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Assessment of drinking water quality and human health risks in Karak and adjoining areas, Southeastern Kohat Basin, Pakistan

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Abstract

Drinking water related environmental issues and diseases are major concern for people living in Karak area, located in arid to semi-arid region of Khyber Pakhtunkhwa, Pakistan. In the present research, surface and subsurface water resources of Karak District are analyzed to determine the concentration ranges of various contaminants for effluence and assess their health-related risks. Surface and subsurface samples were collected from Kamangar, Shagi, Khusrara, Dabli Louaghar, Tiran Kuhi, Mamani, Kanda and Karak areas of the District Karak. The physico-chemical characteristics i.e. color, odor, taste, turbidity, Eh, chloride (Cl), sulfate (SO4) and potassium (K) were found within their separate tolerable parameters in comparison with WHO fixed values of 2008. However, the concentrations of sodium (Na), total dissolved solids (TDS) and pH exceeded the acceptable parameters in few water samples. The concentrations of heavy metals e.g. iron (Fe), chromium (Cr) and zinc (Zn) were observed within the specified values fixed by WHO, 2008. For heavy metals, hazard quotient (HQ) indices and daily chronic intake (CDI) were tabulated. Daily chronic intake (CDI) values were found as Zn > Fe > Cr, whilst the HQ indices values were observed as Zn > Fe > Cr. The hazard quotient >1 shows no human health threats. The present study represents that the surface and subsurface water sources from Tehsil Karak of District Karak, are found suitable for the drinking purpose based on their chemical constituents.

Keywords: Drinking water, Heavy and light metals, Average daily dose, Health risks, Karak.

1. Introduction

Like other living organism on the earth, the important constituent for the survival of Human beings is water. A human body comprised of 70% of water, to maintain this balance and remain hydrated, we have to rely on fresh water. Similarly, a human body requires 5 liters/day for daily routine activities (Gleick, 1999). In an individual, 2.5% decrease in volume of water causes 25% loss in the volume of blood. Under such conditions, human blood can become thick and heavy, in return our heart has to work hard to pump to every part of our body. Water is not only required for growth of our body, but also for food production, power generation and running of manufacturing companies on daily basis. Communities and individuals can survive without comforts of life such as shelter and food (for a certain time), however, if water sources are depleted, living organisms will be wiped from the face of the earth in a course of few days. The intertwining relationship between water life, has brought together the entire humanities, religions and cultures through innumerable means.

Drinking water quality is a critical issue for the masses of the modern age. Access to fresh and hygienic water, should be the basic right of every human being (Tahir, 2004; Ilyas et al., 2017). For simplicity, water sources are generally divided into 1) surface and 2) subsurface water, utilized by the public for different purposes, such as cleaning, food production, personal hygiene and other domestic purposes (Shirley et al., 2000; Cahill, 2000), however, its utilization is strictly depending upon the quality of water (Eldon and Bradley, 2004). Drinking water must have a balance in biological and physio-chemical properties for safe and healthy use (Rezaee et al., 2001). The High concentration of Cr, Pb, Cu, Cd, Ni and other trace metals in fresh water may severely affect the quality of water and can have adverse outcomes on our healths (Storelli et al., 2005; Zhang et al., 2014).

Both anthropogenic (industries, mining, agriculture activities and wastewater) and natural (ore deposits and denudation of rocks) origins have been attributed to contaminate water (Muhammad et al., 2010; Khan et al., 2013). Considerable amount of essential and non-essential toxic elements is released by these sources to water bodies (Santos et al., 2005; Kumar and Ramanathan, 2015). The heavy metals are believed to be severe pollutants because of the toxicity, bio-accumulative nature in atmosphere and perseverance (Pekey et al., 2004). According to Ouyang et al. (2002), the consuming of very low amount of Heavy metals i.e. Mn, Cd, Cr and Pb to human and marine life can cause toxicity. Purgative effects of sulfates have a greater risk for Human health. TDS is directly proportional to Na and Cl i.e. a decrease in TDS decreases the concentration of Na and Cl and an increase in TDS enhances the concentration of Na and chloride. In developing countries, dissolved salt in water can develop a major concerned due to SO4 and Cl, making water indigestible and therefore, people are compelled to utilize water, that is prone to be bacteriologically contaminated (Cairncross and Feachem, 1991). Similarly, Fe found as ferrous (Fe^{2+}) in ground water, also alter color and taste of water that affect food growth (Read, 1970; Moore, 1973). Due to excessive ingestion of Fe, can develop a number of diseases over the time, e.g. intestinal infection, nausea, damage to liver and heart, constipation and abdominal pain, however, in contrary, Fe deficiency can cause anemia (Peter, 2000; Bhattacharjee, 2001). Generally, food is a good source of essentials chemicals, therefore, the deficiency of these chemicals in water is not considered a severe problem (Cairncross and Feachem, 1991). If these elements, however, are consumed in excessive amount, may create serious health problems, e.g. cancers, kidney problems, neurocognitive effects and cardiovascular diseases (Haq et al., 2005; Azizullah et al., 2010). Also a specific amount of Cr is required for normal body functions, but its excessive use may cause cancer, kidney and liver diseases (Zhang et al., 1987; Knight et al., 1997; Strachan, 2010). Cr is present in small quantities in most of the food's, however, Cr is not mandatory in our daily diet, due to the fact that it does not has any nutrients role in our body.

Our research is focused on the water analysis of Tehsil Karak, District Karak, KP, Pakistan (Fig. 1). There are large reserves of Eocene evaporite (salt and gypsum) in Karak region. The freshwater resources in the Karak area are, therefore, susceptible to contamination caused by dissolved SO4, Cl and Na constituents of salt and gypsum. In the present research, samples from dug wells, hand pumps, streams, tube wells and springs are collected from Tehsil Karak of District Karak, Khyber Pakhtunkhwa to determine their physico-chemical and heavy metal concentrations for the assessment of their role in health-related risks.

