Vijay K Bharti*, Arup Giri and Krishna Kumar

Defence Institute of High Altitude Research (DIHAR), DRDO, Leh-Ladakh, Jammu & Kashmir, India

*Corresponding author: Vijay K Bharti, Defence Institute of High Altitude Research (DIHAR), DRDO, Leh-Ladakh, Jammu & Kashmir, India, E-mail: vijaykbharti@rediffmail.com

Research Article

Evaluation of Physico-Chemical Parameters and Minerals Status of Different Water Sources at High Altitude

Abstract

Physico-chemical properties and minerals status is an important decisive factor for assessment of drinking water quality. There are limited literatures on this aspect for drinking water quality of high altitude areas; therefore, the present investigation was carried out to evaluate different physico-chemical parameters and some essential minerals status in different drinking water sources. These water samples were collected from different sources like deep tube well, spring, and river from different villages of Leh District, Jammu & Kashmir, India. Thereafter, it was analyzed for physico-chemical parameters viz. dissolve oxygen, alkalinity, hardness, chloride, phosphate, sulphate, and nitrate according to standard methods. Similarly, all the essential minerals viz. sodium, calcium, magnesium, potassium, iron, sulphur, and manganese were analyzed by using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). All the results were compared with the WHO standard for drinking water. The findings of this investigation indicated that dissolved oxygen, alkalinity and hardness were above the desirable level at some places as per WHO standards. Whereas, chloride, nitrate, and sulphate levels were lower in all the water samples collected across the sources. Among all the minerals, iron, potassium and aluminium level were above and sodium, magnesium, and manganese were lower than the desirable level at all the different altitude as per WHO standards. Interestingly, chloride, sodium, sulphur and aluminium level were high in Indus river water collected from the nearby city area. Therefore, it can be concluded that water sources near the city area are more contaminated than the other sites. Hence, present findings indicated variation in physico-chemical parameters and mineral status of water of different sources of high altitude Himalayan region. More or less, the quality of drinking water is suitable for consumption except the hardness and aluminium level.

Introduction

Water is an essential component of our food and contributes to many minerals nutrients, too [1,2]. Important natural sources of water are surface water such as lakes, streams, river, pond, etc. and ground water such as bore well and wells [3]. Fresh water is essential for agriculture, industry, domestic use, and drinking purpose for human and animals [4]. Water quality depends upon the physical, chemical, minerals, and biological characteristics of water [6]. Hence, animal and human health as well as sustainable agricultural and industrial development will not be possible without availability of quality fresh water in adequate quantity [6]. In general, water sources are less anthropogenic contaminated in Himalayan region as compared to plain areas due to less industrial growth and low human population with comparison to plain areas. However, in recent years due to increase in human population,

tourism, and industrialization, water sources are brink of contamination on indiscriminate waste disposal. Leaching of this water into ground water at different strata of rock further contribute to ground water contamination [7-9]. Recently, due to environmental pollution, several surface water sources are not acceptable for drinking as these are often contaminated with various organic, inorganic, and microbial agents [6,7,10–15]. According to WHO, about 80% of all the diseases in human beings are caused by water? It is therefore becomes imperative to regularly monitor the quality of water and to device ways and means to protect it [16]. Some reports on soil, water and fodder minerals status indicated deficiency or excess of some minerals at high altitude [17,18]. Since, physico-chemical properties and mineral status are interlinked with mineral availability of water. The composition of surface and groundwater vary with the altitude, topography, hydrological and biological present in the drainage basin [19,20]. Therefore, evaluation

of different sources of water collected from different altitude is essential for knowing their suitability for drinking purpose. Since, the scanty of literatures on water quality of high altitude collected from different sources; therefore it is important to evaluate physico-chemical properties and minerals status. Therefore, we investigated physico-chemical parameters and some minerals in all the water collected from different sources at high altitude. This study will help in identification of good water sources and developing remedial measures for water resource management at high altitude.

Materials and Methods

Study area

The study area occupies a part of the Indus river valley. The Indus River in the study area flows throughout the year. The overall drainage system is controlled by the river and many canals which are filled through glacier melted water. In the summer season, irrigation is fully dependent on these canal systems. The characteristics of rocks in this region are igneous, metamorphic and sedimentary in nature. They have Tertiary granitic batholith of Ladakh. The area remained magmatically active from Cretaceous to post-Oligocene period. They are shale and limestone. Leh plains are underlain by moraine deposits consisting of boulders, cobbles, pebbles embedded in an arenaceous matrix and lake deposits comprising predominantly of clays, sandy clays and silt. Ground water development through construction of tube wells and hand pumps is very much possible in this district. Till date ground water development in this district was in ancient stage. People mainly depend on surface water sources and springs for meeting water supply requirements. Thus, the stage of ground water development is least [21].

