Desalination and Water Treatment
www.deswater.com
doi: 10.5004/dwt.2019.24925

171 (2019) 105–114
December

Estimation of water quality, management and risk assessment in Khyber Pakhtunkhwa and Gilgit-Baltistan, Pakistan

Muhammad Tayyab Sohail[a,*], Rashid Aftab[b], Yusra Mahfooz[c,d,*], Abdullah Yasar[e], Yat Yen[f], Sarfaraz Ahmed Shaikh[g], Samina Irshad[h]

[a]*School of Management, Xi'an Jiaotong University, Xi'an Shaanxi, 710049, China, email: tayyabsohail@yahoo.com*
[b]*Riphah Institute of Public Policy, Riphah International University, Islamabad 44000, Pakistan, email: rashid.aftab@riphah.edu.pk*
[c]*Sustainable Development Study Center, GC University Lahore, 54000 Pakistan*
[d]*School of Earth and Space Sciences, University of Science and Technology, Hefei 230026, Anhui, China, email: sdsc8888@gmail.com*
[e]*Sustainable Development Study Center, GC University Lahore, 54000 Pakistan, email: yasar.abdullah@gmail.com*
[f]*College of Urban and Environmental Science, Peking University, Beijing, 100871, China, email: yy2014@mail.ustc.edu.cn*
[g]*Newports Institute of Communication and Economics Karachi, 74700 Pakistan, email: sarfarazz.ahmed@gmail.com*
[h]*School of Earth and Space Sciences, University of Science and Technology, Hefei, 230026 Anhui, China, email: saminakhan@mail.ustc.edu.cn*

Received 27 April 2019; Accepted 19 September 2019

ABSTRACT

The present study is based on water quality assessment for drinking and irrigation purpose in 10 districts of Khyber Pakhtunkhwa and Gilgit-Baltistan, Pakistan. A total of 181 water samples were collected with random sampling criteria and undergone quality assessment through the American Public Health Association standard procedures. Electrical conductivity (EC), turbidity and arsenic were found higher in drinking water than upper permissible limits of World Health Organization (WHO) and the National Environmental Quality Standards-Pakistan (NEQs-Pak). Multivariate quality indexes were applied, water quality index determined that overall water quality was good for drinking purpose. However, health risk assessment was evaluated, and results showed that values of hazard index (HI) were near the threshold limit (HI ≥ 1) both in adult and children. Irrigation water quality for surface water was determined by using sodium absorption ratio and magnesium absorption ratio indexes showed that water used for irrigation purpose was in good quality. Permeability index was found unsuitable for surface water. However, EC, turbidity, and arsenic were exceeding a limit for drinking purpose. Reducing anthropogenic activities including waste disposal, regular monitoring of water supplies and apply preventive measures can improve the water quality status.

Keywords: Drinking water; Health risk; Irrigation water; KPK Pakistan; Water quality index

1. Introduction

Access to safe and pure drinking water is at the center of development goals worldwide [1]. Drinking water is a dynamic element in the environment and a valued gift to human beings from nature [2,3]. Water scarcity and water quality are currently provoking topographical issues and in the near future, a large portion of the globe will be underwater crisis [4]. Drinking water sources in the world where the gastroenteritis diseases are the major contributor to human illness are continuously damaged and polluted with various physiochemical contaminants and microbes [5,6]. Trace metals such as chromium (Cr), calcium (Ca), copper (Cu), iron (Fe), potassium (K), magnesium (Mg), zinc (Zn) and sodium (Na) are essential for body in some amount, due to lack of these metals there may be retarded biological processes, while their additional levels can be a reason for

* Corresponding authors.

toxicity [7,8]. Water quality can be monitored by checking physicochemical, microbiological, and aesthetic aspects of water quality [9,10]. Globally, many local government authorities have comprehensive and effective schemes to maintain and manage water distribution networks very often by checking water quality in the region [11]. There is a number of studies in Pakistan related to check water quality but the remote, rugged and poverty-stricken mountainous areas continued least monitored or neglected. Unfortunately, it is not on priority in Pakistan by local government [4]. In many developing countries such as Pakistan, the diminution of water quantity tied with increasing water demand lead to severe water shortage in virtually all sectors. The per capita water accessibility in Pakistan reduced from 5,000 in 1951 to 1,100 m^3 per annum [12]. The main reason is the increasing population but there is no alternative solution for the development of water resources in the country [13]. The situation is more alarming in areas which are far from Indus basin due to less per capita water accessibility per annum [14], along with water scarcity Pakistan is also facing another problem which is water contamination [15]. Contaminated water can be the reason for causing many diseases to human being such as viruses, protozoa, and bacteria [16,17]. In the present time, due to rapid urbanization, climate change, intensive industrialization reduces the groundwater quality. Groundwater contamination harmfully affects the ecosystem and causes damage to human health [18,19]. Arsenic can be a main toxic heavy metal that is obviously dispersed in groundwater contamination and has impacts on human health [20,21]. Generally, groundwater is safer for drinking and irrigation drives; but, due to heavy metal pollution linked with the growth of urbanization and industrialization is becoming a serious threat to groundwater quality [22,23]. Many floods hit northwest Pakistan previously and millions of people were affected nationwide. Those floods contaminated hundreds of wells in Khyber Pakhtunkhwa and presented a public health hazard [24]. Another reason of water contamination in the study area can be hand-dug wells because these well having a diameter just large enough for the diggers and can be lined to protect them from surface water contamination [24]. The microbial contamination of drinking water is a serious problem in Pakistan while the availability of freshwater is poor due to poor financial constraints and lack of proper management [25,26]. Regular evaluation of water quality tells its status and has utmost importance for making policy in the environmental protection department [27]. This paper pertains water quality monitoring covering five districts (Buner, Mardan, Swat, Lower Dir, and Upper Dir) of Khyber Pakhtunkhwa and the Gilgit-Baltistan, Pakistan (Skardu, Gilgit, Ghanche, Ghizer, and Diamer). As per 2017 censes of Government of Pakistan, the population of Khyber Pakhtunkhwa was 207,774,520 [28]. The specific objectives of this paper were to (i) estimate the water quality, management and risk assessment of the mountainous areas, (ii) to calculate the water quality assessment including water quality index (WQI), water health risk assessment and assessment of irrigation water quality, (iii) this study will help policymakers and relevant authorities to have a look at the present situation of water quality and take suitable measures in time.

1.1. Study area

The Khyber Pakhtunkhwa (KPK), which lies between latitude 31° 40′ and 36° 57′ N and longitude 69° 19′ and 74° 70′E, is a mountainous area located around Hindu Kush and Himalaya Ranges. The climate of this region differs widely due to its size and topography and mountain terrain of Nanga Parbat which block the winds, making the area dry. Temperature range of KPK is 16°C–36°C while minimum (in November) rainfall was recorded 2.1 mm and maximum (in April) was 28.3 mm [29]. The present study covered 10 main districts from Khyber Pakhtunkhwa (Buner, Mardan, Swat, Lower Dir, and Upper Dir) and Gilgit-Baltistan (Skardu, Gilgit, Ghanche, Ghizer, and Diamer). Fig. 1 shows a map of the study area.