2. Materials and techniques

2.1. Study area

Geographically, the research area constitutes part of Shinghar Range and Kohat Plateau, lying between longitudes 71° 03' 00"E to 71° 19' 30"E and latitudes 33° 02' 25" N to 33° 08' 46" N, covering the topographic sheet No 38 O/4 and 38 O/8 of the Geological Survey of Pakistan. The climate of the area is characterized by arid to semi-arid nature, winter temperature close to freezing, 0°C – 15°C, and scorching summer temperature of 25°C – 40°C. However, during the month of June and July for few days, the temperature may reach as high as 48°C. The area receives plenty of rain during winter from the clouds blowing west to east from Afghanistan. Summer rain is the result of the Monsoon, with an average annual rainfall of 13 – 37cm. Most of the rainfall is between the months of July and September, however, occasionally rainfall in December.

Geologically, the study area is bounded by the Karak Fault Zone in the north, Bannu Basin in the west, Shakardara hills in the east and

Shinghar-Surghar ranges in the south. The study area can be assessed by a network of roads from different parts of the country, and lies at a distance of ~123 km from Peshawar toward the south (Fig. 1). A total of 220 Km2 area has been covered by collecting 96 water samples from the proposed project area (Fig. 2).

2.2. Water Sampling

Total of Ninety-Six (96) samples were taken from the water sources. These sources include the hand pumps, dug wells, tube wells, streams, seepages and springs from various areas of Tehsil Karak, District Karak (Fig. 2 & Table 1). Plastic bottles (Pre labelled) of half litre were used for retrieving water samples. By using detergents, first the bottles were washed and then rinsed with deionized water to avoid any contamination. Each sample was retained in clean polythene bottle 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 water samples were examined to determine TDS, pH, EC, sampling site temperature, they are presented in Table 1. Measurement of pH were made by Mettler Delta 320 pH meters and through conductivity meter (model CM-4060), the EC data was measured. Similarly, temperature and salinity were determined at the sample site using Hanna Instruments meter (HI 9828, Hanna Instruments, Woonsocket, RI, USA, described by Machado and Bordalo, 2014). Sulfate was determined with turbid metric method using spectrophotometer (Hitachi, U-2900). Alkalinity and chloride (Cl) were determined using titration method. The concentrations of light metals Na and K were measured by using flame photometer (Jenway PFP-7), while the heavy Metals (Cr, Fe, and Zn) concentration were determined through polarized Zeeman atomic absorption spectrophotometer (Hitachi Model Z-2000). In order to acquire the data of standard quality, the water samples were analyzed cautiously with standard solution and repeat samples were run regularly to judge the reliability of the data. Standard techniques were followed for the determination of TDS, nitrite, alkalinity, chloride, hardness and light and heavy metals concentration (APHA, 1998). Acids and reagents of analytical evaluation were utilized. The above analyses were performed at the PCSIR laboratory, Lahore, Pakistan. Detailed description of the collected water samples along with their chemical results are tabulated in the Table 1.

2.4. Health threat evaluation

Interviews of the inhabitants of the project area were conducted through a questionnaire to understand the opposing effects of polluted water on the health of people. Questions regarding their body weight, education, age, occupational exposure, smoking and non-smoking habit, general body issues, aquatic diseases and monthly revenue were inquired in the questionnaire.

Standard procedures were used for evaluations of Health-related threats. The daily intake indices (CDI) were calculated with the help of equation revised by Muhammad et al. (2011).

$$CDI = C \times DI / BW \quad (1)$$

According to Muhammad et al., (2011), the C represent heavy metal concentrations (μg/L), BW is the body weight and DI is known as the daily intake of water. For non-carcinogenic risks, the hazard quotient (HQ) is calculated by the equation 2.

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

The RfD represents the reference dose and CDI is chronic daily intake. According to US EPA (1999), the RfD are in the order of, 5.0E-04, 7.0E-01, 3.0E-01 and 1.5 mg/kg per day for Cd, Fe, Zn, and Cr, respectively.

2.5. Statistical analysis

Data were statistically analyzed using DAS and SPSS Version 17.0 computer programs to calculate average mean, standard deviation, median and implication of the raw data are presented in Table 2.

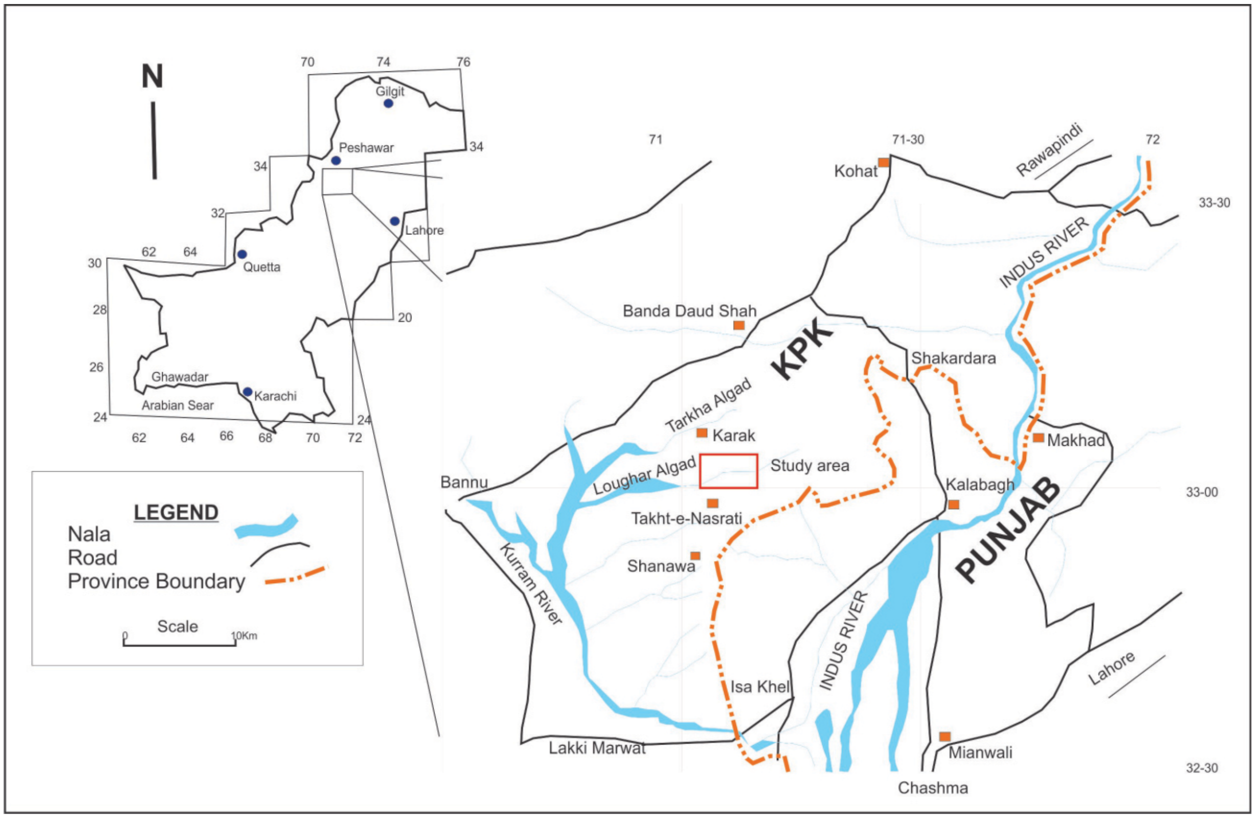

Fig. 1. Location map of the project area.

