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REVIEW ARTICLE

A review on water quality and dairy cattle health: a special emphasis on high-altitude region

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Abstract
Water is the wonder of nature which is an essential source of nutrient for all forms of life. It helps in proper digestion, energy metabolism, transport of nutrients and metabolites, cellular functions, and excretion of waste materials from our body and animals. Furthermore, water plays a vital role in body thermoregulatory and electrolyte health, and performance the fluidity and cushioning environment for the developing fetus in the human and animals. The quality of water determines the health and productivity of milk and their quality, as it causes bioaccumulation of water solutes in the milk and body tissues. Therefore, its quality has to be good for optimum health, and performance of dairy cattle. The high-altitude environments have limited surface and groundwater resources and more dependent on snow precipitations, very deep bore well groundwater, and mountain river. Recently, quality of high-altitude water resources has become questionable due to more environmental pollution, climate change, and high anthropogenic activities at high altitude. Therefore, there is a continuous requirement to monitor water quality, dairy product quality, and cattle health for prevention and control of waterborne diseases. This review reveals the water quality and the probable effects on the health performance of dairy cattle with a particular emphasis on high-altitude regions. From this review, it can be concluded that global warming and an increase in tourists at high-altitude regions have caused deterioration of water quality, which may affect the health, reproduction, and production of quality dairy products. This may lead to bioaccumulation of some toxic molecules and metals into higher food chain and affecting public health.

Keywords Dairy cattle health · Heavy metals · High altitude · Water quality

Introduction

For the survival of all living organisms, water is crucial. The health of the natural ecosystem depends on the physicochemical and biological characteristics of water (Venkatesharaju et al. 2010). The primary sources of water whether it is plain or high-altitude/mountain regions are groundwater and surface water (rivers, streams, and ponds) for all our social and economical consumption. The worldwide quality of water differs from one location to another location depending upon the environmental factors and locations. There are a number of physical, chemical, and microbiological parameters which are interrelated to define the water quality (Barik and Thorat 2015). Therefore, all of these paramters need to be assessed critically for better health of dairy cattle and production of quality milk and milk products. The quantification of chemical properties may quantify higher levels of the chemical load in the environment, and at the same instant is applicable for both physical and microbial parameter analysis which will help in assessing the water quality of a region in view of the rapid changes in water quality (Liu and Kujawinski 2015).

Groundwater quality is going to alter due to the increase in population size, industrial effluents, and several types of anthropogenic activity (Barnes et al. 2009). Most concerns of the deteriorating water quality revealed with the high load of heavy metals like arsenic, lead, cadmium, and presence of persistent organic pollutants. Arsenic is ubiquitously present in nature. In India, the number of arsenic-prone zones is increasing due to the overexploitation of groundwater and mainly anthropogenic activity. Arsenicosis also affects livestock animals, and through the food chain, the arsenic level rises in the human population also (Tikenbala et al. 2010).

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Table 1 Review of different physicochemical and microbiological parameters in groundwater

Sl. no.	Parameters	Reported levels	References
1.	Temperature	15.51–17.24 °C	Giri (2018)
		29.40 °C	Affum et al. (2015)
2.	pH	7.70–7.97	Giri (2018)
		6.00	Bariki et al. (2015)
		5.94	Affum et al. (2015)
3.	Conductivity	432.01–488.74 µS/cm	Giri (2018)
		692.00 µS/cm	Affum et al. (2015)
4.	Total dissolved solids	83.42–238.50 mg/L	Giri (2018)
		345.00 mg/L	Affum et al. (2015)
5.	Salinity	0.04–0.21 mg/L	Giri (2018)
6.	Turbidity	8.83–24.74 NTU	Giri (2018)
		5.00 NTU	Bariki et al. (2015)
7.	Dissolved oxygen	9.76–10.03 mg/L	Giri (2018)
		4.90 mg/L	Bariki et al. (2015)
8.	*E. coli*	1.47–12.90 CFU/mL	Giri (2018)
		< 1 CFU/100 mL	Affum et al. (2015)
9.	Chloride	20.41–22.74 mg/L	Giri (2018)
		12.70 mg/L	Bariki et al. (2015)
		132.90 mg/L	Affum et al. (2015)
10.	Alkalinity	442.54–494.49 mg/L	Giri (2018)
		13.50 mg/L	Affum et al. (2015)
11.	Calcium hardness	129.19–134.26 mg/L	Giri (2018)
		< 0.50 mg/L	Affum et al. (2015)
12.	Total hardness	184.26–256.50 mg/L	Giri (2018)
		84.00 mg/L	Bariki et al. (2015)
		45.80 mg/L	Affum et al. (2015)
13.	Sulfate	2.84–5.59 mg/L	Giri (2018)
		0.90 mg/L	Bariki et al. (2015)
		82.90 mg/L	Affum et al. (2015)
14.	Phosphate	0.03–0.04 mg/L	Giri (2018)
		0.09 mg/L	Affum et al. (2015)
15.	Carbonate	2.69–3.72 mg/L	Giri (2018)
16.	Bicarbonate	27.15–28.25 mg/L	Giri (2018)
		13.50 mg/L	Affum et al. (2015)
17.	Nitrate	0.15–0.22 mg/L	Giri (2018)
		Below detection limit	Bariki et al. (2015)
		0.60 mg/L	Affum et al. (2015)
18.	TOC	1.92–2.94 mg/L	Giri (2018)

Among the heavy metals, lead, arsenic, and cadmium causes the most hazards in domestic animals. Due to mainly anthropogenic activity, the environment is getting contaminated with a higher level of these heavy metals.