2. Methodology

2.1. Sample collection

The paper is based on the determination of water quality (physicochemical parameters and metals) in five districts of Khyber Pakhtunkhwa (including Upper Dir, Lower Dir, Swat, Buner, and Mardan) and the Gilgit-Baltistan (Ghizer, Diamer, Ghanche, Skardu and Gilgit). A total of 10 sites were selected and 181 samples were collected by random sampling. The sampling was conducted largely where drinking and irrigation water were in easy access to the local residents. Samples were collected in a 1-L bottle which was already washed by distilled water many times. For metal analysis, samples were preserved at less than 2 pH by adding few drops (<1 mL) of nitric acid in order to prevent precipitation and adsorption of trace metals by container walls [30,31,32]. All the bottles were sealed, labelled accurately and brought to the laboratory for analysis. Analytical procedures for all parameters were given in Table 1. For arsenic, standard solutions of arsenic were prepared in deionized water with the concentrations ranging from 0, 10, 25, 50, 100, 250, and 500 mg L^{-1} similar to Kearns and Tyson [33].

2.2. Water quality assessment

2.2.1. Determination of WQI

For WQI assessment, the following steps were followed [8]:

Weight (AW_i) was assigned to every parameter based on a literature survey which was ranged from 1 (lowest) to 4 (highest). Then relative weight (RW) was calculated by using Eq. (1). In which assigned weight was divided by the sum of assigned weights.

$$\mathrm{RW} = \frac{\mathrm{AW}_i}{\sum_{i=1}^{n} \mathrm{AW}_i} \tag{1}$$

Quality rating (Q_i) was determined in all selected parameters by Eq. (2), where concentration (C_i) of *i*th parameters was divided by its standard value (S_i) and multiplied by 100.

$$Q_i = \left[\frac{C_i}{s_i}\right] \times 100 \tag{2}$$

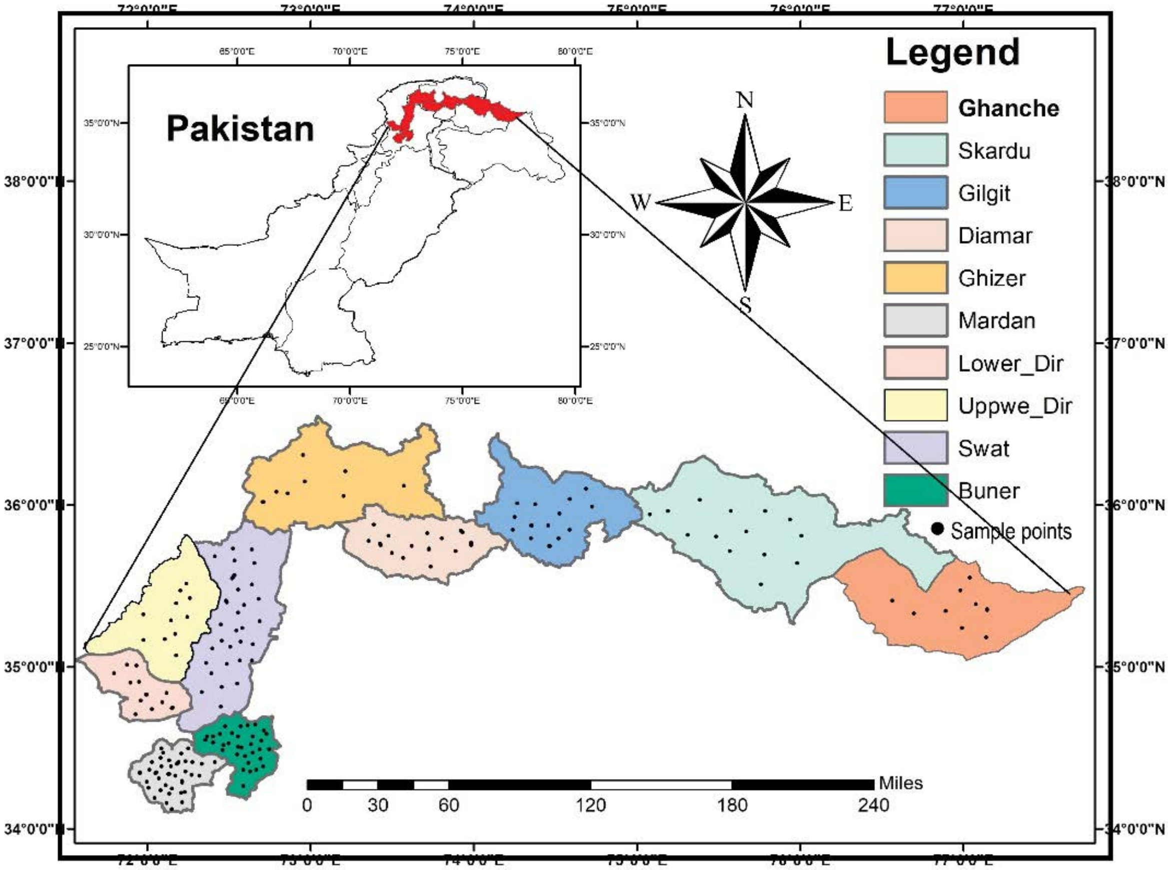

Fig. 1. Map of the study area.

Table 1
Analytical procedure for water parameters

Sr. #	Parameters	Procedure/method
1	Alkalinity (m.mol/L as $CaCO_3$)	2320, Standard method (1992)
2	Bicarbonate (mg/L)	2320, Standard method (1992)
3	Calcium (mg/L)	3500-Ca-D, Standard Method (1992)
4	Carbonate (mg/L)	2320, Standard method (1992)
5	Chloride (mg/L)	Titration (silver nitrate), Standard Method (1992)
6	Conductivity (mS/cm)	E.C meter, Hach-44600-00, USA
7	Fluoride (mg/L)	8029, SPADNS Method (Hach) by Spectrophotometer
8	Hardness (mg/L)	EDTA Titration, Standard Method (1992)
9	Iron (mg/L)	TPTZ Method (Hach-8112) by Spectrophotometer
10	Magnesium (mg/L)	2340-C, Standard Method (1992)
11	Nitrate Nitrogen (mg/L)	Cd. Reduction (Hach-8171) by Spectrophotometer
12	pH	At 25°C pH Meter, Hanna Instrument Model 8519, Italy
13	Potassium (mg/L)	Flame photometer PFP7, UK
14	Sodium (mg/L)	Flame photometer PFP7, UK
15	Sulphate (mg/L)	SulfaVer4 (Hach-8051) by Spectrophotometer
16	TDS (mg/L)	2540C, Standard method (1992)
17	Turbidity (NTU)	Turbidity Meter, LaMotte, Model 2008, USA
18	Arsenic (mg/L)	AAS vario, Analytik AG, Germany

The larger the value of the quality rating, the higher the pollution in the water samples [34]. At the end, sub-indices (SI_i) were primarily estimated for every parameter and then it was utilized to calculate the WQI by Eqs. (3) and (4).

$$SI_i = RW \times Q_i \quad (3)$$

$$WQI = \sum_{i=1}^{n} SI_i \quad (4)$$

WQI was classified as if the values below 50 the water quality was excellent, between 50 and 100 quality was good, between 100 and 200 quality was categorized as poor while between 200 and 300 quality was very poor and above 300 water became unsuitable for drinking purpose [35].