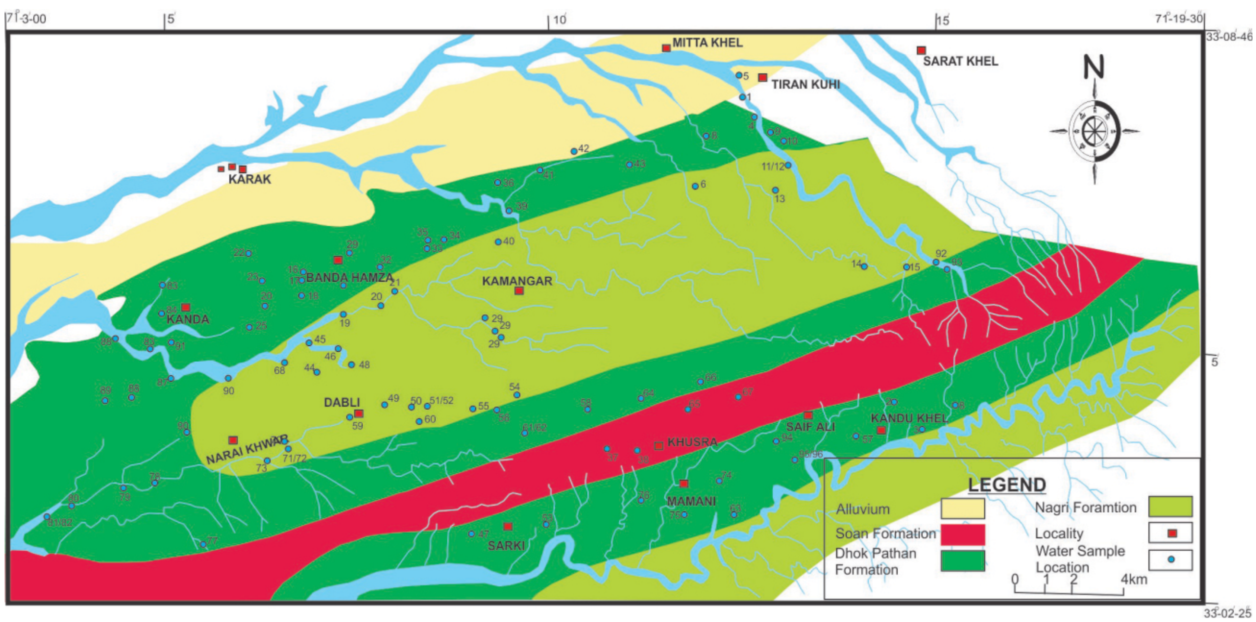

Fig. 2. Map showing water samples locations and geology of the study area (After Ali et al., 2008).

Table 2. Interpreted resistivity and subsurface geology of area

Sample No	NGR	T. Sheet No.	Nature of Sample	Temp (C)	pH	TDS mg/l	$SO4^{-2}$ ppm	Cl^{-1} ppm	Ca^{+2} ppm	Mg^{+2} ppm	Na^{+1} ppm	K^{+1} ppm	Zn ppb	Cr ppm	Fe ppm
1	27158160	38O/4	Hand Pump	20°	7.40	852	21	44	297	4	0.01	0.04	49	0.04	0.048
2	27158145	38O/4	Hand Pump	22°	7.37	1520	33	72	621	7	0.09	0.08	38	0.5	0.069
3	27158120	38O/4	Hand Pump	22°	7.04	2004	40	63	687	5	0.2	0.02	44	0.05	0.038
4	27608165	38O/4	Hand Pump	23°	7.35	1014	29	22	122	4	0.17	0.05	28	0.03	0.068
5	27258225	38O/4	Tube Well	24°	7.15	268	30	16	75	2	1	0.01	43	0.01	0.01
6	26057960	38O/4	Hand Pump	24°	7.38	455	38	39	101	3	0.38	0.02	47	0.06	0.115
7	27308105	38O/4	Tube Well	19°	7.57	270	69	15	19	2	3	0.03	41	0.03	0.101
8	27758080	38O/4	Tube Well	21°	7.51	390	78	18	42	5	2	0.07	33	0.03	0.045
9	26308070	38O/4	Spring	18°	8.87	212	5	2	100	1	0.03	0.03	44	0.02	0.051
10	28008060	38O/4	Tube Well	18°	7.63	514	77	55	58	5	1	0.2	39	0.01	0.056
11	28108005	38O/4	Hand Pump	20°	7.39	265	40	26	56	2	0.47	0.08	40	0.01	0.074
12	28108005	38O/4	Hand Pump	20°	7.39	265	39	26	55	2	0.22	0.05	21	0.06	0.117
13	27907945	38O/4	Spring	21°	7.51	260	70	23	11	3	0.01	0.03	43	0.04	0.079
14	29807780	38O/4	Hand Pump	21°	7.45	290	48	34	44	5	0.29	0.06	36	0.5	0.053
15	30757780	38O/4	Spring	19°	7.68	318	57	35	36	4	0.4	0.03	25	0.05	0.041
16	17457750	38O/4	Hand Pump	23°	7.76	385	19	18	152	4	0.06	0.03	34	0.03	0.043
17	17407700	38O/4	Tube Well	18°	8.06	141	14	15	164	2	2	0.02	47	0.01	0.041
18	18507675	38O/4	Stream	14°	8.49	237	31	21	57	5	1	0.03	29	0.06	0.09
19	19157680	38O/4	Tube Well	18°	7.70	310	30	32	60	6	1	0.07	23	0.01	0.064
20	19507705	38O/4	Spring	13°	7.75	348	37	28	68	3	0/35	0.02	35	0.02	0.031
21	162778	38O/4	Tube Well	21°	8.08	395	21	16	180	2	3	0.06	49	0.05	0.042
22	16607725	38O/4	Hand Pump	24°	7.60	576	29	24	201	4	0.8	0.05	44	0.04	0.035
23	16657665	38O/4	Hand Pump	22°	7.86	922	18	9	376	3	0.05	0.03	39	0.05	0.095
24	16407625	38O/4	Hand Pump	23°	7.75	673	14	6	212	3	0.56	0.05	23	0.02	0.075
25	21607655	38O/4	Spring	16°	8.11	23	27	22	48	5	0.05	0.01	28	0.05	0.042
26	21776400	38O/4	Spring	25°	7.98	222	14	17	60	5	0.09	0.01	30	0.02	0.06
27	21807620	38O/4	Spring	25°	8.00	205	12	13	59	3	0.03	0.06	45	0.04	0.049
28	18507780	38O/4	Hand Pump	19°	7.79	380	24	24	133	3	0.03	0.03	40	0.05	0.084
29	18357710	38O/4	Hand Pump	23°	7.69	581	20	12	168	3	1	0.06	35	0.06	0.054
30	18357710	38O/4	Hand Pump	23°	7.69	581	21	11	171	2	0.4	0.03	22	0.03	0.081
31	19157755	38O/4	Hand Pump	23°	7.88	672	18	11	197	2	2	0.02	85	0.05	0.034
32	20207800	38O/4	Hand Pump	19°	7.64	364	30	31	87	4	0.05	0.01	65	0.03	0.05
33	20657820	38O/4	Spring	11°	8.31	204	23	15	44	6	0.5	0.04		0.04	0.057
34	20157815	38O/4	Hand Pump	21°	7.70	369	23	19	109	4	1	0.01	38	0.01	0.052
35	21757965	38O/4	Hand Pump	23°	7.73	251	21	14	83	3	1	0.07	5	0.03	0.051
36	20807895	38O/4	Hand Pump	19°	7.82	167	28	14	20	4	3	0.04	51	0.07	0.049
37	21607890	38O/4	Spring	18°	7.57	275	59	23	29	3	0.14	0.5	45	0.2	0.05
38	22007895	38O/4	Spring	20°	7.47	240	47	21	23	3	0.08	0.05	32	0.1	0.056
39	21807820	38O/4	Hand Pump	23°	7.60	280	36	18	72	2	2	0.05	39	0.02	0.053