In this study, tube well water (26 total sites), spring water (02 total sites) and river water (05 total sites) were collected from different sites/places at different altitude of Leh district, Jammu & Kashmir, India in the winter season of 2013. Collection sites are located in the cold, arid Himalayan region of India, where the altitude varies between 10465-11884 ft above mean sea level (MSL). Different altitude, latitude and longitude of all the sampling sites/places were recorded by GPS system (Model no. Garmin GPS 72H) and distance of sites/places from main city/industry were given in Table 1 followed by the sampling location map made by the Google Earth 6.1 and QGIS 2.12 software (Figure 1).

Preparation of water samples

The water samples were collected from different sites in plastic bottles, which were previously washed with detergents and HNO_3 acid and later rinsed with sampled water several times. Total 1.5mL of 2M HNO_3 was added to each 100mL samples (pH<3) for metallic ions determination to maintain the stability of the oxidation state of the various elements in solution and prevent precipitation [22].

Analysis of physico-chemical and minerals parameters

All the water samples were analyzed for dissolve oxygen, alkalinity, hardness, chloride, phosphate, sulphate, nitrate, sodium, calcium, magnesium, potassium, iron, sulphur, manganese and aluminium of tube well, spring water and river water as per standard procedures used for water analysis. All the analytical methods are briefly described below and given in Table 2.

DO was determined by Winkler method [23]. Alkalinity was estimated by titrimetric method [24]. Total Hardness and calcium hardness was determined by complex metric titration using Eriochrome Black-T as an indicator by EDTA method and Chloride was estimated by Mohr's method using $AgNO_3$ solution and Potassium Chromate as an indicator [24]. Sulphates and Nitrates were estimated by UV-Visible Spectrophotometer (Biosync Tecknology Pvt Ltd, Model no.-LT2900) [25], inorganic phosphates were determined by UV-Visible Spectrophotometric method [24]. All the minerals viz.

Table 1: Details of sampling site and sources of water.

| Sampling Site Nomenclature	Water sources	Approximate distance from main city	Latitude	Longitude	Altitude (ft)
		Details of sampling sites			
S1	Indus River	35 km	34°02′26.32″N	77°39′54.59″E	10688
S2	Indus River	35 km	34°02′23.79″N	77°39′57.63″E	10587
S3	Indus River	35 km	34°02′21.31″N	77°39′59.29″E	10696
S4	Tube well	5 km	34°06′40.04″N	77°35′19.20″E	10620
S5	Tube well	5 km	34°06′25.55″N	77°35′05.00″E	10550
S6	Tube well	5 km	34°06′29.49″N	77°34′51.06″E	10557
S7	Tube well	5 km	34°04′01.87″N	77°37′47.35″E	10624
S8	Tube well	5 km	34°04′18.10″N	77°38′13.89″E	10665
S9	Tube well	10 km	34°07′28.49″N	77°31′19.57″E	10476
S10	Tube well	10 km	34°07′39.60″N	77°31′18.75″E	10482
S11	Tube well	10 km	34°07′30.19″N	77°31′17.42″E	10472
S12	Tube well	10 km	34°07′29.72″N	77°30′59.18″E	10465
S13	Tube well	10 km	34°07′26.48″N	77°31′02.73″E	10465
S14	Tube well	35 km	34°02′15.47″N	77°40′13.74″E	10704
S15	Tube well	7 km	34°07′46.27″N	77°31′33.40″E	10547
S16	Tube well	10 km	34°03′54.81″N	77°38′13.56″E	10627
S17	Tube well	10 km	34°03′54.55″N	77°38′26.51″E	10627
S18	Tube well	35 km	34°02′08.31″N	77°40′29.66″E	10712
S19	Tube well	10 km	34°03′56.66″N	77°38′37.24″E	10640
S20	Tube well	10 km	34°04′03.99″N	77°38′45.74″E	10665
S21	Tube well	10 km	34°03′59.31″N	77°38′57.69″E	10687
S22	Tube well	35 km	34°02′11.32″N	77°40′17.32″E	10702
S23	Indus River	35 km	34°02′16.12″N	77°39′58.29″E	10695
S24	Indus River	35 km	34°02′19.44″N	77°40′00.01″E	10694
S25	Spring	25 km	34°11′00.56″N	77°29′27.15″E	11884
S26	Spring	35 km	34°03′36.57″N	77°33′12.95″E	11559
S27	Tube well	35 km	34°02′07.50″N	77°40′20.66″E	10714
S28	Tube well	35 km	34°02′04.18″N	77°40′22.45″E	10706
S29	Tube well	35 km	34°02′05.18″N	77°40′28.18″E	10716
S30	Tube well	35 km	34°02′07.36″N	77°40′27.28″E	10710
S31	Tube well	25 km	34°02′27.34″N	77°38′47.94″E	10674
S32	Tube well	25 km	34°02′13.01″N	77°39′04.90″E	10702
S33	Tube well	25 km	34°02′40.43″N	77°39′14.76″E	10679