2.2.2. Health risk assessment

For assessment of health risk, the average daily dose (ADD) (mg/kg/d) of water intake was calculated by using the following formula by USEPA [36]:

$$ADD_i = \frac{C_i \times IR}{BW} \quad (5)$$

Based on total contents, hazard quotient (HQ) was computed as follows:

$$HQ_i = \frac{ADD_i}{RfD} \quad (6)$$

Hazard index is the sum of total HQ in a sample and it was calculated by using the following formula:

$$HI = \Sigma\, HQ_i \quad (7)$$

where C is the ith concentration (mg/L) of metal, IR intake rate (2 L/d in adults and 0.63 in children), BW is body weight (72 kg for adults and 15 kg for children) as described by Rehman et al. [37]. RfD is the reference dose given by USEPA. For As, it is 0.0003 [38] and for Fe it is 0.7 [39]. The HQ > 1 will be considered as chronic risks is more than the threshold level and its probability of occurrence [40,41].

2.2.3. Assessment of irrigation water quality

Some multivariate indexes were followed for assessing the water quality for irrigation described by Obiefuna and Sheriff [42]. The sodium absorption ratio (SAR) was evaluated by using Eq. (8) [43].

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^+ + Mg^2}{2}}} \quad (8)$$

The value of magnesium adsorption ratio (MAR) was evaluated by using Eq. (9) [44].

$$MAR = \frac{Mg^{2+} \times 100}{Ca^{2+} + Mg^2} \quad (9)$$

The value of permeability index (PI) was evaluated by using Eq. (10) according to the study by Doneen [45].

$$PI = \frac{Na^+ + \sqrt{Hc\bar{O}_3 \times 100}}{Ca^{2+} + Mg^{2+} + Na^+} \quad (10)$$

The values of ions used in Eqs. (8)–(10) were expressed in meq/L (Table 2) as described by Obiefuna and Sheriff [42].

3. Results and discussion

3.1. Drinking water quality assessment

Physicochemical parameters of groundwater are regarded as main characteristics to identifying quality, type, and nature of water [46]. Table 3 shows the average concentrations of water parameters. In most of the locations electrical conductivity (EC) was found exceeded from WHO and National Environmental Quality standards of Pakistan [47] permissible limits (i.e., 250 ms/cm) similar to Mardan (615 ms/cm), Buner (632 ms/cm), Swat (429 ms/cm), Upper (409 ms/cm) and lower Dir (550 ms/cm), Gilgit (279 ms/cm), and Skardu (274 ms/cm). While the other three areas Ghanche (208 ms/cm), Diamer (192 ms/cm), and Ghizer (214 ms/cm) were under the permissible limits. The EC showed that salt contents/mineral salts are present in ions form in water [48]. The values of EC were similarly higher from the standards values [47] than those reported by Muhammad et al. [49] in groundwater due to sulphides mineralization. The main lethal outcome of high EC of water is the failure of plants to contest with the ions in the soil solution creating physiological drought condition [50]. pH was found within the limits in all

Table 2
meq/L concentrations for surface/irrigation water quality analysis

Districts	HCO_3	Ca	Mg	K	Na
Buner	3.06	2.6	1.58	0.11	1.04
Gilgit	1.56	1.77	1.11	0.05	0.44
Skardu	0.74	0.7	0.30	0.04	0.39
Ghanche	0.98	1.8	0.54	0.08	0.43
Diamer	0.72	0.74	0.23	0.04	0.42
Ghizer	0.98	1.33	0.25	0.05	0.33

Table 3
Mean concentrations (mg/L) of selected parameters in water samples from KPK and Gilgit, Pakistan

Sr. #	Location	n[a]	Parameters (mg/L)															
			EC (μs/cm)	pH	Turbidity	As	HCO_3	Cl	Hardness	Ca	F	Fe	Mg	NO_3	K	Na	SO_4	TDS
WHO limits (2011)			250	6.5–8.5	5	0.05	1,000	250	500	75	1.5	0.3	50	50	55	200	250	1,000
[b]NEQs (2010)			NA	6.5–8.5	<5	<0.05	NA	<250	<500	NA	<1.5	NA	NA	<50	NA	NA	NA	<1,000
1	Mardan	36	615 ± 226	7.6 ± 0.35	1.18 ± 1.21	0.051 ± 0.02	220 ± 77.7	31.18 ± 25.2	211 ± 76.3	53 ± 20.9	0.44 ± 0.34	0.007 ± 0.006	18.72 ± 11.8	3.31 ± 3.31	1.93 ± 0.87	53.1 ± 36.7	44.4 ± 24.1	349.8 ± 117
2	Buner	33	632 ± 422	7.76 ± 0.40	4.89 ± 7.8	0.04 ± 0.01	240 ± 151	31.5 ± 21.2	297 ± 200	79.4 ± 65.3	0.34 ± 0.32	0.01 ± 0.01	23.9 ± 16.7	4.44 ± 2.5	3.6 ± 3.3	22.6 ± 22.7	41.6 ± 62	368 ± 245
3	Swat	30	429 ± 278	7.34 ± 0.33	1.73 ± 4.75	0.058 ± 0.01	155 ± 99	19.4 ± 15.6	196 ± 125	46 ± 29.4	0.10 ± 0.09	0.005 ± 0.006	19.78 ± 15.2	9.1 ± 7.8	1.76 ± 1.7	13.5 ± 9.9	18.6 ± 14.7	251 ± 162
4	Lower Dir	12	550 ± 173	7.45 ± 0.14	0.9 ± 1.8	0.04 ± 0.01	230 ± 63	19.4 ± 8.9	250 ± 62	67.1 ± 32	0.35 ± 0.12	0.05 ± 0.03	19.4 ± 12.8	6.25 ± 4.5	2.47 ± 2.5	19.4 ± 10	19.3 ± 9.2	314 ± 95
5	Upper Dir	11	409 ± 239	7.6 ± 0.38	2.3 ± 3.6	0.06 ± 0.009	173 ± 107	16.3 ± 11.3	189 ± 115	42.1 ± 28	0.21 ± 0.07	0.03 ± 0.02	19.5 ± 13.5	5.8 ± 5.4	2.9 ± 3.2	16.7 ± 10	13.1 ± 5.4	242 ± 137
6	Gilgit	14	279 ± 158	7.9 ± 2.1	25 ± 49	0.05 ± 0.02	75 ± 45	7.07 ± 2.4	126 ± 72	32.5 ± 17	0.20 ± 0.14	0.01 ± 0.01	10 ± 8.02	0.49 ± 0.29	2.7 ± 1.6	7 ± 6.7	61.3 ± 51	166 ± 101
7	Skardu	14	274 ± 193	7.9 ± 2.1	14.9 ± 27	0.03 ± 0.01	85 ± 53	6.07 ± 2.4	120 ± 83	33 ± 22	0.86 ± 1.2	0.02 ± 0.05	8.42 ± 6.6	0.3 ± 0.2	3.01 ± 2.2	8.35 ± 7.8	54.2 ± 57	168 ± 118
8	Ghanche	9	208 ± 78	7.5 ± 0.3	18.4 ± 45	0.05 ± 0.008	59 ± 31	8.2 ± 4.4	88 ± 35	25 ± 11	0.26 ± 0.12	0.01 ± 0.02	6.4 ± 3.7	0.6 ± 0.9	2.5 ± 1.1	8.3 ± 5.1	39 ± 25	128 ± 45
9	Diamer	14	192 ± 193	7.6 ± 0.3	5.6 ± 5.1	0.05 ± 0.02	60 ± 58	7.1 ± 2.2	69.2 ± 72	21 ± 25	0.45 ± 0.72	0.02 ± 0.01	3.8 ± 3.7	0.8 ± 0.5	2.7 ± 3.3	11 ± 9.5	25 ± 35	111 ± 109
10	Ghizer	8	214 ± 121	7.6 ± 0.34	21 ± 59	0.06 ± 0.01	68 ± 41	8.7 ± 3.6	86 ± 46	28 ± 14	0.22 ± 0.09	0.008 ± 0.01	3.6 ± 2.9	0.65 ± 0.2	1.6 ± 0.8	9.8 ± 6.5	27. ± 15	123 ± 63