40	18156754	38O/4	Hand Pump	21^{o}	7.40	268	39	24	43	2	2	0.07	34	0.07	0.025
41	17147765	38O/4	Hand Pump	19^{o}	7.13	603	70	61	103	2	1	0.03	47	0.06	0.063
42	20156755	38O/4	Spring	15^{o}	7.76	303	91	16	25	2	4	0.03	49	0.05	0.057
43	17857525	38O/4	Hand Pump	24	7.53	382	38	45	105	5	0.2	0.08	41	0.02	0.115
44	17607590	38O/4	Hand Pump	23	7.77	217	22	22	91	2	0.07	0.06	29	0.03	0.074
45	18307570	38O/4	Tube Well	18	7.45	190	44	12	77	2	2	0.05	22	0.05	0.055
46	18407600	38O/4	Hand pump	25	7.53	474	38	27	123	3	0.4	0.02	47	0.06	0.035
47	18607540	38O/4	Tube Well	18	7.86	233	37	27	69	4	0.1	0.03	35	0.01	0.086
48	19407445	38O/4	Spring	18	7.70	363	32	36	100	3	2	0.01	31	0	0.034
49	19907450	38O/4	Hand Pump	22	7.66	219	24	22	66	3	2	0.01	44	0.06	0.117
50	20257445	38O/4	Spring	20	7.72	251	27	21	76	4	3	0.06	39	0.02	0.068
51	20257445	38O/4	Spring	20	7.72	251	26	20	73	4	2	0.01	50	0	0.115
52	20907475	38O/4	Hand Pump	22	7.65	275	53	23	63	3	0.3	0.06	30	0.02	0.053
53	22307480	38O/4	Spring	17	8.05	209	22	23	81	2	0.3	0.02	21	0	0.105
54	23007450	38O/4	Hand Pump	23	7.57	321	34	28	77	3	1	0.05	36	0.07	0.043
55	24757475	38O/4	Hand Pump	21	7.50	385	46	30	99	3	3	0.04	42	0.05	0.035
56	20107415	38O/4	Hand Pump	23	7.89	353	25	24	112	3	1	0.08	47	0.05	0.095
57	22407390	38O/4	Tube Well	18	7.86	414	36	27	111	4	2	0.05	17	0.07	0.066
58	22407390	38O/4	Tube Well	18	7.86	414	11	28	109	3	1	0.06	45	0.02	0.115
59	24357460	38O/4	Hand Pump	24	7.84	446	16	10	119	3	0.2	0.02	92	0.03	0.075
60	24757465	38O/4	Tube Well	19	8.03	484	47	29	123	4	1	0.01	43	0.03	0.038
61	26307505	38O/4	Spring	21	7.55	570	55	34	158	4	4	0.05	50	0.06	0.066
62	27157480	38O/4	Spring	19	8.25	209	23	19	37	3	0.02	0.04	43	0	0.052
63	15907185	38O/4	Spring	20	8.15	236	13	7	102	2	1	0.05	47	0.01	0.039
64	16807315	38O/4	Hand Pump	22	7.61	308	15	62	82	3	3	0.02	41	0.04	0.054
65	15657175	38O/4	Spring	20	8.22	273	31	31	92	3	0.2	0.02	39	0.08	0.03
66	15307130	38O/4	Spring	19	7.50	623	20	36	130	2	2	0.05	44	0.02	0.048
67	17007345	38O/4	Hand Pump	24	7.59	336	20	19	101	3	0.17	0.05	37	0.05	0.084
68	13007245	38O/4	Hand Pump	22	7.29	714	45	51	109	3	3	0.08	29	0.02	0.081
69	12707200	38O/4	Hand Pump	20	7.33	303	45	36	39	2	2	0.05	28	0.08	0.034
70	12507215	38O/4	Tube Well	19	7.41	427	56	11	66	3	0.5	0	50	0.05	0.035
71	14357700	38O/4	Spring	19	8.09	910	27	6	409	2	0.38	0.02	51	0.06	0.046
72	14107555	38O/4	Tube Well	20	7.40	234	48	13	44	2	1	0.06	40	0.03	0.07
73	13357580	38O/4	Tube Well	23	7.56	214	51	9	52	2	1	0.02	33	0.05	0.115
74	13707445	38O/4	Tube Well	19	8.13	493	23	27	150	2	1	0	45	0.03	0.12
75	15007370	38O/4	Spring	22	7.73	387	48	22	125	2	2.47	0.04	39	0.05	0.073
76	31457785	38O/8	Tube Well	24	7.63	252	52	17	18	2	3	0.02	47	0.03	0.085
77	31607765	38O/8	Tube Well	23	7.7	303	47	25	25	2	2	0	34	0.06	0.09
78	32507690	38O/8	Tube Well	20	7.62	304	35	30	39	3	0.5	0.07	38	0.03	0.07
79	32507690	38O/8	Tube Well	20	7.62	304	36	26	42	3	0.6	0.05	43	0.02	0.08
80	32207570	38O/8	Tube Well	20	7.99	422	36	23	133	3	0.1	0.05	28	0.01	0.03
81	71807540	38O/8	Spring	21	8.5	254	28	19	41	4	0.22	0.05	44	0.01	0.1
82	28107440	38O/4	Tube Well	21	8.4	480	20	16	204	3	1	0.07	27	0.07	0.05
83	29807480	38O/4	Spring	19	8.51	191	20	9	39	2	3.29	0.06	56	0.04	0.06
84	29957465	38O/4	Spring	18	8.37	197	14	16	35	3	2	0.03	45	0.05	0.1