Table 2 Review of different trace minerals and metals level in groundwater

Sl. no.	Constituents	Reported levels	References
1.	Cadmium (Cd)	0.0007–0.0019 mg/L	Giri (2018)
		< 0.002 µg/L	Affum et al. (2015)
2.	Lead (Pb)	0.0021–0.0023 mg/L	Giri (2018)
3.	Arsenic (As)	0.0265–0.0300 mg/L	Giri (2018)
		44.00 µg/L	Affum et al. (2015)
4.	Copper (Cu)	1.06 mg/L	Giri (2018)
		4.90 mg/L	Huang et al. (2013)
5.	Zinc (Zn)	2.87–3.12 mg/L	Giri (2018)
		0.11 mg/L	Solange et al. (2013)
6.	Calcium (Ca)	87.40–93.43 mg/L	Giri (2018)
		44.00 mg/L	Bariki et al. (2015)
		< 0.01 mg/L	Affum et al. (2015)
7.	Magnesium (Mg)	33.41–33.67 mg/L	Giri (2018)
		40.00 mg/L	Bariki et al. (2015)
		11.10 mg/L	Affum et al. (2015)
8.	Iron (Fe)	1.03–1.05 mg/L	Giri (2018)
		0.551 mg/L	Singh et al. (2011)
9.	Cobalt (Co)	0.0075–0.0089 mg/L	Giri (2018)
10.	Manganese (Mn)	2.99–3.36 mg/L	Giri (2018)
		0.40 mg/L	Salem et al. (2014)
11.	Sodium (Na)	61.58–62.92 mg/L	Giri (2018)
		265.50 mg/L	Affum et al. (2015)
12.	Potassium (K)	30.08–30.12 mg/L	Giri (2018)
		5.60 mg/L	Affum et al. (2015)
13.	Boron (B)	1.63–1.70 mg/L	Giri (2018)
		32.00 mg/L	Rango et al. 2012
14.	Selenium (Se)	0.05–0.06 mg/L	Giri (2018)
		1.30 µg/L	Huang et al. (2013)
15.	Silicon (Si)	6.12–6.34 mg/L	Giri (2018)
		0.43 mg/L	Solange et al. (2013)
16.	Aluminum (Al)	0.86 mg/L	Giri (2018)
		0.67 µg/L	Solange et al. (2013)

Rapid industrialization increases lead poisoning in urban dairy cattle than the rural cattle. Many studies found that lead poisoning is most common in calves (Cowan and Blakley 2016; Chiwome et al. 2017). Cattle were mainly exposed to the lead after drinking crankcase oil, licking machinery grease, newspapers, and chewing batteries (Cowan and Blakley 2016). It has been found that reticulum is the main site for lead deposition (Cowan and Blakley 2016; Priyanka and Dey 2018).

Currently, in the developing country, numerous health problems are arising due to over access to contaminated water, which becomes a great concern to the government

Table 3 Review of different physicochemical and microbiological parameters in river water

Sl. no.	Parameters	Reported levels	References
1.	Temperature	14.88–15.66 °C	Giri (2018)
		33.51 °C	Kumar et al. (2015)
2.	pH	8.33–8.36	Giri (2018)
		7.07	Sarma et al. (2017)
3.	Conductivity	325.65–336.43 µS/cm	Giri (2018)
		977.60 µS/cm	Kumar et al. (2015)
4.	Total dissolved solids	103.46–155.41 mg/L	Giri (2018)
		689.90 mg/L	Kumar et al. (2015)
5.	Salinity	0.10–0.11 mg/L	Giri (2018)
		0.01–0.02 mg/L	Khalik et al. (2013)
		0.12 mg/L	Charan (2013)
6.	Turbidity	3.38–4.97 NTU	Giri (2018)
		9.80 NTU	Sarma et al. (2017)
		42.78 NTU	Kumar et al. (2015)
7.	Dissolved oxygen	10.17–10.69 mg/L	Giri (2018)
		7.27 mg/L	Kumar et al. (2015)
8.	*E. coli*	6.48–8.18 CFU/mL	Giri (2018)
		236.00 CFU/mL	Kumar et al. (2015)
9.	Chloride	20.44–23.48 mg/L	Giri (2018)
		9.50 mg/L	Sarma et al. (2017)
		74.55 mg/L	Kumar et al. (2015)
10.	Alkalinity	319.25–333.43 mg/L	Giri (2018)
		431.50 mg/L	Kumar et al. (2015)
		22.00 mg/L	Eze and Chigbu (2015)
11.	Calcium hardness	53.85–88.33 mg/L	Giri (2018)
		78.56 mg/L	Kumar et al. (2010)
12.	Total hardness	150.67–187.27 mg/L	Giri (2018)
		66.50 mg/L	Sarma et al. (2017)
		240.80 mg/L	Kumar et al. (2015)
13.	Sulfate	2.28–3.92 mg/L	Giri (2018)
		20.59 mg/L	Kumar et al. (2015)
		0.103 mg/L	Eze and Chigbu (2015)
		73.60 mg/L	Sahoo et al. (2016)
14.	Phosphate	0.27–0.35 mg/L	Giri (2018)
		47.70 mg/L	Kumar et al. (2015)
		0.072 mg/L	Eze and Chigbu (2015)
15.	Carbonate	2.55–2.99 mg/L	Giri (2018)
		16.02 mg/L	Eze and Chigbu (2015)
		2.30 mg/L	Bourasi et al. (2016)
16.	Bicarbonate	21.26–23.46 mg/L	Giri (2018)
		26.84 mg/L	Eze and Chigbu (2015)
		172.62–154.45 mg/L	Kumar et al. (2017)
17.	Nitrate	0.04–0.12 mg/L	Giri (2018)
		3.40 mg/L	Sarma et al. (2017)
		515.30 mg/L	Kumar et al. (2015)
18.	TOC	0.92–1.07 mg/L	Giri (2018)
		117.85 mg/L	Kumar et al. (2015)

Table 4 Level of different minerals and heavy metals in river water

Sl. no.	Constituents	Reported levels	References
1.	Cadmium (Cd)	0.0020–0.0041 mg/L	Giri (2018)
		0.019–0.045 mg/L	Charan (2013)
2.	Lead (Pb)	0.0037–0.0054 mg/L	Giri (2018)
		0.039–228.00 mg/L	Charan (2013)
3.	Arsenic (As)	0.0268–0.0621 mg/L	Giri (2018)
		< 0.001 mg/L	Eze and Chigbu (2015)
4.	Copper (Cu)	1.03–1.04 mg/L	Giri (2018)
		0.50 mg/L	Ambedkar and Muniyan (2012)
5.	Zinc (Zn)	0.46–0.48 mg/L	Giri (2018)
		0.341 mg/L	Charan (2013)
6.	Calcium (Ca)	66.99–70.28 mg/L	Giri (2018)
		32.00 mg/L	Bourasi et al. (2016)
7.	Magnesium (Mg)	31.18–31.49 mg/L	Giri (2018)
		19.3 mg/L	Bourasi et al. (2016)
		6.45– 8.67 mg/L	Potasznik and Szymczyk (2015)
8.	Iron (Fe)	1.06–1.07 mg/L	Giri (2018)
		1.10 mg/L	Sarma et al. (2017)
		0.041 mg/L	Eze and Chigbu (2015)
		0.022 mg/L	Shally et al. (2016)
		0.11 mg/L	Bourasi et al. (2016)
9.	Cobalt (Co)	0.0058–0.0063 mg/L	Giri (2018)
		0.03– 0.07 mg/L	Bhuyan and Bakar (2017)
		0.0135 mg/L	Vaishnavi and Gupta (2015)
		0.63 mg/L	Okegye and Gajere (2015)
10.	Manganese (Mn)	0.62–1.23 mg/L	Giri (2018)
		0.35 mg/L	Sarma et al. (2017)
11.	Sodium (Na)	60.98–62.16 mg/L	Giri (2018)
		1.41 mg/L	Sahoo et al. (2016)
		48–51 mg/L	Sasikala et al. (2015)
12.	Potassium (K)	30.60–31.63 mg/L	Giri (2018)
		2.16 mg/L	Sahoo et al. (2016)
		3.00–5.00 mg/L	Sasikala et al. (2015)
13.	Boron (B)	2.07–2.10 mg/L	Giri (2018)
		1.47 mg/L	Charan (2013)
14.	Silicon (Si)	5.53–9.28 mg/L	Giri (2018)
		0.52–0.61 mg/L	Patra et al. (2011)
15.	Aluminum (Al)	0.85–0.86 mg/L	Giri (2018)
		4.20–11.90 mg/L	Bhuyan and Bakar (2017)