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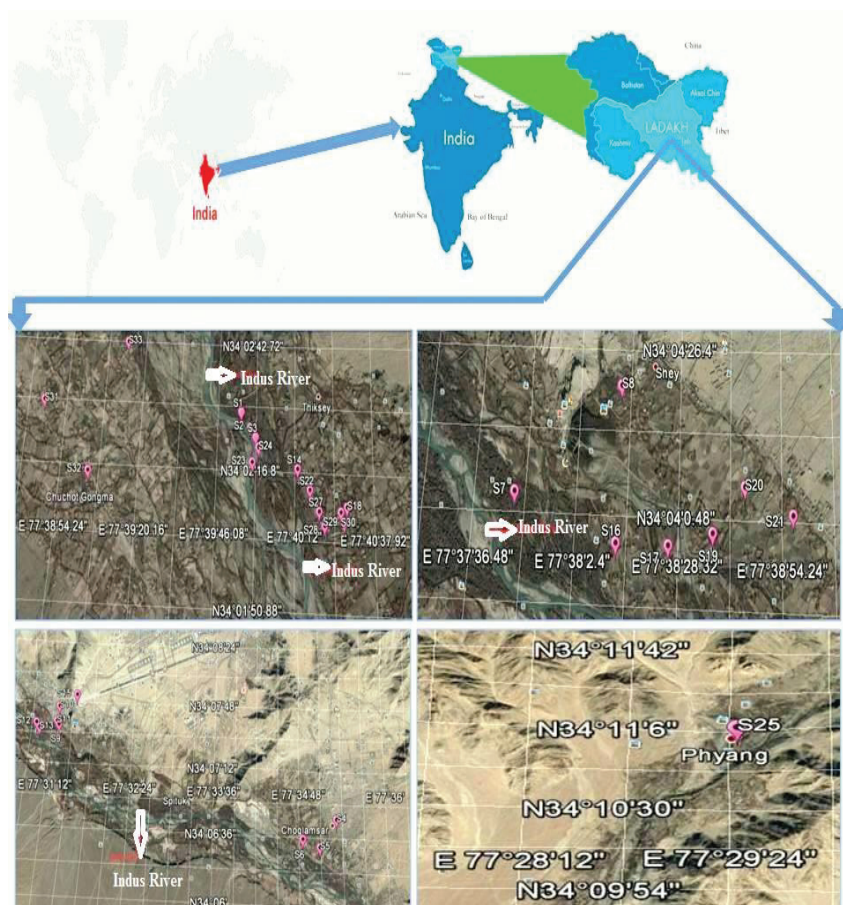
Figure 1: Location of drinking water sampling sites around Leh district. Map presented in the grid view with the help of Google Earth 6.1 and QGIS 2.12 software.

Table 2: Methods and equipments used for water quality analysis.

Sl. No.	Parameter	Unit	Method/Equipment used	Reference
1	Total Hardness	mg/L	EDTA Titrimetric Method	[24]
2	Chloride	mg/L	Mohr's Method	[24]
3	Dissolve Oxygen	mg/L	Winkler Method	[23]
4	Free Carbon dioxide	mg/L	Titrimetric method	[24]
5	Alkalinity	mg/L	Titrimetric method	[24]
6	Sulphates	mg/L	U.V. visible spectro-photometric method	[25]
7	Nitrate	mg/L	U.V. visible spectro-photometry	[25]
8	Phosphate	mg/L	U.V. visible spectro-photometry	[24]
9	Minerals	mg/L	ICP-OES Instrumental method	-

Ca, Na, K, Mg, Mn, Fe, S and Al level were estimated by using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP–OES) (Perkin–Elmer Analyst, Optima 7000 DV).

Statistical analysis

Six samples collected from each sites of different water sources were calculated by Microsoft excel worksheet and all the analyzed data were compared with recommended World Health Organization (WHO) standard values given in Table 3 [26].

Results and Discussion

The parameters like dissolve oxygen, alkalinity, hardness, chloride, sulphate, phosphate, and nitrate are important indices of quality water [2,26,27]. Dissolved oxygen (DO) is very important parameter in water assessment [28]. DO is governed by the water turbulence, surface diffusion, rate of photosynthesis, biological oxygen demand (BOD), water temperature, and carbon dioxide concentration [29,30]. In the present study, levels of DO in all the three sources are higher than the WHO prescribed guidelines (Figure 2). Level of dissolve oxygen in water depends upon the wind action and speed of water flow. As the river and spring water flowing, it has the open chances of water to mix up with natural oxygen. For these reason, river water and spring water might have higher dissolve oxygen level than the WHO prescribed limits. However, the quality of water is good for the aquatic habitat.