85	30307475	38O/4	Spring	20	8.58	186	25	21	36	3	1	0.05	85	0.07	0.11
86	30807485	38O/4	Spring	20	8.58	198	25	18	36	3	4	0.03	65	0.03	0.12
87	23107175	38O/4	Tube Well	20	7.65	533	8	28	243	1	1	0.02	49	0.03	0.05
88	25707190	38O/4	Tube Well	19	7.12	508	28	8	196	2	1	0.03	44	0.05	0.06
89	26907270	38O/4	Tube Well	20	7.13	345	12	27	170	1	3	0.03	39	0.03	0.09
90	27457360	38O/4	Spring	20	7.96	562	13	6	298	2	0.58	0.04	23	0.05	0.87
91	24107175	38O/4	Tube Well	20	6.91	357	45	4	154	2	3	0.06	28	0.03	0.11
92	23907175	38O/4	Tube Well	20	6.69	288	52	24	127	1	2	0	30	0.06	0.06
93	23207164	38O/4	Tube Well	20	6.69	288	52	8	118	2	1	0.01	45	0.03	0.11
94	25107075	38O/4	Stream	22	7.73	250	24	20	79	2	2	0.02	40	0.02	0.07
95	26707190	38O/4	Stream	20	7.7	198	32	10	29	3	1	0.01	35	0.06	0.06

3. Outcomes and discussion

3.1. Water characteristics

Results of the water samples obtained from both surface and subsurface sources of water are given in tables 1 to 4. The drinking water physical properties of the study area were found average and hazardous things for human health was not noticed. The pH, EC and chemical concentrations in drinking water samples are summarized in Table 2 which are collected from the surface and groundwater sources.

The pH of an environment is a controlling factor in the precipitation of certain minerals. For example, calcium carbonate is never precipitated in an acidic environment. For the precipitation of CaCO3 together with an alkaline media, temperature is also an important factor (Reincek and Singh, 1975). The study area pH is acidic to slightly alkaline that ranges from 6.69—8.87. In tube wells of the study area, the pH lies between 6.69 to 8.4 and the mean value was observed as 7.60. In the spring's water, it ranges from 7.47 – 8.87 and the mean value is found as 8.00. While the range of pH in samples collected from streams is 7.7 – 8.49 and the mean is 7.97.

The value of pH in the samples taken from hand pumps is between 7.4 to 7.89 and the mean value is noted as 7.57 as shown in Table 1. The highest pH value, 8.7 is found in a spring' sample obtained from Ziari Algad, while the lowest pH (6.69) is recorded in sample 94 collected from a dug well in village Shinalgadai, tehsil Karak. Among the collected drinking water samples, the pH values compared with the values fixed by the WHO, 2008 are found within their respective permissible parameters with the exception of three samples out of total 96 samples, in which pH values slightly exceeds the standards fixed by the WHO, 2008.

Turbidity values in water samples obtained from the research area were found within the acceptable parameters. The mean value is found as 2.66 NTU. The highest turbidity value of 5 NTU is noticed at Kamanghar village in Kamanghar spring while the minimum (1 NTU) is noticed in drinking water of Kanda village in sample 24 collected from a hand pump.

The samples taken from the tube wells for TDS analysis ranges from 141 mg/l – 737 mg/l, having calculated mean of 305.76 mg/l. The of TDS in the water samples taken from spring's ranges from 191 mg/l – 562 mg/l, with the mean TDS value of 240.67 mg/l. In stream water samples, TDS values were found between 198 mg/l – 237 mg/l and a mean concentration of 228.33 mg/l. The TDS values in drinking water samples collected from hand pumps ranges from 167 mg/l – 2004 mg/l, having a mean of 366.97 mg/l. The highest TDS value i.e. 2004 mg/l was observed at Takki Mitha Khel village in sample 03 and a minimum value of 167 mg/l was observed at Chambai Gharuri village in sample 37. The TDS values of drinking water collected from different sources (i.e. Dug wells, streams, springs, tube wells) compared to the fixed values set by the WHO, 2008 have been found within the permissible limits except three samples in which TDS values were much higher than the permissible limits. The mean TDS concentration in hand pump's water was observed slightly higher than tube wells, springs and stream (Table 1).

Table 2. Physico-chemical parameters of drinking water samples from the study area.