in these countries (Barik and Thorat 2015). These countries regularly have one billion or more incidents of diarrhea annually (Mark et al. 2002). It is estimated that one-third of the world population is using groundwater for drinking (WHO 2002). On the contrary, about eighty percent of natural water is wastewater type, which is not suitable for drinking, agriculture, and industry use. In the global scenario, approximately 1.1 billion people cannot use the improved source of water supply. Moreover, two million deaths per annum occur due to diarrhea. These cases are happening because of the unsafe drinking water supply and improper sanitation (WHO 2013). According to the different

Table 5 Details of various high-altitude regions in different countries (adopted from Mountains of the World 2002)

Sl. no.	Country/regions name	Highest point name	Elevation (m)
1.	Afghanistan	Noshaq	7492
2.	Albania	Korab	2764
3.	Algeria	Mount Tahat	3003
4.	Andorra	Coma Pedrosa	2942
5.	Antarctica	Mount Vinson	4892
6.	Argentina	Aconcagua	6960
7.	Armenia	Mount Aragats	4090
8.	Austria	Grossglockner	3798
9.	Azerbaijan	Mount Bazardüzü	4485
10.	Bhutan	Gangkhar Puensum	7570
11.	Bolivia	Sajama	6542
12.	Brazil	Pico da Neblina	2995
13.	Bulgaria	Musala	2925
14.	Burundi	Mount Heha	2684
15.	Cameroon	Mount Cameroon	4040
16.	Canada	Mount Logan	5959
17.	Cape Verde	Pico do Fogo	2829
18.	Chad	Emi Koussi	3445
19.	Chile	Ojos del Salado	6893
20.	China	Mount Everest	8848
21.	Colombia	Pico Cristóbal Colón Pico Simón Bolívar	5700
22.	Democratic Republic of the Congo	Margherita Peak	5109
23.	Costa Rica	Cerro Chirripó	3820
24.	Dominican Republic	Pico Duarte	3098
25.	Ecuador	Chimborazo	6267
26.	Egypt	Mount Catherine	2629
27.	Equatorial Guinea	Pico Basile on Bioko	3008
28.	Eritrea	Emba Soira	3018
29.	Ethiopia	Ras Dejen	4550
30.	France	Mont Blanc	4810
31.	Georgia	Shkhara	5201
32.	Germany	Zugspitze	2962
33.	Greece	Mount Olympus	2919
34.	Greenland	Gunnbjørn Fjeld on Greenland	3700
35.	Guatemala	Volcán Tajumulco	4220
36.	Guyana	Mount Roraima	2750
37.	India	Kangchenjunga	8586
38.	Indonesia	Puncak Jaya	4884
39.	Iran	Damavand	5610
40.	Iraq	Cheekha Dar	3611
41.	Italy	Monte Bianco	4810
42.	Japan	Mount Fuji on Honshu	3776
43.	Kazakhstan	Khan Tengri	7010
44.	Kenya	Mount Kenya	5199
45.	Kyrgyzstan	Jengish Chokusu	7439
46.	Lebanon	Qurnat as Sawda	3088
47.	Lesotho	Thabana Ntlenyana	3482
48.	Malawi	Mount Mulanje	3002
49.	Malaysia	Gunung Kinabalu on Borneo	4095
50.	Mexico	Volcán Citlaltépetl (Pico de Orizaba)	5636

Table 5 (continued)

Sl. no.	Country/regions name	Highest point name	Elevation (m)
51.	Mongolia	Khüiten Peak	4374
52.	Morocco	Jbel Toubkal	4165
53.	Myanmar	Hkakabo Razi	5881
54.	Nepal	Mount Everest	8848
55.	New Zealand	Aoraki/Mount Cook in the South Island	3724
56.	Oman	Jabal Shams	3009
57.	Pakistan	K_2	8611
58.	Panama	Volcán Barú	3475
59.	Papua New Guinea	Mount Wilhelm	4509
60.	Peru	Huascarán	6768
61.	Philippines	Mount Apo on Mindanao	2954
62.	Réunion	Piton des Neiges	3069
63.	Russia	Mount Elbrus	5642
64.	Rwanda	Mount Karisimbi	4507
65.	Saudi Arabia	Jabal Sawda	3000
66.	South Africa	Mafadi	3450
67.	South Sudan	Kinyeti	3187
68.	Spain	Teide on Tenerife	3718
69.	Sudan	Deriba Caldera	3042
70.	Switzerland	Dufourspitze (Monte Rosa)	4634
71.	Taiwan	Yu Shan	3952
72.	Tajikistan	Ismoil Somoni Peak	7495
73.	Tanzania	Kilimanjaro	5892
74.	Turkey	Mount Ararat	5137
75.	Turkmenistan	Aýrybaba	3139
76.	Uganda	Margherita Peak	5109
77.	United States	Denali	6190.5
78.	Uzbekistan	Khazret Sultan	4643
79.	Venezuela	Pico Bolívar	4978
80.	Vietnam	Fan Si Pan	3143
81.	Yemen	Jabal an Nabi Shu'ayb	3666

international agencies like WHO, CPCB, BIS, and ICMR, in India, seventy percent of river water quality has contaminated due to an increasing level of direct pollutant discharges in rivers. Some of the river water in India is highly contaminated that cannot be used for any purpose (Daud et al. 2017; Rodriguez-Tapia and Morales-Novelo 2017). In India, about 95% of the rural population depends on groundwater for their primary domestic uses. Around 70% of the total water resources are severely polluted. Further, 75% of illness and 80% of child mortality are attributed to water pollution as groundwater has been deteriorated in the plain area as well as in high-altitude regions (Aris et al. 2009; Giri 2018).