The Alkalinity of water is its capacity to neutralize a strong acid. It is normally due to the presence of carbonates, bicarbonates and hydroxides compounds of Ca^{2+}, Mg^{2+} and Na^+ [31]. Water bodies having total alkalinity (Table 4, Figure 3) above 50mg/L can be considered productive. Therefore, in the study area it might be said that water sources are highly productive [32]. However, in this region, soil showed the alkaline in nature [17, 18]. This is the most probable reason for showing the higher level of alkalinity in all the three water sources than the WHO guidelines.
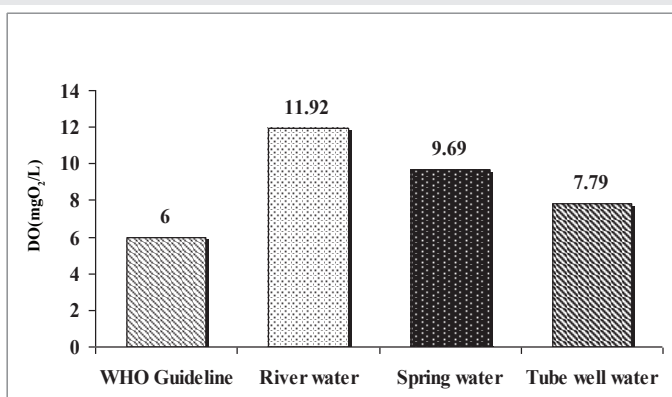
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Hardness is the property of water, which is due to the salts of Ca^{2+} and Mg^{2+} [31,33]. Level of hardness (Table 4, Figure 4) was higher in most sampling sites than the desirable limits prescribed by WHO guideline. Low magnesium level and high hardness value in the study sites indicates that hardness is mainly due to calcium level.

Chlorides usually occur as $NaCl$, $CaCl_2$, $MgCl_2$, and in widely varying concentration in all natural water [34]. An increase in the number of chloride (Cl^-) content of water may indicate possible pollution from human sewage, animal manure or industrial wastes [35]. In the present study, chloride concentration (Table 5, Figure 5) was below the permissible level of WHO guidelines. In the winter season, all the mentioned probable sources of chlorides to water remain low. For this reason, all the three water sources showed the lower level than the WHO guidelines.

Table 3: Value of drinking water quality prescribed by WHO.

Sl. No.	Parameters	WHO standard
1	Temp (^{0}C)	NS#
2	pH	6.5-8.5
3	DO (mg/L)	4-6
4	Free CO_2 (mg/L)	N/A*
5	Total Hardness (mg/L)	100
6	Total alkalinity (mg/L)	250
7	Chlorides (mg/L)	250
8	Phosphate (mg/L)	N/A*
9	Sulphates (mg/L)	500
10	Nitrate (mg/L)	50
11	Iron (mg/L)	0.3
12	Calcium (mg/L)	100
13	Magnesium (mg/L)	20
14	Sodium (mg/L)	200
15	Manganese (mg/L)	0.4
16	Aluminium (mg/L)	0.3
17	Sulphur (mg/L)	N/A*
18	Potassium (mg/L)	12

#NS: Non significant, *N/A: Not Available.

Table 4: Physico-chemical quality of water collected from different sites at high altitude.

Sites no.	Water sources	DO (mg/L)	Free CO_2 (mg/L)	Alkalinity (mg/L)	Hardness (mg/L)
1	Indus River	14.20**	13.30	269.00**	192.00**
2		12.80**	14.70	263.50**	150.00**
3		12.20**	14.90	267.00**	150.00**
4	Tube well	8.40**	14.66	263.15**	200.00**
5		8.00**	15.00	260.00**	232.00**
6		9.10**	14.00	266.00**	254.00**
7		8.20**	17.20	267.00**	249.00**
8		7.20**	11.60	300.00**	216.00**
9		6.80**	14.80	266.00**	220.00**
10		6.60**	15.70	175.00*	192.00**
11		5.90	16.20	300.00**	230.00**
12		6.50**	14.00	160.00*	180.00**
13		6.80**	15.72	278.00**	210.00**
14		6.70**	15.00	200.00*	140.00**
15		9.30**	19.20	265.00**	300.00**
16		7.40**	17.00	287.00**	256.00**
17		7.60**	17.10	280.00**	265.00**
18		7.00**	16.00	160.00*	152.00**
19		7.60**	16.60	249.00	215.00**
20		7.60**	14.60	310.00**	240.00**
21		7.80**	14.00	260.00**	210.00**
22		7.20**	14.00	275.00**	188.00**
23	Indus River	10.20**	14.00	273.37**	144.00**
24		10.20**	14.40	282.00**	160.00**
25	Spring	10.08**	15.80	288.00**	160.00**
26		9.30**	16.00	273.08**	148.00**
27	Tube well	7.40**	16.00	177.00*	204.00**
28		6.90**	16.00	235.29	220.00**
29		8.90**	14.80	277.00**	282.00**
30		9.60**	15.00	269.00**	165.00**
31		7.60**	16.80	302.00**	160.00**
32		6.60**	15.20	173.07*	160.00**
33		7.80**	15.89	179.7*	162.00**