Parameters	Statistics	Tube wells n=30	Springs n =28	Streams n=3	Hand pumps n=35	WHO, 2008	Pak, EPA, 2010
	Range	120-415	140-265	105-365	135-465		
Alkalinity mg/l	Mean	208	245	195	218.5	< 500	< 500
	StD d	187	175	107	136		
	Skewness	1.568	2.866	3.971	1.234		
	Range	208-358	198-396	204-364	187-368		
Total Hardness mg/l	Mean	269	285	343	258	< 500	< 500
	StD d	112	97	238	189		
	Skewness	5.186	3.975	7.832	4.733		
	Range	6.69-8.4	7.47-8.87	7.7-8.49	7.4-7.89		
pH	Mean	7.6	8	7.97	7.57	6.5-8.5	6.5-8.5
	StD d	0.43	0.39	0.45	0.21		
	Skewness	-0.43	0.43	1.72	-0.53		
	Range	141-737	191-562	198-237	167-2004		
TDS mg/l	Mean	305.76	240.67	288.33	366.97	< 1000	< 1000
	StD d	101.7	194.01	27.06	451.9		
	Skewness	0.096	1.8194	-1.293	1.951		
	Range	1.00-6.00	1.00-6.00	2.00-5.00	2.00-7.00		
K mg/l	Mean	2.7	3.07	3.33	3.22	12	12
	StD d	1.414	1.12	1.52	1.113		
	Skewness	1.004	0.7	0.9	1.27		
	Range	18-248	11-409	29-79	20-687		
Na mg/l	Mean	104.7	79.03	55	147.8	200	-
	StD d	61.02	85.4	25.06	145.8		
	Skewness	0.38	2.72	0.357	2.926		
	Range	3-173	1.00-228	8.00-14	1-398		
Cl mg/l	Mean	42.8	35.46	10.33	62.62	250	250
	StD d	35.1	53.27	3.21	82.16		
	Skewness	1,98	2.5	1.54	2.56		
	Range	4.00-55	2.00-36	10.00-21	6.00-72		
Mg mg/l	Mean	20.66	18.63	17	28.4	150	-
	StD d	104	9.195	6.082	16.865		
	Skewness	0,089	2.866	3.971	1.09		
	Range	8.00-78	5.00-91	24-32	14-70		
Ca mg/l	Mean	38.1	31.82	29	30.88	200	-
	StD d	18.81	19.8	4.358	12.635		
	Skewness	0.29	1.218	1.63	0.967		
	Range	1.00-126	1.00-67	3.00-94	2.00-835		
So_4 mg/l	Mean	36.63	20.71	45.66	119	250	250
	StD d	33.1	16.79	45.76	202.6		
	Skewness	0.99	1.178	0.5486	2.592		
	Range	0.01-0.12	0.03-0.12	0.02-0.09	0.02-0.117		
Fe mg/l	Mean	0.069	0.092	0.06	0.065	0.3	-
	StD d	0.03	0.15	0.036	0.025		
	Skewness	0.37	5.061	-1.152	0.6266		

Parameters	Statistics	Tube wells n=30	Springs n =28	Streams n=3	Hand pumps n=35	WHO, 2008	Pak, EPA, 2010
Cr mg/l	Range	0.01-0.07	0.01-0.05	0.01-0.03	0.01-0.08	0.05	0.05
	Mean	0.04	0.05	0.02	0.045		
	StD d	0.04	0.08	0.01	0.022		
	Skewness	2.228	5.021	-1.00E-15	0.085		
Zn mg/l	Range	0.1-3	0.01-4	1.00-2.00	0.02-3	3	5
	Mean	1.4	1.2	1.66	1.93		
	StD d	0.0904	1.397	0.577	0.989		
	Skewness	0.656	0.925	1.7321	1.06		

The ground water hardness was found between 208 – 396 mg/l and a mean of 269 mg/l, while in surface waters it ranges from 204-364 mg/l, and mean of 343 mg/l. The peak value of 396 mg/l is noted in hand pumps samples from Mamani Village. Springs samples have higher compared to the rest of the samples collected in the study area (Table 2).

The concentration of Cl in the samples from tube wells fall in the range between 3 mg/l – 173 mg/l, and mean concentration of 42.8 mg/l. Chloride concentration in spring water samples ranges from 1 – 228 mg/l, calculated mean of 35.46 mg/l. The Cl concentration in stream samples ranges between 8 – 14 mg/l, and mean noted of 10.3 mg/l. The range of Cl in samples of hand pump's water was found between 1 mg/l to 398 mg/l, and mean of 62.6 mg/l. The highest value of Cl level in drinking water samples collected from hand pump was found to be 398 mg/l at village Takki Mitha Khel, and the lowest level of 1.0 mg/l was found at village Chambai in the project area.

In tube wells water samples, concentration of sulfates ranges from 1 – 126 mg/l and the mean is found to be 36.63mg/l, while its concentration in water samples collected from springs ranges between 1-67 mg/l, and the calculated mean is found to be 20.71 mg/l. The water samples that are taken from streams, the concentration of sulfates was observed between 3 – 94 mg/l, calculated mean observed is 45.66 mg/l, while, its concentration in hand pumps water samples was between 2-835 mg/l, and mean is found to be 119 mg/l. In all the water samples taken from different sources in the study area the highest value of sulfate is 835 mg/l marked in sample 02 collected from hand pump at village Takki Mitha Khel, whilst the lowest value of 1 mg/l was detected in village of Khusra Loughar at Tehsil Karak. The sulfate concentration of water sources in the study area are in the acceptable limit of WHO (2008), with the exception of few samples in which it exceeds the permissible limits.

In water samples collected from tube well Ca concentrations ranges from 8 – 78 mg/l, yielded a mean of 38.16 mg/l. Ca concentration in spring water samples lie between 5 – 91 mg/l, mean value of 31.82 mg/l. The stream water samples have Ca concentration ranges 24 _ 32 mg/l, giving a mean of 29 mg/l. The highest Ca concentration i.e. 70 mg/l and 14 mg/l of lowest are observed in hand pumps, yielding mean of 30.88 mg/l. Ca in samples of hand pumps, tube wells, streams and springs were found within their acceptable range compared to the criteria established by the WHO, 2008.