The high temperature is causing the melting of glaciers, altered pattern of precipitation, and snowfall. The water level in groundwater is decreasing and quality deteriorating due to the irregular pattern of rainfall and high population loading. Socioeconomic balance is now under a tremendous pressure due to the scarcity of water in terms of quality and quantity. As there is an increase in dynamic flow of population at high-altitude region, water quality is also deteriorating from the last decade in most of the high-altitude regions throughout the globe (Giri 2018; Giri et al. 2017; Bharti et al. 2017a).

In this scenario of deteriorating water quality of different sources in the world, the present study has taken into account to review the various causes deterioratting the water quality and their effects on animal health with particular emphasis on the water quality at high-altitude regions.

Water quality evaluations of different sources at low-altitude region

Groundwater resource

Alves (2002) examined the drinking water for the microbiological quality after the collection of 18 samples from

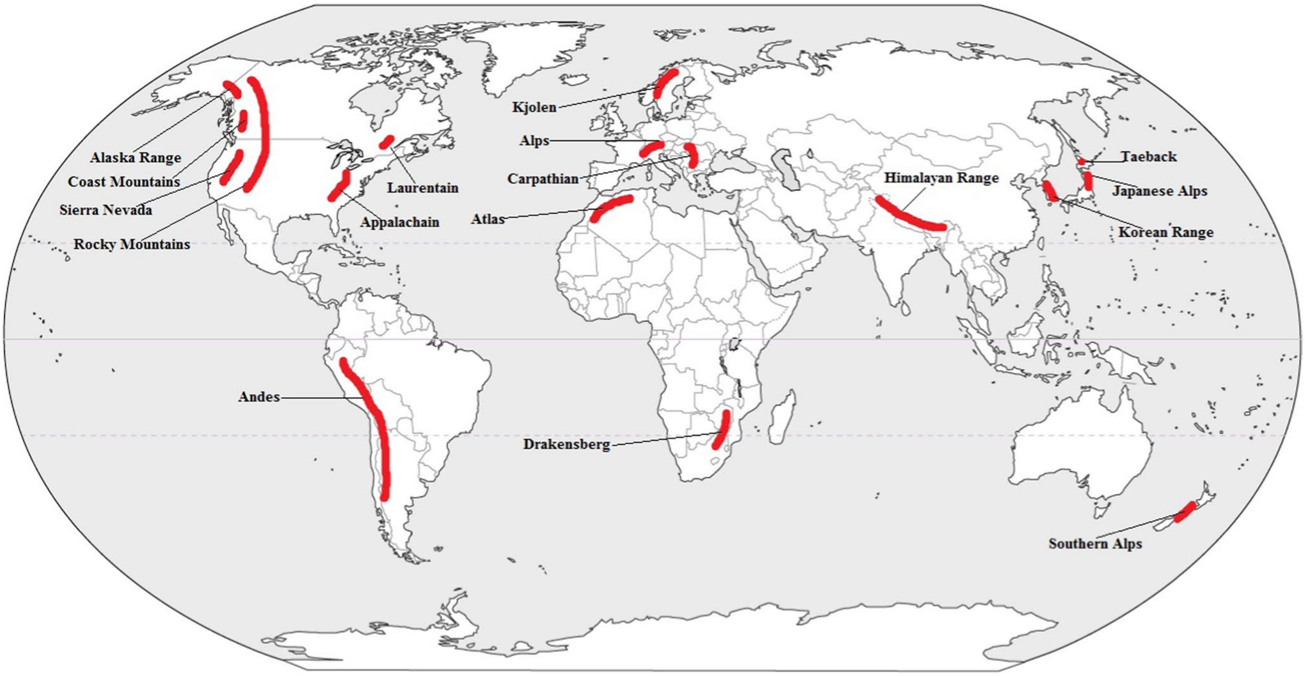

Fig. 1 Location of different high-altitude regions around the globe. Adopted from nationsonline.org