* Indicates lower level than the WHO standard.
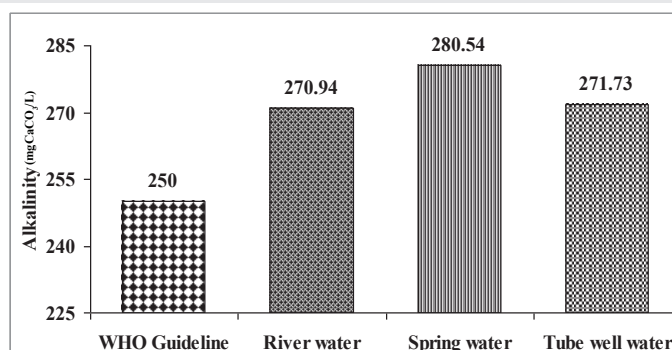** Indicates higher level than the WHO standard.

Figure 2: Mean dissolve oxygen (DO) concentration of three water sources compared with drinking water quality standard of WHO.

Figure 3: Mean alkalinity concentration of three water sources compared with drinking water quality standard of WHO.

Phosphate (PO_4^{3-}) may occur in groundwater because of domestic sewage, detergents, agricultural effluents with
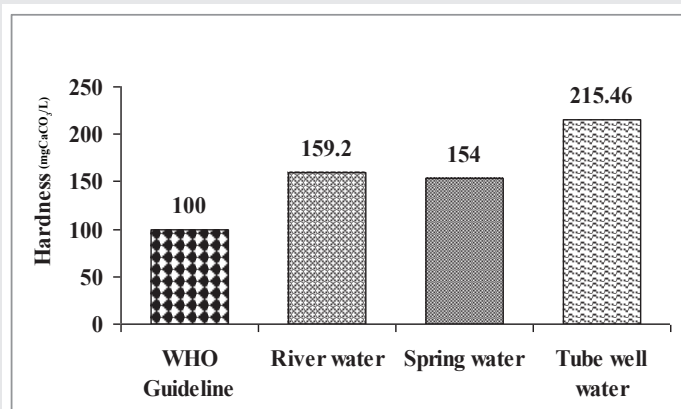
Figure 4: Mean total hardness concentration of three water sources compared with drinking water quality standard of WHO.

Table 5: Different cationic and anionic analytes of water collected from different sites at high altitude.

Sites no.	Water sources	Chloride (mg/L)	PO₄³⁻ (mg/L)	SO₄⁻(mg/L)	NO₃⁻(mg/L)
1	Indus river	29.99*	ND	43.71*	0.138*
2		26.94*	ND	46.31*	0.180*
3		25.29*	ND	54.34*	0.002*
4	Tube well	14.54*	ND	38.04*	0.041*
5		12.76*	ND	75.14*	0.140*
6		14.52*	ND	71.83*	0.097*
7		12.87*	ND	12.71*	0.583*
8		16.42*	ND	31.19*	0.708*
9		12.53*	ND	41.35*	0.023*
10		13.97*	ND	41.58*	0.012*
11		16.01*	ND	36.15*	0.029*
12		16.04*	ND	35.68*	0.026*
13		14.62*	ND	37.80*	0.004*
14		12.89*	ND	36.62*	0.020*
15		23.86*	ND	50.33*	0.357*
16		23.42*	ND	11.53*	0.099*
17		26.72*	ND	63.32*	0.036*
18		26.50*	ND	52.45*	0.190*
19		24.43*	ND	32.60*	0.015*
20		25.29*	ND	44.42*	0.038*
21		27.42*	ND	83.41*	0.031*
22		22.88*	ND	18.66*	0.176*
23	Indus river	16.06*	ND	71.83*	0.027*
24		26.04*	ND	72.30*	0.065*
25	Spring Water	15.80*	ND	8.99*	4.411*
26		16.92*	ND	37.09*	0.023*
27	Tube well	24.86*	ND	36.62*	0.087*
28		22.76*	ND	20.32*	0.008*
29		22.65*	ND	13.30*	1.480*
30		24.52*	ND	10.66*	0.005*
31		20.89*	ND	12.99*	1.260*
32		27.64*	ND	25.52*	0.560*
33		27.98*	ND	38.04*	0.041*

* Indicates lower level than the WHO standard.
** Indicates higher level than the WHO standard.
ND: Not detected.

fertilizers and industrial waste water [11]. The phosphate content in most of the study area was not detectable (Table 5). Since, all the samples were collected in the winter season. During winter season, domestic sewage is very low and no agriculture activity. Moreover, not much industry has been established, hence phosphate contaminants was under detectable limit.