Main natural sources of magnesium are dolomite, mafic and ultramafic rocks. In tube wells, the concentration of Mg ranges from 4 – 55 mg/l with mean of 20.66 mg/l. Peak value of Mg in drinking water samples collected from spring was found as 36 mg/l with a lowest value of 2.0 mg/l, yielding a mean of 18.63 mg/l. The Mg concentration in samples collected from stream water is from 10–21 mg/l, giving a mean of 17 mg/l. Similarly, hand pump water samples Mg concentration lie between 6–72 mg/l, and mean is 28.4 mg/l.

Alkalinity of tube wells samples from Tehsil Karak and adjoining areas ranges from 12-415 mg/l, whilst the mean is 208 mg/l. Spring water alkalinity are in the range of 140 – 265 mg/l with a mean concentration of 245 mg/l. In stream's water samples alkalinity is found between 105 – 365 mg/l and mean of 195 mg/l, whereas samples collected from hand pumps alkalinity ranges between 135 – 465 mg/l, acquiring mean of 218.50 mg/l (Table 2). All the drinking water samples that are taken from various sources i.e. hand pumps, tube wells, streams and springs the alkalinity range is found within admissible threshold.

In tube wells drinking water of Tehsil Karak, K concentrations is recorded between 1.0 – 6.0 mg/l, yielding mean concentration of 2.70 mg/l. Spring water samples have K of 1.0 – 6.0 mg/l and, attaining the mean of 3.07 mg/l. The concentration of K in stream water samples range from as 2.0 – 5.0 mg/l, with noted mean of 3.33 mg/l. The K concentration ranges from 2.0 – 7.0 mg/l in the samples obtained from the hand pumps and mean value was observed as 3.22 mg/l. The maximum value of K concentration was observed as 7.0 mg/l in drinking water sample taken from hand pump at village Takki Mitha Khel in sample no. 2, while, the lowest level of 1.0 mg/l was found in sample nos. 83, 87, 92 collected from tube wells at village Sarkai loughar, Mamani Loughar and Shinalgadai in the study area. The concentration of K in drinking water samples obtained from all the sources i.e. hand pumps, streams, tube wells, and springs were noted in their respective tolerable boundaries on comparison with the criteria fixed by the WHO, 2008.

The Na concentrations in the samples taken from tube wells ranges from 18 – 243 mg/l, with mean of 104.7 mg/l. The Na concentration in samples that is taken from springs ranges from 11 – 409 mg/l, yielding a mean of 79.03 mg/l. The Na concentration in stream water samples ranges from 29 -79 mg/l, and mean found is 55 mg/l. Hand pump samples have Na that is ranges from 20 – 687 mg/l, and observed mean is 147.80 mg/l. From the collection different water sources, the concentration of Na that is found is within their respective acceptable limits, with the exception of samples collected from streams and most of the spring water.

Concentration of Na in drinking water of the study is 11.00 – 687.00 mg/l, higher than the permissible limit (200 mg/l) of WHO (2008) in Khastorai banda (409 mg/l), Mamani village (298 mg/l), Saif Ali banda (204 mg/l), Sarkai loughar (243 mg/l), Takki Mitha Khel (297 mg/l, 621 mg/l and 687 mg/l) and village Kanda Karak (201 mg/l, 376 mg/l and 212 mg/l).

The water samples obtained from various sources are also analyzed for heavy metals and metalloids. The detection limits of the instrument for Fe, Zn, Pb, Cd, Cu, Cr, As and Co reported are as 0.002 mg/l, 0.02 mg/l, 0.02 mg/l, 0.03 mg/l, 0.01mg/l, 0.005mg/l, 0.05 mg/l and 0.001 mg/l, respectively. The amount of Cu, Pb, As and Co were found below the detection limit and are, therefore, not given in Table 2.

In tube well's water samples, the Cr concentration is from 0.01-0.07 mg/l, with recorded mean of 0.04 mg/l. The Cr in springs water samples is from 0.01-0.05 mg/l, giving a mean of 0.05 mg/l. In water samples acquired from stream, Cr is between 0.01-0.03 mg/l, yields a mean of 0.02 mg/l. Samples collected from hand pumps, the maximum concentration value observed is 0.08 mg/l, while the lowest level value is 0.01 mg/l, with a mean of 0.045 mg/l.

Zn concentration in water samples collected from tube wells of Tehsil Karak and adjoining areas ranges from 0.1 – 3.00 mg/l, giving a mean of 0.904 mg/l. In spring water samples Zn concentration lie between 0.01 – 4.00 mg/l, yielding a mean of 1.20 mg/1. In stream water samples, the Zn concentration is in the limits of 1.0 - 2.00 mg/l, and the mean noted is 1.66 mg/l. In hand pumps, the Zn concentration observed ranges from of 0.02 – 3.00 mg/l, with mean recorded is 1.93 mg/l. The Zn concentration obtained from all sources in samples that are used for drinking purpose are found within their respective acceptable range compared to the reference values fixed by the WHO, 2008.

In water samples acquired from tube wells of Tehsil Karak, the Fe concentration is from 0.01 – 0.12 mg/l, with mean of 0.069 mg/l, whereas the concentrations of Fe ranges between 0.03 – 0.12 mg/l in the samples from the spring source, and the recorded mean is 0.092 mg/l. The water samples that are taken from stream, Fe is between 0.02 mg/l to 0.0.09 mg/l, with mean noted is 0.06 mg/l. The Fe contents ranges from 0.02 – 0.117 mg/l in hand pumps samples, which yield a mean of 0.065 mg/l. The highest Fe concentration in all the water samples is 0.12 mg/l, highest found in sample no. 62 obtained from tube well at village Shagai Loughar while the lowest Fe concentration is observed 0.01 mg/l in sample no. 5 also collected from tube wells at village Mitha Khel, Tehsil Karak. Fe concentration in drinking water sources are found within their respective acceptable parameters set by WHO, 2008.

3.2. Health risk assessment

In the research area, the main sources of the drinking water for the locals are the Dug wells, hand pumps, tube wells and springs. For the determination of drinking water health quality, samples were taken from different sources including tube wells, springs and hand pumps, and were selected to define the heavy metals concentration, and their related health threats evaluation such as CDI and HQ.