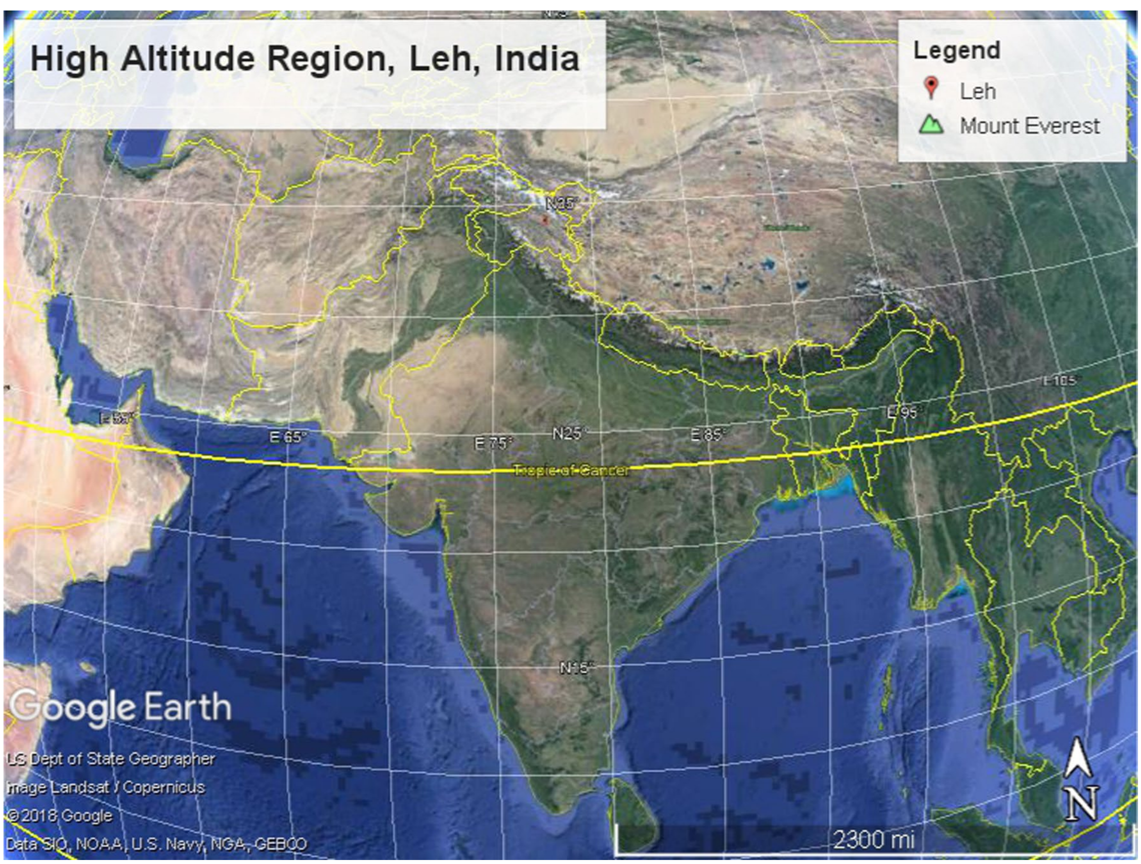

Fig. 2 Experimental location in Leh, a high-altitude region of India. Map prepared using Google Earth 3D Pro Software

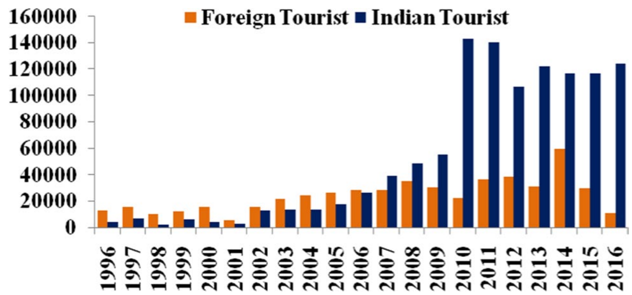

Fig. 3 Tourist load in Leh, Ladakh, India from 1996 to 2016. *Source* Ladakh Tourism Center, Leh, India

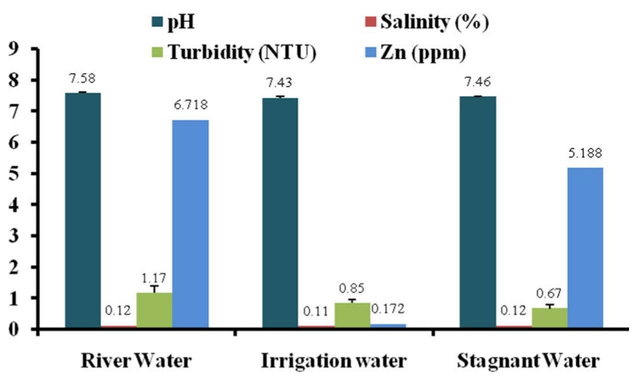

Fig. 4 Level of pH, turbidity, salinity, and Zn level in different sources of water from high-altitude region of India

some areas of Brazil. Results showed that reservoir water was contaminated with coliform group bacteria.

Shittu et al. (2008) analyzed well water for the physicochemical analyses in Nigeria. The results were compared with the prescribed limit of the EPA and WHO. They interpreted that most of the physicochemical parameters were within the normal level of the WHO and EPA.

Ukpong et al. (2012) analyzed groundwater samples for physicochemical and bacterial parameters. Results showed that except for coliform bacteria, water might be consumable for drinking purposes. The range of total coliform count was from 0 to 38 CFU/100 ml.

Narasimha et al. (2012) studied the drinking water for the physicochemical parameters. The result showed that about 27.7% of groundwater samples have higher level of chloride than the prescribed limit of WHO guidelines. An extensive review has been done on the physicochemical, microbiological, and minerals level in groundwater, as presented in Tables 1 and 2.

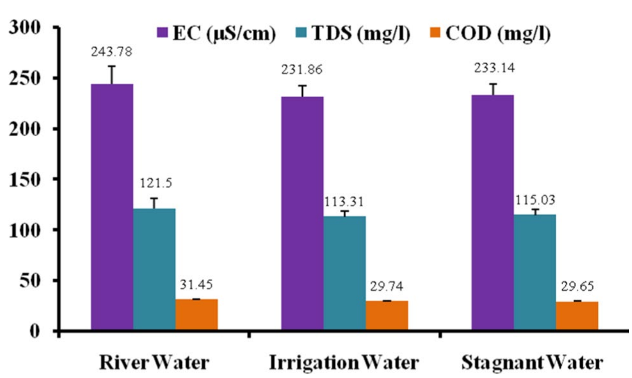

Fig. 5 Level of EC, TDS, and COD level in different sources of water from high-altitude region of India

River water resource

Debels et al. (2005) studied on the Chilean River in Central Chile. They observed that in the dry season, water quality conditions were critical mainly due to the direct discharge of wastewater from the urban area to the river.

A study conducted on the Pamba River water quality in Kerala (John 2009), and samples were analyzed for different physicochemical parameters like salinity, turbidity, temperature, dissolved oxygen, pH, dissolved carbon dioxide, etc. The study found that river water has a high salinity level than the prescribed limit by WHO.

Khalik et al. (2013) conducted a study on the physicochemical parameters of Bertam River located in Cameron Highlands. The result indicates that the Bertam River water quality was deteriorating and extensive monitoring is required.

Shekha (2016) conducted drinking water quality test of Greater Zab River located in Iraq. The sample analyzed for several physical parameters, minerals, and heavy metals indicated that the water of the Zab River is suitable for drinking purposes. Some of the works which are carried out throughout the globe on the quality of river water are presented in Tables 3 and 4.

Water quality at high-altitude region

High-altitude region in different countries

The high-altitude region sometime defined as the altitudinal region, which starts from 2400 meters above mean sea level (MSL). Some of the important high-altitude regions worldwide inhabited are listed in Table 5 and presented in Fig. 1. The high-altitude region has covered one-fifth of the total earth surface area. Various ecosystems characterize these high-altitude regions. Approximately thirteen hundred million people reside in this region, and this number fluctuates due to the dynamic population in terms of tourist (Zafren and Honigman 1997). The most crowded high-altitude region of India is Leh, Ladakh, whose data are presented in Fig. 2. Since 1996, at Ladakh, a high-altitude region of India, in terms of