[a]Number of samples.
[b]National Environmental Quality Standards, Pakistan [47].

the samples. Turbidity was higher than 5 NTU, recommended by WHO and NEQs [47,51] in northern areas including Gilgit (25.5 NTU), Skardu (14.9 NTU), Ghanche (18.43 NTU), Diamer (5.62 NTU) and Ghizer (21.4 NTU) while Khyber Pakhtunkhwa areas were found within range. Arsenic was higher (<0.05) in Mardan (0.051 mg/L), Swat (0.058 mg/L), Upper Dir (0.064 mg/L), Gilgit (0.05 mg/L), Ghanche (0.054 mg/L), Diamer (0.05 mg/L), Ghizer (0.06 mg/L). The values of arsenic were higher than reported by Muhammad et al. [49], that is, 0.01 mg/L in drinking water from the northern region of Pakistan and found lower from Nickson et al. [52], that is, 0.905 mg/L in Muzaffargarh, Pakistan. Higher values of metal indicate anthropogenic actions such as combustion and agricultural of coal in brick kilns [53]. Calcium was found higher only in Buner (79 mg/L), which exceeded the limit (75 mg/L) and other all areas found within the limit for all water samples. Calcium is a significant mineral and vital for carrying out many functions in the body such as blood clotting and transmission of nerve impulses [54].

WQI was evaluated, all the sites were under the category of excellent water quality except Gilgit and Ghizer. However, the water quality was also good in both districts but less than other with 56 and 53 value of WQI, respectively (Fig. 2).

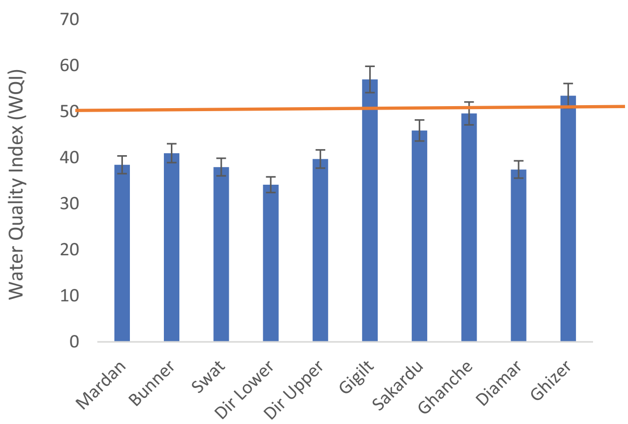

Fig. 2. Water quality index (WQI) of drinking water samples from KPK and Northern areas.

The range of WQI was 34.10 (minimum) to 56.95 (maximum). The order for WQI in all areas with WQI values was as: Gilgit (56.95) > Ghizer (53.41) > Ghanche (49.59) > Skardu (45.87) > Buner (40.94) > Upper Dir (39.68) > Mardan (38.43) > Swat (37.94) > Diamer (37.41) > Lower Dir (34.10). This indicated that a slight difference in water quality in Gilgit and Ghizer that may be due to anthropogenic activities in those areas. Many studies used as evidence that various anthropogenic sources put the massive pressure on water resources and its quality. A study by Shabbir and Ahmad [55] measured the WQI of Islamabad and Rawalpindi and determined that main part of the study area had poor drinking water quality. Change in water quality may be the reason for the altered taste of drinking water and is also harmful to local people [56]. Ali et al. [57] have evaluated WQI of 30 drinking water samples from Mardan, KPK. The results showed that mean values of WQI were categorized under unsuitable water quality which is higher than the present study.

Health risk assessment was conducted based on two metals (As and Fe) analyzed in drinking water samples. The value of HQ in all sampling sites for arsenic in adult and children was higher than Fe. Health risk from arsenic was at threshold level. HI of combined metal was also a near-threshold limit (HI ≥ 1). Children were more prone to health risk. The HI values in children were slightly higher than adults (Table 4). The range of HI in adults was 2.96E + 00 to 5.93E + 00 while in children was 4.48E + 00 to 8.96E + 00. The order of HI value in different areas was as: Skardu (2.96E + 00) < lower Dir (3.71E + 00) < Buner (4.26E + 00) < Gilgit (4.63E + 00), Diamer (4.63E + 00) < Mardan (4.72E + 00) < Ghanche (5.00E + 00) < Swat (5.37E + 00) < Dir upper (5.93E + 00) in adults while Skardu (4.48E + 00) < lower Dir (5.60E + 00) < Buner (6.44E + 00) < Gilgit (7.00E + 00), Diamer (7.00E + 00) < Mardan (7.14E + 00) < Ghanche (7.56E + 00) < Swat (8.12E + 00) < Ghizer (8.40E + 00) < Dir upper (8.96E + 00) in children. The results indicated that Dir upper, Ghanche, Swat, and Mardan have more risk potential in drinking water for both adults and children than the other areas such as Skardu, Buner, and Diamer. The HQ ≤ 1 indicates insignificant risk (lower or equal concentration to the WHO guideline value), whereas HQ > 1 indicates a health risk (higher concentration than the WHO guideline