Sulphate (SO_4^{2-}) occurs naturally in water because of leaching from gypsum and other common minerals [36]. Low levels of sulphate (Table 5, Figure 6) in the study area were indicating low level of leaching from the igneous, metamorphic and sedimentary rocks of this region.

Nitrate (NO_3^-) being the highly oxidized form of nitrogen compounds, which is present in the surface and groundwater sources [37]. Significant sources of nitrates are fertilizers, decayed vegetable and animal matter, domestic and industrial effluents and atmospheric washouts. In our study, nitrate concentration (Table 5, Figure 7) was below the permissible limit in all sources of water. Therefore, it might be said that drinking water might be free from hazardous sources as mainly the zero levels agricultural system.

Sodium (Na) concentration plays an important role in evaluating the groundwater quality for irrigation because sodium causes an increase in the hardness of soil as well as a reduction in its permeability [38]. For the low level of sodium concentration (Figure 8) in the study area, cultivation might be affected with low production.

The major source of potassium (K) in natural fresh water is weathering of rocks but the quantities increase in the polluted water due to disposal of waste water [25]. Average potassium level was higher in the nearby city area. Therefore, it can be said that, disposal of waste water in water sources nearby city area is more than the other area. Ruminants are largely depends on non-protein nitrogen sources, such as urea, biuret, or ammonium phosphate. Inadequate level of sulfur in the study area might be effect on the feed intake, digestibility, rate of weight gain, and milk production [39]. Manganese (Mn) is often associated with calcium in all kinds of waters, but its concentration remains generally lower than the calcium [40]. In this study, low levels of Mn can potentially lead to a decrease in overall animal growth [41]. In most of the analyzed water samples, iron and aluminium were above the permissible limit. Most of the groundwater samples contain iron and aluminum in trace amounts in practically all sediments and rock formations [25,42]. So, it may have adverse effect on long-term consumption of these water [43,44]. Hence, these findings indicated contamination of some water sources at certain sites, which seem to be investigated in time-to-time for devising some remedial measures. As this is a first time report on these parameters and different water sources at high altitude, however further studies are required to analyze more samples collected across the location in different seasons for comprehensive understanding of these variations in physico-chemical and mineral parameters (Table 6, Figure 9-13).

Overall quality of the drinking water has shown higher level

of alkalinity, hardness, potassium, iron, and aluminium level. High alkalinity and hardness of water may be corrected boiling followed by the filtration. However, gravity or reverse osmosis (RO) based multi staged filter would be useful for removal of
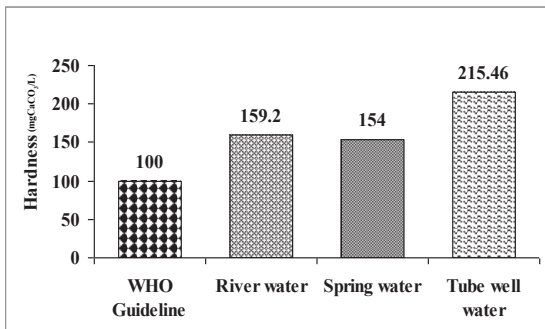

Figure 5: Mean chloride concentration of three water sources compared with drinking water quality standard of WHO.
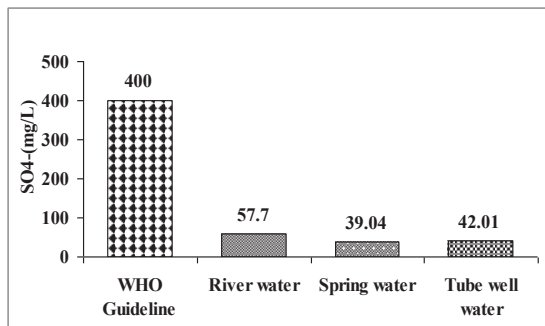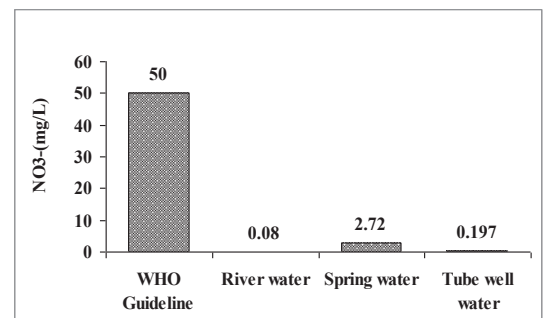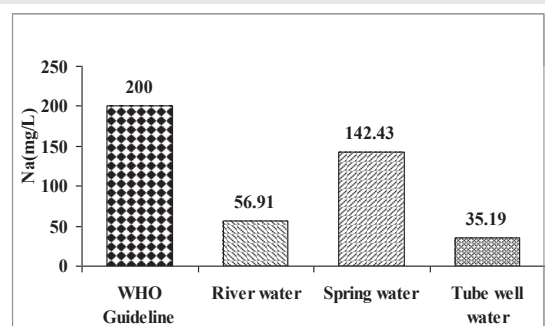