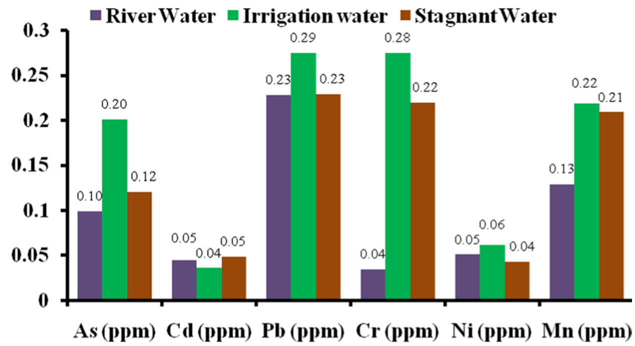

Fig. 6 Level of different metals in different sources of water at high-altitude region of India

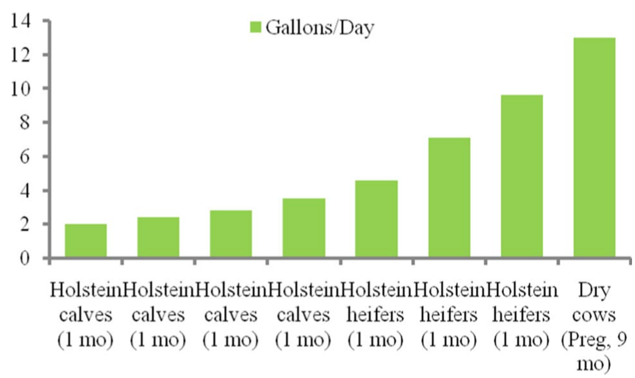

Fig. 7 Normal water intake of dairy cattle. Adopted from Adams and Sharpe (1914)

the dynamic flow of tourists, has increased to a hundred times (Fig. 3).

Physicochemical, microbial, and heavy metal contamination at high altitude

An evaluator study on water quality was conducted in Nepal located at the elevation of 4530 to 5480 m MSL. The study concluded that most of the lakes have poor water quality that might be due to the increase in atmospheric pollutant loads and geo-lithological changes (Gabriele et al. 2002). In Nepal, it found that at the elevation of 1900–5300 m MSL, water quality is going to deteriorate due to the increasing level of tourists and tracking in this area (Narayan et al. 2013). Earlier findings also indicated that Himalayan rivers like Alaknanda, Bhagirathi, Ganga, and Mandakini ware polluted due to the presence of *E. coli* (Kumar et al. 2010).

The water of Anchar Lake of Kashmir Valley was evaluated for different physicochemical parameters. It was found that most of the parameters showed a positive correlation except between dissolved oxygen and biological oxygen demand, and pH and dissolved carbon dioxide (Salim et al. 2013). Sukhnag stream is a significant inflow stream of Lake Wular. Data analyzed by multivariate statistical analysis indicated that total phosphorus, calcium, sodium, total solids, and total dissolved solids were the most effective factors for changing the pattern of water quality. The overall study showed that water quality is going to altered (Salem et al. 2014).

Different sources of water in Leh, Ladakh, a cold desert high-altitude region of India, were analyzed. Results showed that the level of Mn, Zn and Cr was below the prescribed limit of WHO, but As, Pb, Ni, and Cd were higher than the WHO limits. The levels of different physicochemical and mineral parameters in various sources of water are presented in Figs. 4, 5 and 6. Long-term consumption of water may pave the health hazards to the local animals as well as to human (Charan 2013).

Fig. 8 Variation of relative humidity (RH), maximum temperature (T_{max}), and minimum temperature (T_{min}) of six consecutive years (2010–2015) at experimental location of Leh, Ladakh, Kashmir (Bharti et al. 2017a, b)

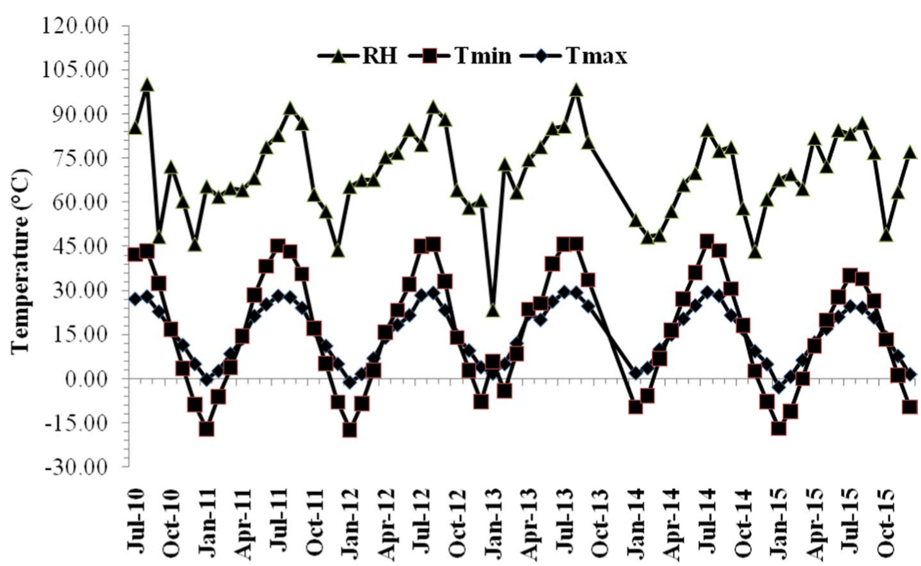

Table 6 Primary requirements of essential minerals in ruminants and non-ruminants (adopted from Underwood and Suttle 2001)