Table 4
Health risk assessment of drinking water in KPK and Gilgit

Locations	Concentration (mg/L)		ADD adult mg/kg/d		ADD child mg/kg/d		HQ adult		HI adult	HQ child		HI child
	As	Fe	As	Fe	As	Fe	As	Fe		As	Fe	
Mardan	0.051	0.007	0.001417	0.000194	0.002142	0.000294	4.72E + 00	2.78E-04	4.72E + 00	7.14E + 00	4.20E-04	7.14E + 00
Buner	0.046	0.01	0.001278	0.000278	0.001932	0.00042	4.26E + 00	3.97E-04	4.26E + 00	6.44E + 00	6.00E-04	6.44E + 00
Swat	0.058	0.005	0.001611	0.000139	0.002436	0.00021	5.37E + 00	1.98E-04	5.37E + 00	8.12E + 00	3.00E-04	8.12E + 00
Dir Lower	0.04	0.05	0.001111	0.001389	0.00168	0.0021	3.70E + 00	1.98E-03	3.71E + 00	5.60E + 00	3.00E-03	5.60E + 00
Dir Upper	0.064	0.03	0.001778	0.000833	0.002688	0.00126	5.93E + 00	1.19E-03	5.93E + 00	8.96E + 00	1.80E-03	8.96E + 00
Gilgit	0.05	0.01	0.001389	0.000278	0.0021	0.00042	4.63E + 00	3.97E-04	4.63E + 00	7.00E + 00	6.00E-04	7.00E + 00
Skardu	0.032	0.02	0.000889	0.000556	0.001344	0.00084	2.96E + 00	7.94E-04	2.96E + 00	4.48E + 00	1.20E-03	4.48E + 00
Ghanche	0.054	0.018	0.0015	0.0005	0.002268	0.000756	5.00E + 00	7.14E-04	5.00E + 00	7.56E + 00	1.08E-03	7.56E + 00
Diamer	0.05	0.02	0.001389	0.000556	0.0021	0.00084	4.63E + 00	7.94E-04	4.63E + 00	7.00E + 00	1.20E-03	7.00E + 00
Ghizer	0.06	0.008	0.001667	0.000222	0.00252	0.000336	5.56E + 00	3.17E-04	5.56E + 00	8.40E + 00	4.80E-04	8.40E + 00

value) to the consumers from drinking polluted water [39]. The present study has lowered the HQ values for children and adult as compared with studies conducted by Begum et al. [27], Rehman et al. [37]; Muhammad et al. [58]; and Kavcar et al. [59]. HQ value for arsenic was higher than reported by Gul et al. [32] and lower in the case of Fe. High consumption of metals resulted in higher hazard quotient in human reasons included weathering, mining, and erosion of rocks in the same study area of KPK [60]. High HQ level may attribute different malignancies, kidney problems, cancer, and anaemia. There is a need to take special measures to minimize children from being exposed to such health hazards [37].

3.2. Irrigation water quality assessment

Surface water quality of six areas was evaluated for selected parameters which were further used to assess the irrigation quality. Buner and Gilgit have the higher values of bicarbonates (186.6 and 95 mg/L), calcium (52 and 35.4 mg/L), magnesium (19.3 and 13.5 mg/L), potassium (4.3 and 2.14 mg/L), and sodium (24 and 10.2 mg/L) than other areas including Skardu, Ghanche, Diamer, and Ghizer. The order for the higher parameters in different areas was as Bun er > Gilgit > Ghanche > Ghizer > Diamer > Skardu (Fig. 3). Presence of magnesium and calcium bicarbonates in water made it hard which is not fit for drinking purpose and can cause gastric diseases [56]; while sodium in high amount can be the reason for high blood pressure [61]. Saline and brackish nature of underground water might be the reason for higher sodium (Na) levels in drinking water [62].

3.3. Sodium absorption ratio

SAR was evaluated to determine the sodium hazard. SAR is a significant measure of the sodium hazard. It is a measure of sodium absorption with respect to magnesium and calcium. EC and SAR are generally used reciprocally to demonstrate the quality of water for irrigation purpose [63]. The values of SAR ranged from 0.56 to 0.27 in all water samples and found under the safe limits. The order for SAR in different areas was as: Buner (0.56) > Diamer (0.45) > Skardu (0.42) > Ghanche (0.3) > Gilgit (0.29) (Fig. 4). According to sodium hazards, SAR values > 9 were regarded as unsuitable for irrigation purpose [64]. Buner has slightly higher value of SAR as compared with other sites but all within the permissible limits indicating the good irrigation water quality. High SAR values make sodium salinity danger by falling soil water availability affecting the growth of yields by falling the ratio of magnesium and calcium major nutrients [65]. Talib et al. [18] evaluated SAR for 59 samples from Indus river water and found their mean concentration 3.41 ± 0.37, classified under low SAR, similar to the present study. Rasool et al. [7] measured the quality of tube well for drinking purpose and irrigation in Punjab. The results of their study showed that the water quality of tube well was marginally fit for irrigation purpose.

3.4. Magnesium absorption ratio

Fig. 5 presents the graphical values for magnesium absorption ratio (MAR) for irrigation purpose. The values were ranged from 15.82 to 38.5. The order of MAR in different areas was as: Gilgit (38.54) > Buner (37.80) > Skardu (30) > Diamer (23.71) > Ghanche (23.08) > Ghizer (15.82). If the value exceeds 50%, the risk may start [63]. The high absorption of magnesium retards the infiltration of soil as magnesium is 50% more than the calcium, so not involved with

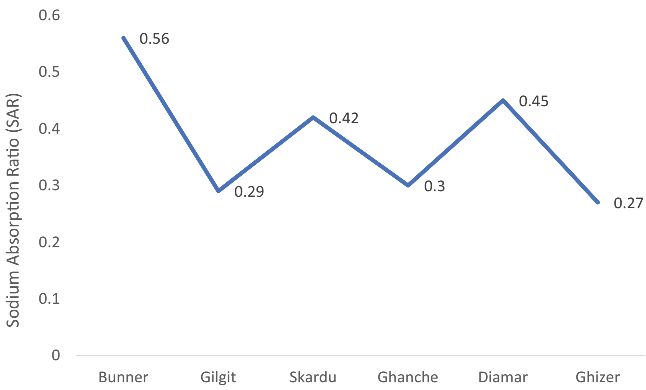

Fig. 4. Sodium absorption ratio (SAR) for irrigation water in selected areas of KPK.

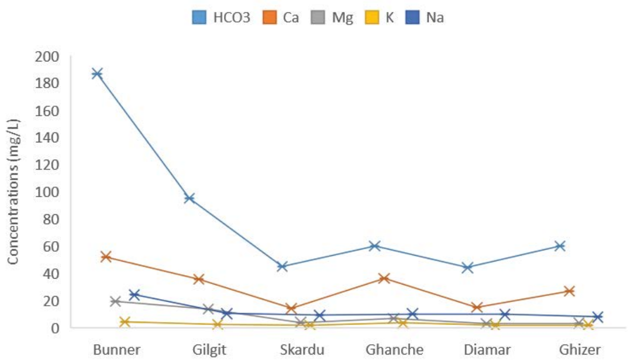

Fig. 3. Mean concentration of water quality of surface water used for irrigation purpose.