Figure 6: Mean sulphate concentration of three water sources compared with drinking water quality standard of WHO.

Figure 7: Mean nitrate concentration of three water sources compared with drinking water quality standard of WHO.

Figure 8: Mean sodium concentration of three water sources compared with drinking water quality standard of WHO.
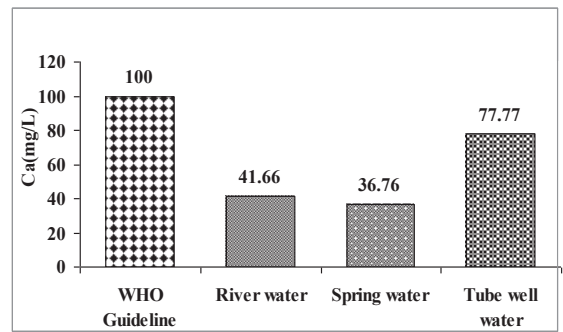

Figure 9: Mean calcium concentration of three water sources compared with drinking water quality standard of WHO.
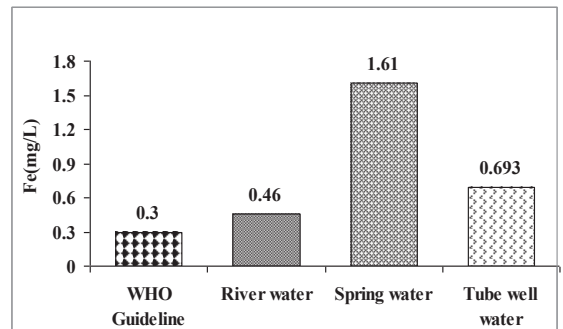

Figure 10: Mean iron concentration of three water sources compared with drinking water quality standard of WHO.
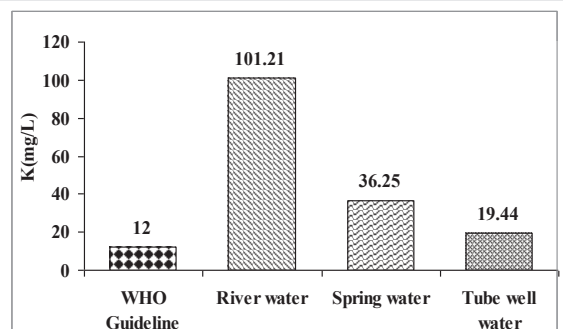

Figure 11: Mean potassium concentration of three water sources compared with drinking water quality standard of WHO.
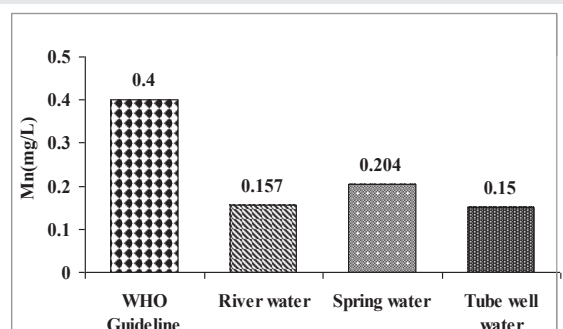

Figure 12: Mean manganese concentration of three water sources compared with drinking water quality standard of WHO.

excess inorganic salts and minerals. Since, the high altitude region has limited electricity coverage, so RO filter may not be feasible and gravity based filter has limited capacity to remove

Table 6: Minerals analytes of water collected from different sites at high altitude.