Minerals	Sheep	References	Cattle	References	Pigs	References	Poultry	References
Calcium	4 g kg^{-1} DM	AFRC (1991)	4.5 g kg^{-1} DM	AFRC (1991)	7.6 g kg^{-1} DM	ARC (1981)	8.5 g kg^{-1} DM	NRC (1994)
Phosphorus	1.7–3.8 g kg^{-1} DM	NRC(1985)	2.2–4.3 g kg^{-1} DM	NRC (1975)	5.9–8.8 g kg^{-1} DM	ARC (1981)	4.5 g kg^{-1} DM	NRC (1994)
Magnesium	0.7–1.8 g kg^{-1} DM	ARC (1980)	0.7–1.8 g kg^{-1} DM	ARC (1980)	400 mg kg^{-1} DM	NRC (1988)	0.5 g kg^{-1} DM	NRC (1994)
Sodium	0.8–2.7 g kg^{-1} DM	ARC (1980)	1.8 g kg^{-1} DM	NRC (1989)	0.8–1.1 g kg^{-1} DM	Meyer et al. (1950)	0.5–0.6 g kg^{-1} DM	Shaw and Philips (1953)
Potassium	3–5 g kg^{-1} DM	ARC (1980)	6–8 g kg^{-1} DM	Thompson (1972), NRC (1994)	2.6–3.3 g kg^{-1} DM	Combs (1981), Meyer et al. (1950)	4–6 g kg^{-1} DM	Thompson (1972)
Sulfur	1.1–1.6 g kg^{-1} DM	ARC (1980)	1.1–1.6 g kg^{-1} DM	ARC (1980)	–	–	–	–
Cobalt	0.07 mg kg^{-1} DM	ARC (1980)	0.07 mg kg^{-1} DM	ARC (1980)	10–18 μg kg^{-1} DM	ARC (1981)	3–10 μg kg^{-1} DM	NRC (1994)
Copper	0.13–0.18 mg kg^{-1} DM	ARC (1980)	4–6 mg kg^{-1} DM	ARC (1980)	4 mg kg^{-1} DM	ARC (1981)	4 mg kg^{-1} DM	NRC (1994)
Iodine	50–100 μg Day^{-1}	Mitchell and McClure (1937)	400–800 μg Day^{-1}	Mitchell and McClure (1937)	80–160 μg Day^{-1}	Mitchell and McClure (1937)	0.2–1.0 mg kg^{-1} DM	Wilgus et al. (1953)
Iron	25–40 mg kg^{-1} DM	Lawlor et al. (1965)	30–60 mg kg^{-1} DM	Matrone et al. (1957)	40–100 mg kg^{-1} DM	NRC (1988)	80 mg kg^{-1} DM	NRC (1994)
Manganese	13 mg kg^{-1} DM	Masters et al. (1988)	20–25 mg kg^{-1} DM	ARC (1980)	4 mg kg^{-1} DM	NRC (1988)	60 mg kg^{-1} DM	NRC (1994)
Selenium	0.03 mg kg^{-1} DM	Grace et al. (1994)	0.07 mg kg^{-1} DM	Grace et al. (1994)	0.16 mg kg^{-1} DM	ARC (1981)	0.20–0.28 mg kg^{-1} DM	NRC (1994)
Zinc	20–51 mg kg^{-1} DM	ARC (1980)	12–34 mg kg^{-1} DM	ARC (1980)	50 mg kg^{-1} DM	NRC (1988)	50 mg kg^{-1} DM	NRC (1977)

According to the investigation carried out by Bharti et al. (2017a) on water quality of different sources in Leh District, a high-altitude region situated above the 3500 m MSL, India, it was found that alkalinity and hardness were higher than the prescribed limit of WHO. The study concluded that more or less water quality is safe for drinking purposes in this region.

Another extensive study was carried out in the same high-altitude region on groundwater quality and evaluated total twenty-five parameters in seventy number of groundwater samples collected from different sites of Leh in both summer and winter seasons (Giri et al. 2017). Results showed that water quality levels go down due to the dissolution process of salts, leaching process, and increased level of population in terms of tourists (Fig. 3).

Persistent organic pollutants (POPs) at high altitude

Due to globalization, the untouched area of the earth, like many high-altitude regions, is getting crowded, and several studies indicate that the level of persistent organic pollutants (POPs) is getting higher. Dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs) are the essential POPs. All these pollutants are depositing at high-altitude regions by transport and day-by-day increasing trend of tourists at these places. POPs are getting lodged in the snow layer, and

Table 7 Some important metalloenzymes in livestock (adopted from Underwood and Suttle 2001)

Metal	Enzyme	Function
Iron	Succinate dehydrogenase	Aerobic oxidation of carbohydrates
	Cytochromes a, b and c	Electron transfer
Copper	Catalase	Protection against H_2O_2
	Cytochrome oxidase	Terminal oxidase
	Lysyl oxidase	Lysine oxidation
	Ceruloplasmin	Iron utilization: copper transport
	Superoxide dismutase	Dismutation of superoxide radical O_2^-
Zinc	Carbonic anhydrase	CO_2 formation
	Alcohol dehydrogenase	Alcohol metabolism
	Carboxypeptidase A	Protein digestion
	Alkaline phosphatase	Hydrolysis of phosphate esters
	Nuclear poly(A) polymerase	Cell replication
	Collagenase	Wound healing
Manganese	Pyruvate carboxylase	Pyruvate metabolism
	Super oxide dismutase	Antioxidant by removing O_2^-
	Glycosyl aminotransferases	Proteoglycan synthesis
Molybdenum	Xanthine dehydrogenase	Purine metabolism
	Sulfite oxidase	Sulfite oxidation
	Aldehyde oxidase	Purine metabolism
Selenium	Glutathione peroxidase (four)	Removal of H_2O_2 and hydroperoxidase
	Type II and III deiodinase	Conversion of thyroxine to active form

Table 8 Pathophysiology of mineral-responsive diseases in dairy cattle (adopted from Underwood and Suttle 2001)

Minerals	Depletion	Deficiency	Dysfunction	Disease
Calcium	Young: bone ↓	Serum	Chondrodystrophy	Rickets
	Old: bone ↓	Serum	Irritability ↓	Recumbency
Magnesium	Young: bone ↓	Serum	Irritability ↑	Convulsion
	Old: bone	Serum	Irritability ↑	Convulsion
Copper	Liver ↓	Serum	Disulfide bonds ↓	Wool crimp ↓
Cobalt	Liver B_{12} ↓	Serum	MMA ↑	Inappetence
	Serum B_{12} ↓	< 350 pmol l^{-1}		
Iodine	T_4 ↓	T_3 ↓	BMR ↓	Goiter
	Thyroid colloid ↓		Thyroid hypertrophy	
	Thyroid I ↓			
Selenium	GSH-Px in erythrocyte ↓	Serum Se ↓	Serum creatine kinase ↑	Myopathy gangrene of ear/tail

in summer, they leached to the underground water (Olatunji 2019). One study on the presence of POPs at high-altitude region of Italy conducted. The results of these study revealed that the study area is slightly contaminated with POPs (Giulia et al. 2017). Environmentally pertinent POPs affect the cellular level to exert the neurotoxic effects in the animals (Kodavanti 2006).