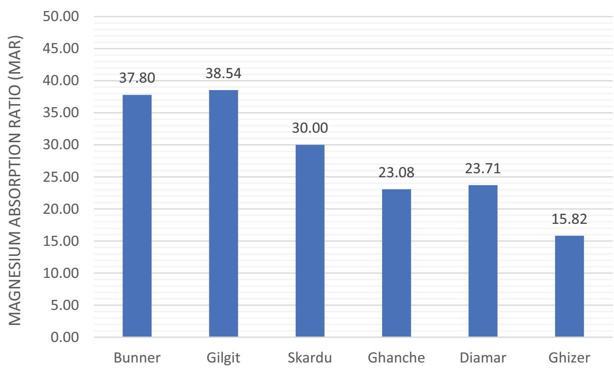

Fig. 5. Magnesium absorption ratio (MAR) for irrigation water in selected areas of KPK.

Fig. 6. Permeability index (PI) for irrigation water in selected areas of KPK.

clay particles. As a result of this, a lot of water is adsorbed between clay particles and magnesium reducing soil infiltration capability [66,67]. In the present study, all the samples were within the safe range (<50) but Gilgit and Buner were near the threshold limit of MAR. Aher and Gaikwad [63] also determined the MAR for irrigation water quality assessment and found that all samples were above the permissible limits and unsuitable for irrigation.

3.5. Permeability index

PI was evaluated for selected areas (Buner, Gilgit, Skardu, Ghanche, Diamer, and Ghizer). PI values of all water samples in the current study were ranged from 3.5 to 6.4 which were below 25 and water categorized as unsuitable for irrigation purpose. The order for PI in different selected areas was as: Skardu (6.47) > Diamer (6.41) > Ghizer (5.36) > Gilgit (3.89) > Ghanche (3.73) > Buner (3.55) as mentioned in Fig. 6. PI criterion included three classes, class I and II are known as good for irrigation purposes with PI of 75 or above and class III water is considered as unfit for irrigation with PI of 25 or below it [68]. If the water used for agriculture containing (Ca^{2+}, Mg^{2+}, Na^{+}, HCO^{3-}) for long term, it may decrease the permeability of the soil and indirectly affect crop production [69,70]. Therefore, the PI operates the water quality by humiliating agricultural soil [42,71]. Aher and Gaikwad [63] evaluated PI and found their sampling sites were suitable for irrigation purpose with values higher than 25.

4. Conclusions

Groundwater is a main source of water for daily life and it is very important to maintain its quality and reasonable accessibility for future generations. Physicochemical properties are measured to assess the quality of groundwater for agricultural and drinking purposes. In the present study, the physiochemical parameters were within the WHO and NEQs limits except for EC, turbidity, and arsenic. Most of the values found higher in Mardan, Swat, Upper Dir, Ghanche. The WQI showed the water is good in quality for drinking purpose. Health risk index showed the arsenic-related hazard was near the threshold limit in adults and children. Overall water quality was acceptable. However, the surface water used for irrigation purpose has an unsafe limit for PI. While all other indexes such as SAR and MAR were within the safe range. The results of multivariate analysis showed that the water can be used for drinking and irrigation purpose. The concerned authorities and management of the study area should use these assessment tools for the determination of water quality in order to prevent any dangerous conditions. This data can further be used for policymaking.

References

[1] M.T. Mahmoud, A.M. Hamouda, R.R. Al Kendi, M.M. Mohamed, Health risk assessment of household drinking water in a district in the UAE, Water, 10 (2018) 1726.
[2] K. Khan, Y. Lu, H. Khan, S. Zakir, S. Khan, A.A, Khan, Health risks associated with heavy metals in the drinking water of Swat, northern Pakistan, J. Environ. Sci., 25 (2013) 2003–2013.
[3] Y. Zhang, D. Huang, L. Zhou, Escherichia coli inactivation by pressurized CO_2 treatment methods at room temperature: critical issues, J. Environ. Sci., 43 (2016) 285–292.
[4] M. Mohsin, S. Safdar, F. Asghar, F. Jamal, Assessment of drinking water quality and its impacts on resident's health in Bahawalpur city, Int, J. Humanit. Soc. Sci., 3 (2013) 114–128.
[5] R. Hussain, L. Ali, I. Hussain, S.A. Khattak, Source identification and assessment of physico-chemical parameters and heavy metals in drinking water of Islampur area, Swat, Pakistan, J. Himal. Earth Sci., 47 (2014) 99–106.
[6] O. Hillebrand, K. Nödler, M. Sauter, T. Licha, Multi tracer experiment to evaluate the attenuation of selected organic micropollutants in a karst aquifer, Sci. Total Environ., 506 (2015) 338–343.
[7] A. Rasool, A. Farooqi, S. Masood, K. Hussain, Arsenic in groundwater and its health risk assessment in drinking water of Mailsi, Punjab Pakistan, Hum. Ecol. Risk. Assess., 22 (2016) 187–202.
[8] Y. Mahfooz, A. Yasar, M.T. Sohail, A.B. Tabinda, R. Rasheed, S. Irshad, B. Yousaf, Investigating the drinking and surface water quality and associated health risks in a semi-arid multi-industrial metropolis (Faisalabad), Pakistan, Environ. Sci. Pollut. Res., 26 (2019) 1–13.
[9] Y. Deng, W. Jiang, R. Sadiq, Modeling contaminant intrusion in water distribution networks: a new similarity-based DST method, Expert Syst. Appl., 38 (2011) 571–578.
[10] S. Ponsadailakshmia, S. Sankarib, M.S. Prasannac, G. Madhurambald, Evaluation of water quality suitability for drinking using drinking water quality index in Nagapattinam district, Tamil Nadu in Southern India, Groundwater Sust. Dev., 6 (2018) 43–49.
[11] N. Khanal, S.G. Buchberger, S.A. Mckenna, R.M. Clark, W.M. Grayman, Vulnerability Assessment of Water Distribution System to Chemical Intrusions, In Proceedings of the World Water and Environmental Resources Congress, Anchorage, Alaska, May 2005, Volume 56, pp. 15–19.
[12] WB-SCEA, Pakistan Strategic Country Environmental Assessment, Main report, Report no. 36946-PKWorld Bank; 2006 pp. 1–66.
[13] N.E. Joshua, M.E. Abimbola, M. Ntwanano, O.O. John, Evaluation of water quality and human risk assessment due to heavy metals in groundwater around Muledane area of Vhembe District, Limpopo Province, South Africa, Chem. Cent J., 12 (2018) 2.
[14] PAK-EPA, State of Environment Report, Pakistan Environmental Protection Agency (Pak-EPA). Govt. of Pakistan, Islamabad, Ministry of Environment, Pakistan, 2005.
[15] M.T. Sohail, H. Delin, M.A. Talib, X. Xiaoqing, M.M. Akhtar, An Analysis of Environmental Law in Pakistan-policy and Conditions of Implementation, Res. J. Appl. Sci. Eng. Technol., 8 (2014) 644–653.
[16] J. Ali, N. Ali, S.U.U. Jamil, H. Waseem, K. Khan, G. Pan, Insight into eco-friendly fabrication of silver nanoparticles by *Pseudomonas aeruginosa* and its potential impacts, J. Environ. Chem. Eng., 5 (2017) 3266–3272.