3.2.1. Chronic daily intake (CDI)

The CDI values of the water samples taken from tube wells have Zn concentration ranges from 0.23 – 22.51 µg/kg-day, and the mean is 2.143 µg/kg-day, while in spring's water, the CDI values of Zn is noted between 0.24 - 61.7 µg/kg-day, and the mean recorded is 13.038 µg/kg-day. The Zn in stream water have CDI values ranges from 0.0 - 0.24 µg/kg-day, and mean found is 0.0462 µg/kg-day. Similarly, hand pump samples have CDI values of Zn ranges from 0.22 - 35.7 µg/kg-day, with mean recorded is 14.553µg/kg-day that is shown in Table 3.

The CDI values of Fe in tube wells water range from 0.00 – 2.25 µg/kg-day and mean for Fe noted is 0.703 µg/kg-day, whereas in spring samples it ranges from 0.00 – 1.62 µg/kg – day, with mean noticed is 0.642 µg/kg-day. In stream water samples the CDI values of Fe range between 0.00 – 0.24 µg/kg-day, with mean value of 0.0691µg/kg – day, whilst in hand pumps water samples the recorded Fe ranges from 0.00 – 0.26 µg/kg-day, and the mean value is found as 0.0476 µg/kg-day (Table 3).

The samples taken from the tube wells of Tehsil Karak have the CDI values of Cr range between 0.00 – 0.53 µg/kg–day, with mean of 0.018 µg/kg–day, whereas the CDI values for Cr is between 0.00 – 0.55 µg/kg-day in the samples obtained from the springs of the project area and the mean value found is 0.021 µg/kg–day. In stream water samples, the CDI values of Cr fall in the range of 0.0 – 0.46 µg/kg–day, and mean value noted is 0.012 µg/kg-day, while the water samples collected from hand pumps Cr occur in the limits of 0.0 – 0. 38 µg/kg-day, and mean value observed is 0.011 µg/kg-day (Table 3). The CDI indices in Tehsil Karak (south of Indus Highway) show that Zn > Fe > Cr. However, CDI values of Pb, As, Co and Cu recorded are under the limit in the samples acquired from the study area.

3.2.2. Hazard quotient

The non-cancer risks acknowledged HQ indices for heavy metals (Zn, Fe and Cr) consumption through drinking water by the inhabitants of Tehsil Karak are calculated according to the US-EPA (2000, 2004), which are in Table 4. Water samples obtained from tube wells of the study area, mean values of HQ index of Cr, Zn, Fe and recorded are 1.04E – 04, 1.54E – 02 and 1.34E – 02 respectively, whereas samples acquired from the spring are noticed as 1.23E – 02, 1.02E – 02 and 1.01E – 05. In stream samples, mean HQ index values of Zn, Cr and Fe are 2.43E – 02, 1.34E – 02 and 1.08E – 02 whilst in water samples obtained from hand pumps, the mean HQ index values for Cr, Zn and Fe were recorded as 1.04E – 02, 2.84E – 02 and 1.06E – 02 respectively. The recorded HQ indices in Tehsil Karak were in the order of i.e. Zn is greater than Fe and Fe is greater than Cr. When compared to the US EPA (1999), Muhammad et al. (2011), Khan et al. (2008), and Jabeen et al (2014), the HQ indices for the heavy metals represents no health-related threat to the community in the research area.

Table 3. Showing CDI indices for heavy metals (µg/kg-day) in the drinking water of project area.

Parameters	Statistics	Tube wells n=30	Springs n =28	Streams n=3	Hand pumps n=35
Zn	Range	0.23-22.51	0.24-61.7	0.00-0.24	0.22-35.7
	Mean	2.143	13.038	0.0462	14-553
	StD d	3.452	18.77	0.1298	12.124
Fe	Range	0.00-2.25	0.00-1.62	0.00-0.24	0.00-0.26
	Mean	0.703	0.642	0.0691	0.0476
	StD d	0.3162	0.5382	0.1249	0.1078
Cr	Range	0.00-0.53	0.00-0.55	0.00-0.46	0.00-0. 38
	Mean	0.018	0.021	0.012	0.011
	StD d	0.1223	2.3412	0.1011	0.1732

Table 4. Showing HQ indices for heavy metals through drinking water consumption.

Parameters	Statistics	Tube wells n=30	Springs n =28	Streams n=3	Hand pumps n=35
Zn	Range	0.00-5.85E-03	0.00-8.75E-04	0.00-2.68E-01	0.00-1.70E-02
	Mean	1.04E-02	1.23E- 02	2.43E-02	2.84E-02
	StD d	1.60E-02	2.67E-04	4.54E-02	6.83E-02
Fe	Range	0.00-1.20E-02	0.00-2.40E-03	0.00-1.40E-01	0.00-4.40E-02
	Mean	1.04E-02	1.02E-02	1.08E-02	1.06E-02
	StD d	1.54E-02	1.46E-02	1.84E-02	1.64E-02
Cr	Range	0.00-4.00E-04	0.00-2.40E-02	0.00-4.85E-03	0.00-4.60E-04
	Mean	1.40E-04	1.50E-05	1.34E-02	2.08E-02
	StD d	2.85E-02	7.26E-05	1.46E-02	6.83E-02

4. Conclusions

The present research work indicates that the physico-chemical parameters i.e. taste, color, odor, conductivity, and turbidity of the drinking water of a part of Tehsil Karak are within permissible limits of WHO, 2008. The mean concentration values of both pH and TDS of water samples are also observed within admissible limits. However, the concentration of pH and TDS in 3 samples are exceeding the permissible limits fixed by WHO, 2008. The concentrations of Na are found higher than the accepted limit (200 mg/l) of WHO (2008) in some of the samples taken from hand pumps and tube wells. The mean concentration of the studied heavy minerals was also found in the nontoxic range. In additional, heavy metal concentrations of Zn, Fe and Cr are also observed to fall within the acceptable limits, when compared to fixed values set by the WHO (2008). The HQ and CDI indices calculated for the heavy metals in the samples that are collected from a part of Tehsil Karak are observed in the order of Zn > Fe> Cr and Zn > Fe > Cr, respectively, and indicate that there are no health risks to the local inhabitants.

Author's contribution

Nazir ur Rehman, Afrasiab and Waqar Azeem executed the field and collected the samples.

Fayaz Ali, Shuja Ullah, Rizwan Ullah and Mumtaz Khan helped in laboratory work and preparation of samples. Nazir ur Rehman and Shah Faisal interpreted the data, drafted the article and constructed the maps. Sajjad Ahmad did supervision of research work and reviewed the paper.

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