BL	BL
	Mean	0.022			
	Std d	0.1111			
Zn	Range	0.27-23.61	0.00-0.27	0.27-83.3	0.27-38.9
	Mean	3.167	0.0694	13.278	14.953
	Std d	4.692	0.1389	20.780	14.242
Fe	Range	0.00-2.22	BL	BL	BL
	Mean	0.833			
	Std d	0.7172			

<sup>b</sup> Below Limits

<sup>c</sup>Standard Deviation



Table 3. Hazard Quotient (HQ) indices for heavy metals via drinking water consumption.

Parameter	Statistics	Tehsil Jamrud		Tehsil Landikotal	
		Tube Wells <i>n</i> =25	Springs <i>n</i> =04	Tube wells <i>n</i> =15	Springs <i>n</i> =06
Cd	Range	BL <sup>b</sup>	BL	0.00-5.60E-01	0.00-1.30E-01
	Mean			1.49E-01	3.73E-01
	Std d <sup>c</sup>			2.56E-01	2.89E-01
Cr	Range	0.00-4.00E-04	BL	BL	BL
	Mean	1.50E-05			
	Std d	7.46E-05			
Zn	Range	0.00-7.87E-02	0.00-9.00E-04	0.00-2.80E-01	0.00-1.30E-01
	Mean	1.06E-02	2.33E-04	4.43E-02	4.84E-02
	Std d	1.56E-02	4.67E-04	6.93E-02	4.85E-02
Fe	Range	0.00-3.20E-03	BL	BL	BL
	Mean	1.19E-03			
	Std d	1.03E-03			

bBelow Limits

cStandard Deviation

#### 4. Conclusions

This study revealed that the physico-chemical parameters such color, odor, taste, turbidity, pH and conductivity of the drinking water of Khyber agency are within permissible limits. The mean concentration of studied heavy metals and metalloids in drinking water also lies within the safe limit. However, the concentrations of Ca and Mg were exceeding the safe limit in some of the samples collected from both the tehsils of Khyber Agency. Heavy metals and metalloids such as Co, Cu, Pb and As were generally found below detection limit while acceptable amount of Zn, Fe, and Cr were recorded in most of the drinking water samples of Khyber Agency. However, Cd in few water samples collected from Tehsil Landikotal were found exceeding the safe limit. The CDI and HQ indices calculated for heavy metals in the drinking water of Khyber agency were found in order of Zn > Fe > Cd > Cr and Zn > Cd > Fe > Cr respectively and are suggesting no any health related risk as far as the studied light and heavy metals and metalloids in are concerned.

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