Sites no.	Water sources	Mg (mg/L)	Fe (mg/L)	Na (mg/L)	K (mg/L)	S (mg/L)	Mn (mg/L)	Al (mg/L)	Ca (mg/L)
1	Indus river	6.05*	0.302	47.12*	0.30*	85.81	0.147*	0.347	38.30*
2		5.28*	0.276*	79.53*	94.80**	92.57	0.147*	0.303	40.02*
3		6.20*	0.304	58.71*	100.10**	71.59	0.165*	1.874**	45.90*
4	Tube well	12.20*	0.786**	24.31*	8.03*	30.27	0.146*	2.838**	70.96*
5		11.89*	0.876**	45.41*	8.61*	41.75	0.145*	2.115**	71.36*
6		16.35*	0.197*	30.68*	3.11*	43.74	0.162*	1.302**	92.71*
7		16.37*	0.695**	25.90*	6.05*	77.91	0.195*	2.756**	117.00**
8		14.35*	0.414**	25.33*	3.90*	38.20	0.141*	0.887**	68.75*
9		11.81*	1.329**	22.28*	6.92*	67.45	0.153*	4.100**	69.88*
10		11.39*	1.420**	20.12*	66.50**	50.99	0.150*	1.085**	66.97*
11		13.70*	0.453**	29.99*	7.05*	65.57	0.145*	0.980**	77.53*
12		11.00*	2.307**	22.25*	3.03*	46.16	0.153*	0.907**	56.09*
13		11.80*	1.151**	21.21*	7.51*	51.12	0.146*	1.083**	73.52*
14		4.15*	2.054**	8.85*	1.01*	11.69	0.156*	1.134**	55.62*
15		14.11*	0.079*	24.10*	97.71**	88.88	0.138*	0.055*	77.50*
16		10.41*	1.041**	26.34*	10.17*	56.85	0.919*	2.077**	69.02*
17		13.28*	0.588**	36.67*	7.89*	72.90	0.139*	2.652**	83.24*
18		3.48*	0.728**	6.67*	1.30*	18.33	0.145*	2.184**	56.51*
19		11.82*	3.463**	28.23*	6.12*	47.14	0.165*	1.256**	81.60*
20		15.19*	1.003**	26.32*	33.62**	86.43	0.155*	1.251**	107.40
21		12.97*	0.975**	281.20**	26.82**	107.40	0.259*	2.535**	126.90**
22		5.40*	0.450**	6.53*	1.29*	14.02	0.142*	2.506**	71.43*
23	Indus river	5.05*	1.372**	10.81*	3.52*	27.20	0.177*	1.687**	52.99*
24		6.32*	0.860**	55.35*	114.30**	35.18	0.146*	0.002*	31.09*
25	Spring Water	3.45*	0.540**	6.90*	40.05**	35.06	0.136*	0.033*	31.05*
26		4.68*	3.162**	7.96*	2.45*	14.47	0.273*	2.535**	42.48*
27	Tube well	4.91*	0.739**	5.66*	1.36*	19.95	0.147*	2.607**	72.45*
28		5.53*	0.657**	4.87*	1.61*	15.99	0.146*	1.662**	71.98*
29		6.70*	0.070*	22.72*	48.77**	113.10	0.166*	0.050*	73.39*
30		7.43*	2.433**	34.37*	15.30**	279.00	0.238*	1.280**	105.20
31		5.56*	0.063*	24.39*	58.24**	109.00	0.161*	0.022*	56.96*
32		5.83*	0.069*	36.38*	83.45**	59.16	0.145*	0.016*	47.03*
33		5.20*	0.786**	24.31*	8.03*	30.27	0.146*	2.838**	70.96*

* Indicates lower level than the WHO standard.
** Indicates higher level than the WHO standard.
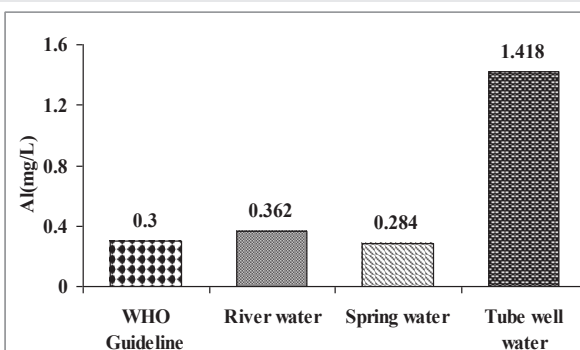
Figure 13: Mean aluminium concentration of three water sources compared with drinking water quality standard of WHO.

the soluble metal salt contaminants. Hence, research should be undertaken to develop economic and user friendly individual or community based water treatment system using activated charcoal, nanoadsorbant, metal chelators, etc.

Conclusions

The present investigation findings indicated variations in physico-chemical parameters and mineral status of water of different sources. Further, there was wide variation of water quality constituents among different sources of water. Physical parameters like alkalinity and hardness were higher than WHO standard level at different altitude. Among minerals, iron, potassium and aluminium level were more than the prescribed ground water quality limits by WHO. Interestingly, chloride, sodium, sulphur and aluminium level were high in Indus river water collected from the nearby city area. Therefore, it can be concluded that water sources near the city area are contaminated. However, more or less, the quality of drinking

water is suitable for consumption except the hardness and aluminium level. Though, this study finding further advocates the extensive study on water quality of different sources at high altitude.

Acknowledgements

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