[17] Q. Cui, T. Fang, Y. Huang, P. Dong, H. Wang, Evaluation of bacterial pathogen diversity, abundance and health risks in urban recreational water by ampliconnext-generation sequencing and quantitative PCR, J. Environ. Sci., 57 (2017) 137–149.
[18] M.A. Talib, Z. Tang, A. Shahab, J. Siddique, M. Faheem, M. Fatima, Hydrogeochemical characterization and suitability assessment of groundwater: a case study in Central Sindh, Pakistan, Int. J. Environ. Res. Publ. Health., 16 (2019) 886.
[19] M. Radfard, M. Yunesian, R. Nabizadeh, H. Biglari, S. Nazmara, M. Hadi, A.H. Mahvi, Drinking water quality and arsenic health risk assessment in Sistan and Baluchestan, Southeastern Province, Iran, Human Ecol. Risk Asses: Int. J., 25 (2019) 949–965.
[20] K.M. Wai, M. Umezaki, O. Mar, M. Umemura, C. Watanabe, Arsenic exposure through drinking Water and oxidative stress Status: a cross-sectional study in the Ayeyarwady region, Myanmar, J. Trace Elem. Med Biol., 54 (2019) 103–109.
[21] S. Mishra, R.N. Bharagava, N. More, A. Yadav, S. Zainith, S. Mani, P. Chowdhary, Heavy Metal Contamination: An Alarming Threat to Environment and Human Health, In Environmental Biotechnology: For Sustainable Future, 2019, pp. 103–125.
[22] M.T. Sohail, Y. Mahfooz, K. Azam, Y. Yen, L. Genfu, S. Fahad, Impacts of urbanization and land cover dynamics on underground water in Islamabad, Pakistan, Desal. Wat. Treat., 159 (2019) 402–411.
[23] N. Masood, A. Farooqi, M.I. Zafar, Health risk assessment of arsenic and other potentially toxic elements in drinking water from an industrial zone of Gujrat, Pakistan: a case study, Environ. Monit. Assess., 191 (2019) 95.
[24] R. Ali, M.A. Bünzli, L. Colombo, S.A. Khattak, S. Pera, M. Riaz, C. Valsangiacomo, Water quality before and after a campaign of cleaning and disinfecting shallow wells: a study conducted during and after floods in Khyber Pakhtunkhwa, Pakistan, J. Water Sanit. Hyg. Dev., 9 (2019) 28–37.
[25] R. Unaib, Z. Fatmi, Arsenic contamination of drinking water and mitigation in Pakistan: a case of Indus River Basin, Arsenic Water Res. Contam., (2020) 273–296.
[26] A. Azizullah, M.N.K. Khattak, P. Richter, D.P. Häder, Water pollution in Pakistan and its impact on public health—a review, Environ. Int., 37 (2011) 479–497.
[27] S. Begum, M.T. Shah, S. Muhammad, S. Khan, Role of mafic and ultramafic rocks in drinking water quality and its potential health risk assessment, Northern Pakistan, J. Water Health., 13 (2015) 1130–1142.
[28] Pakistan Bureau of statistics. province wise provisional results of census. Available at: http://www.pbs.gov.pk/sites/default/files/PAKISTAN%20TEHSIL%20WISE%20FOR%20WEB%20CENSUS_2017.pdf (Accessed: 21 July 2019)
[29] A. Riaz, S. Khan, S. Muhammad, M.T. Shah, Mercury Contamination in Water and Sediments and the Associated Health Risk: A Case Study of Artisanal Gold-mining, Mine Water Environ., (2019) 1–8.
[30] USEPA, Acid digestion of waters for total recoverable or dissolved metals for analysis by FLAA or ICP spectroscopy, METHOD 3005A. Available at: https://www.epa.gov/sites/production/files/2015-12/documents/3005a.pdf (Accessed: 21 July 2019).
[31] K.S. Subramanian, C.L. Chakrabarti, J.E. Sueiras, I.S. Maines, Preservation of some trace metals in samples of natural waters, Anal Chem., 50 (1987) 444–448.
[32] N. Gul, M.T. Shah, S. Khan, N.U. Khattak, S. Muhammad, Arsenic and heavy metals contamination, risk assessment and their source in drinking water of the Mardan District, Khyber Pakhtunkhwa, Pakistan, J. Water Health, 13 (2015) 1073–1084.
[33] J. Kearns, J. Tyson, Improving the Accuracy and Precision of an Arsenic Field Test Kit: Increased Reaction Time and Digital Image Analysis, 2012.
[34] S.K. Mohanty, Water Quality Index of Four Religious Ponds and its Seasonal Variation in the Temple City, Bhuvaneshwar, In: A. Kumar, Ed., Water pollution, APH Publishing Corporation, New Delhi, 2004, pp. 211–218.
[35] C.R. Ramakrishnaiah, C. Sadashivaiah, G. Ranganna, Assessment of water quality index for the ground water in Tumkur Taluk, E-J. Chem., 6 (2009) 523–530.
[36] USEPA, Risk Assessment Guidance for Superfund, Vol I Human Health Evaluation, Manual (Part A), Office of Emergency and Remedial Response Washington, 1989.
[37] I. Rehman, M. Ishaq, L. Ali, S. Khan, I. Ahmad, I. Din, H. Ullah, Enrichment, spatial distribution of potential ecological and human health risk assessment via toxic metals in soil and surface water ingestion in the vicinity of Sewakht mines, district Chitral, Northern Pakistan, Ecotoxicol. Environ. Saf., 154 (2018) 127–136.
[38] ATSDR. Agency for Toxic Substances and Disease Registry. U.S. Department of Health and Human Services, Public Health Service. Toxicological profile for Arsenic. Available at: http://www.atsdr.cdc.gov/toxprofiles/tp2.pdf (Accessed: 21 June 2019).
[39] R. Törnqvist, J. Jarsjö, B. Karimov, Health risks from large-scale water pollution: trends in Central Asia, Environ. Int., 37 (2011) 435–442.
[40] USEPA, Guidelines for Carcinogen Risk Assessment, In: Risk Assessment Forum USEPA, editor, Washington, DC, EPA/630/P-03/001F, 2005.
[41] J. Xiong, Z. Wang, X. Ma, H. Li, J. You, Occurrence and risk of neonicotinoid insecticides in surface water in a rapidly developing region: application of polar organic chemical integrative samplers, Sci. Total Environ., 648 (2019) 1305–1312.
[42] G.I. Obiefuna, A. Sheriff, Assessment of shallow ground water quality of Pindiga Gombe Area, Yola Area, NE, Nigeria for irrigation and domestic purposes, Res. J. Environ. Earth Sci., 3 (2011) 131–141.
[43] L.A. Richards, Diagnosis and Improvement of Saline and Alkali Soils Agric Handbook 60, USDA and IBH Pub. Coy Ltd., New Delhi, India, 1954, pp. 98–99.
[44] I.M. Raghunath, Groundwater, 2nd edn., Wiley Eastern Ltd., New Delhi, India, 1987.
[45] L.D. Doneen, Notes on Water Quality in Agriculture, Published as a Water Science and Engineering Paper 4001, Department of Water Science and Engineering, University of California, 1964.
[46] S. Selvakumar, K. Ramkumar, N. Chandrasekar, N.S. Magesh, S. Kaliraj, Groundwater quality and its suitability for drinking and irrigational use in the Southern Tiruchirappalli district, Tamil Nadu, India, Appl. Water Sci., 7 (2017) 411–420.
[47] National Environmental Quality Standards (NEQs), The Gazette of Pakistan, Pakistan Environmental Protection Agency (Pak-EPA). Govt. of Pakistan, Islamabad, Ministry of Environment, Pakistan, 2010.
[48] C.M. Laluraj, G. Gopinath, Assessment of seasonal variation of groundwater quality of Pheretic aquifer - a river basin system, Environ. Monit. Assess., 117 (2006) 45–57.
[49] S. Muhammad, T.M. Shah, S. Khan, Arsenic health risk assessment in drinking water and source apportionment using multivariate statistical techniques in Kohistan region, northern Pakistan, Food Chem. Toxicol., 48 (2010) 2855–2864.
[50] S. Naseem, S. Hamza, E. Bashir, Groundwater geochemistry of Winder agricultural farms, Balochistan, Pakistan and assessment for irrigation water quality, Eur. Water., 31 (2010) 21–32.
[51] World Health Organization (WHO), World Health Statistics. Available at: https://www.who.int/gho/publications/world_health_statistics/EN_WHS2011_Full.pdf (Accessed: 13 February 2019)
[52] R.T. Nickson, J.M. McArthur, B. Shrestha, T.O. Kyaw-Mynt, D. Lowery, Arsenic and other drinking water quality issues, Muzaffargarh district, Pakistan, Appl. Geochem., 20 (2005) 55–68.
[53] B. Kumari, V. Kumar, A.K. Sinha, J. Ahsan, A.K. Ghosh, H. Wang, G. Deboeck, Toxicology of arsenic in fish and aquatic systems, Environ. Chem. Lett., 15 (2017) 43–64.
[54] N. Khan, S.T. Hussain, A. Saboor, Physicochemical investigation of the drinking water sources from Mardan, Khyber Pakhtunkhwa, Pakistan, Life Sci. J., 16 (2019) 64–74.