Impact of water quality on dairy cattle

Dairy cattle reproduction and production depend upon the water and feed quality, and water plays a vital role in providing some essential nutrients. Nowadays, dairy production is

Table 9 Safe concentrations of some potentially toxic nutrients and contaminants in water for cattle

Chemical compounds	Abbreviation of compounds	Threshold level[a] (mg/l)	Highest desirable limit[b] (mg/l)
Aluminum	Al	5.0	0.5
Arsenic	As	0.2	0.05
Boron	B	5.0	5.0
Cadmium	Cd	0.05	0.005
Chromium	Cr	1.0	0.1
Cobalt	Co	1.0	1.0
Copper	Cu	0.5	1.0
Fluoride	F	2.0	2.0
Lead	Pb	0.1	0.015
Manganese	Mn	Not available	0.05
Mercury	Hg	0.01	0.01
Nickel	Ni	1.0	0.25
Nitrogen dioxide	NO_2–N	10.0	–
Selenium	Se	0.05	0.05
Vanadium	V	0.1	0.1
Zinc	Zn	25.0	5.0
Salinity (total soluble salts)	Sal	3000.0	–
Toxic algae	–	No heavy growth	–

[a]Ontario Ministry of the Environment 1984

[b]NRC (1975, 1980), EPA (2009)

[c]No value available

going to decrease due to the lack of attention for the proper nutrition and health management of dairy cattle by farmers and nutritionists. It is found that, from any other landmass animal, dairy cows have the highest water requirements for proper performance, as 80% of water is required for milk synthesis (Woodford et al. 1984). Daily water intake by dairy cattle is presented in Fig. 7. In the animal body, water helps in proper digestion, energy metabolism, and electrolyte balance. It also helps in nutrient and metabolites transport to and from the tissue by the circulatory system. It plays a vital role in excretion, proper ion, and heat balance. Water maintains the fluidity and cushioning environment for the developing fetus in the animal body (Murphy 1992). Therefore, water is considered an essential nutrient for dairy cattle. However, the role of water in cattle body depends upon the source and quality of water. Most of the farmers and the dairy farms have no accessibility for water quality testing facility. The micro-eco-geology of water sources is very complicated as the mechanism of this complex in the animal body is less understood (Van Eenige et al. 2013). Requirements of water minerals nutrients in ruminants and non-ruminants are listed in Table 6. Among all these minerals nutrients, most of them act as the cofactor in most essential enzymes in the cattle body. Minerals that are necessary for the enzymatic activity are listed in Table 7. In the deficiency of these minerals, several diseases occurred, which are listed in Table 8.

Poor quality of water affects herd health through adversely changing feed intake, body nutrients balance, milk production, and reproduction. Toxic pollutants present in the water may bioaccumulate in the animal body which in turn may affect the whole human population after contaminated milk consumption. Therefore, regular evaluation of water quality may reduce the health hazzard in a dairy herd (Wegener 2012). Hence, the priority must be to provide to access of potable water to every individual and whole community. Microbe-contaminated water adversely affects human and animal health due to outbreaks of waterborne diseases and may cause an epidemic situation (Watson et al. 2007). Chemical aspects of water quality have less acute effects on human health, whereas long-term exposure causes chronic effects and, within time, may be curable. Possible encounters by chemical aspects of water quality may be affected by human health, where levels of certain chemicals are at excessive levels due to the high natural or anthropogenic activity (Hunter et al. 2010; Jaishankar et al. 2014). Eight liters of unpolluted water may turn too polluted by only one liter of contaminated water. One survey by UNESCO in India found that 115 million homes are without toilets and the domestic sewage contributed about 75% (UNESCO 2003). However, current government schemes and clean village mission

Fig. 9 Schematic presentation of different water sources (hand pump water, river water) contamination and bioaccumulation cycle in dairy cattle herd at Leh, Ladakh, India

increased the water sanitation through minimization of open defecation and increase in toilets number.

On the other hand, farmers do not pay much attention to water quality for crop irrigation and animal drinking, which may affect the health status of animals through affecting metabolic activity. Water contaminated with higher levels of sulfate significantly decreased the water intake of cattle. High levels of sulfate in dairy cattle affect their normal metabolic pathways (Grout et al. 2006). It has been found that TDS in drinking water controls the water intake behavior of domestic animals. If the TDS level is low, then it was proved that the water intake by animals decreases. Consequently, it also established that the decrease in water and feed intake of animals will lead to poor growth and production of animals (Bharti et al. 2017b; Kalia et al. 2017; Giri et al. 2017). The normal level of water containing minerals and metals in cattle body is represented in Table 9.

With the changing scenario of climate due to global warming, precipitation patterns also are changing. Weather data at Leh, Ladakh, India, are presented in Fig. 8; it is an indicator of global warming and climate changes. So for cultivation, farmers are abruptly using the groundwater instead of surface water. Over abstraction of groundwater has to change the hydrogeochemical and biological processes in the rock–soil system. Therefore, it is a great concern to check the groundwater quality for the physical and chemical properties (Hasanuzzaman et al. 2017). In Leh, drinking water facilities are not acceptable. Nearly half of the population in this region uses drinking water from public sources, and approximately eight percent of the households depend upon private sources. Natural water sources like running river, snowmelt water, and deep bore well groundwater also play a significant role as a source of drinking water in this region. The dependency of the local populace on the private source of water may increase by the unique vision of the government in this region. A few decades before, people of Leh were using mostly river water for drinking and other purposes. The surface water was as so clean and sweet as that of the adjoining springs. However, due to the increase in population and human settlements nearby water sources, people let the sewage drain into the river and thus polluted the available surface water. The most probable contaminate way in different water sources and dairy cattle herd at Leh, a high-altitude region of India, is presented in Fig. 9. Now, the people are compelled to use only the groundwater for drinking purposes in many places (Ground Water Information Brochure of Leh District 2011; Giri et al. 2017).

Conclusion

Most of the research work on groundwater and surface water showed that physicochemical, microbial, minerals, and heavy metals levels were higher than the prescribed limits as per the WHO, APHA, EPA, OSHA, ISI, ICMR guidelines throughout the world. Our study revealed that water quality is also going to deteriorate at high-altitude region of Leh, Ladakh, and other region worldwide due to global warming and increased anthropogenic activities. The main causal factors of water quality at high altitude bear upon the cattle health including excess mineral level, high bacterial load, presence of persistent organic pollutants, and high level of heavy metals. The poor availability and quality of drinking water would affect the dairy cattle health and production at both high-altitude and low-altitude regions. Henceforth, myth that water is neat and clean in the mountain region is now breaking. From this review, it can be concluded that due to global warming and an increase in tourists at high-altitude regions, water quality is getting deteriorate tremendously, which may affect the reproduction and milk production of dairy cattle. Therefore, it is the earliest time to prevent such alteration of water quality by inventing some ameliorative measurements so that cattle herd health and the productivity may be protected for quality dairy produce production. This will help in better health of dairy produce consumers and minimizing bioaccumulation of some toxic molecules in higher food chain.

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