[55] R. Shabbir, S. Ahmad, Use of geographic information system and water quality index to assess groundwater quality in Rawalpindi and Islamabad, Arabian J. Sci. Eng., 40 (2015) 2033–2047.
[56] S. Khalid, B. Murtaza, I. Shaheen, I. Ahmad, M.I. Ullah, T. Abbas, F. Rehman, M.R. Ashraf, S. Khalid, S. Abbas, M. Imran, Assessment and public perception of drinking water quality and safety in district Vehari, Punjab, Pakistan, J. Clean. Prod., 181 (2018) 224–234.
[57] W. Ali, M. Nafees, S.A. Turab, M.Y. Khan, K. Rehman, Drinking water quality assessment using water quality index and geostatistical techniques, Mardan District, Khyber Pakhtunkhwa, Pakistan, J. Himalayan Earth Sci., 52 (2019) 65–85.
[58] S. Muhammad, M.T. Shah, Health risk assessment of heavy metals and their source apportionment in drinking water of Kohistan region, northern Pakistan, Microchem. J., 98 (2011) 334–343.
[59] P. Kavcar, A. Sofuoglu, S.C. Sofuoglu, A health risk assessment for exposure to trace metals via drinking water ingestion pathway, Int. J. Hyg. Environ. Health, 212 (2009) 216–227.
[60] U. Saddique, S. Muhammad, M. Tariq, H. Zhang, M. Arif, I.A.K. Jadoon, N.U. Khattak, Potentially toxic elements in soil of the Khyber Pakhtunkhwa province and Tribal areas, Pakistan: evaluation for human and ecological risk assessment, Environ. Geochem. Health, 40 (2018) 2177–2190.
[61] A. Hassan, M. Nawaz, Microbiological and physicochemical assessment of ground water quality at Punjab, Pakistan, Afr. J. Microbiol. Res., 8 (2014) 2673–2681.
[62] N. Raza, S.B. Niazi, M. Sajid, F. Iqbal, M. Ali, Studies on relationship between season and inorganic elements of Kallar Kahar Lake (Chakwal), Pakistan, J. Res. Sci. B. Z. Univ., 18 (2007) 61–68.
[63] K. Aher, S. Gaikwad, Irrigation groundwater quality based on hydrochemical analysis of Nandgaon block, Nashik district in Maharashtra, Int. J. Adv. Geosci., 5 (2017) 1–5.
[64] M. Awais, M. Arshad, S.H.H. Shah, M. Anwar-Ul-Haq, Evaluating groundwater quality for irrigated agriculture: spatio-temporal investigations using GIS and geostatistics in Punjab Pakistan, Arabian J. Geosci., 10 (2017) 510.
[65] M. Vasanthavigar, K. Srinivasamoorthy, K. Vijayaragavan, R.R. Ganthi, S. Chidambaram, P. Anandhan, S. Vasudevan, Application of water quality index for groundwater quality assessment: Thirumanimuttar sub-basin, Tamilnadu, India, Environ. Monit. Assess., 171 (2010) 595–609.
[66] Y. Hussain, S.F. Ullah, G. Akhter, A.Q. Aslam, Groundwater quality evaluation by electrical resistivity method for optimized tubewell site selection in an agostressed Thal Doab Aquifer in Pakistan, Model Earth Syst. Environ., 3 (2017) 15.
[67] Y. Hussain, S.F. Ullah, M.B. Hussain, A.Q. Aslam, G. Akhter, H. Martinez-Carvajal, M. Cardenas-Soto, Modelling the vulnerability of groundwater to contamination in an unconfined alluvial aquifer in Pakistan, Environ. Earth Sci., 76 (2017) 84.
[68] N.J. Raju, Hydrogeochemical parameters for assessment of groundwater quality in the upper Gunjanaeru River basin, Cuddapah District, Andhra Pradesh, South India, Environ. Geol., 52 (2007) 1067–1074.
[69] O.O. Falowo, Y. Akindureni, O. Ojo, Irrigation and drinking water quality index determination for groundwater quality evaluation in Akoko Northwest and Northeast Areas of Ondo State, Southwestern Nigeria, Am. J. Water Sci. Eng., 3 (2017) 50.
[70] A.K. Singh, G.C. Mondal, S. Kumar, T.B. Singh, B.K. Tewary, A. Sinha, Major ion chemistry, weathering processes and water quality assessment in upper catchment of Damodar River basin, India, Environ. Geol., 54 (2008) 745–758.
[71] M. Idrees, S. Batool, H. Ullah, Q. Hussain, M.I. Al-Wabel, M. Ahmad, J. Kong, Adsorption and thermodynamic mechanisms of manganese removal from aqueous media by biowaste-derived biochars, J. Mol. Liq., 266 (2018) 373–380.