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 parameters 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).
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.

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).

### Table 1
Review of different physicochemical and microbiological parameters in groundwater

| Sl. no. | Parameters          | Reported levels          | References     |
|---------|---------------------|--------------------------|----------------|
| 1.      | Temperature         | 15.51–17.24 °C, 29.40 °C | Giri (2018)    |
|         |                     |                          | Affum et al. (2015) |
| 2.      | pH                  | 7.70–7.97, 6.00, 5.94    | Giri (2018)    |
|         |                     |                          | Bariki 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, 5.00 NTU | Giri (2018)    |
| 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, 12.70 mg/L, 132.90 mg/L | Giri (2018)    |
|         |                     |                          | Bariki 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, < 0.50 mg/L | Giri (2018)    |
|         |                     |                          | Affum et al. (2015) |
| 12.     | Total hardness      | 184.26–256.50 mg/L       | Giri (2018)    |
|         |                     | 84.00 mg/L, 45.80 mg/L   | Bariki et al. (2015) |
|         |                     |                          | Affum et al. (2015) |
| 13.     | Sulfate             | 2.84–5.59 mg/L, 0.90 mg/L, 82.90 mg/L | Giri (2018)    |
|         |                     |                          | Bariki et al. (2015) |
|         |                     |                          | Affum et al. (2015) |
| 14.     | Phosphate           | 0.03–0.04 mg/L, 0.09 mg/L | Giri (2018)    |
|         |                     |                          | Affum et al. (2015) |
| 15.     | Carbonate           | 2.69–3.72 mg/L           | Giri (2018)    |
| 16.     | Bicarbonate         | 27.15–28.25 mg/L, 13.50 mg/L | Giri (2018)    |
|         |                     | 13.50 mg/L               | Affum et al. (2015) |
| 17.     | Nitrate             | 0.15–0.22 mg/L, Below detection limit, 0.60 mg/L | Giri (2018)    |
|         |                     |                          | Bariki et al. (2015) |
| 18.     | TOC                 | 1.92–2.94 mg/L           | Giri (2018)    |

### 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 33.51 °C          | Giri (2018)                       |
|         |                              | 7.07                             | 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 977.60 μS/cm | Giri (2018)                       |
|         |                              | 7.07                             | Kumar et al. (2015)               |
| 4.      | Total dissolved solids      | 103.46–155.41 mg/L 689.90 mg/L   | Giri (2018)                       |
|         |                              | 0.10–0.11 mg/L 0.01–0.02 mg/L    | Giri (2018)                       |
|         |                              | 0.12 mg/L                        | Khalik et al. (2013)              |
| 5.      | Salinity                    | 3.38–4.97 NTU 9.80 NTU 42.78 NTU | Giri (2018)                       |
|         |                              | 9.08 NTU                         | Sarma et al. (2017)               |
|         |                              | 42.78 NTU                        | Kumar et al. (2015)               |
| 6.      | Turbidity                   | 10.17–10.69 mg/L 7.27 mg/L       | Giri (2018)                       |
|         |                              | 7.27 mg/L                        | Kumar et al. (2015)               |
| 7.      | Dissolved oxygen            | 6.48–8.18 CFU/mL 236.00 CFU/mL   | Giri (2018)                       |
|         |                              | 20.44–23.48 mg/L 9.50 mg/L       | Giri (2018)                       |
|         |                              | 74.55 mg/L                       | Sarma et al. (2017)               |
| 8.      | E. coli                     | 319.25–333.43 mg/L 431.50 mg/L   | Giri (2018)                       |
|         |                              | 431.50 mg/L                      | Kumar et al. (2015)               |
| 9.      | Alkalinity                   | 2.28–3.92 mg/L 20.59 mg/L        | Giri (2018)                       |
|         |                              | 20.59 mg/L                       | Kumar et al. (2015)               |
| 10.     | Calcium hardness            | 0.27–0.35 mg/L 47.70 mg/L        | Giri (2018)                       |
|         |                              | 47.70 mg/L                       | Kumar et al. (2015)               |
|         |                              | 0.072 mg/L                       | Eze and Chigbu (2015)             |
| 11.     | Total hardness              | 2.55–2.99 mg/L 16.02 mg/L        | Giri (2018)                       |
|         |                              | 16.02 mg/L                       | Eze and Chigbu (2015)             |
| 12.     | Sulfate                     | 2.55–2.99 mg/L 0.27–0.35 mg/L    | Giri (2018)                       |
|         |                              | 0.27–0.35 mg/L 47.70 mg/L        | Kumar et al. (2015)               |
|         |                               | 2.55–2.99 mg/L 0.072 mg/L        | Eze and Chigbu (2015)             |
| 13.     | Phosphate                   | 2.55–2.99 mg/L 16.02 mg/L        | Giri (2018)                       |
|         |                              | 16.02 mg/L                       | Eze and Chigbu (2015)             |
|         |                               | 2.30 mg/L                        | Bourasi et al. (2016)             |
| 14.     | Carbonate                   | 0.04–0.12 mg/L 3.40 mg/L         | Giri (2018)                       |
|         |                              | 3.40 mg/L                        | Sarma et al. (2017)               |
|         |                               | 0.04–0.12 mg/L 3.40 mg/L         | Sarma et al. (2017)               |
|         |                               | 172.62–154.45 mg/L 150.67–187.27 mg/L | Kumar et al. (2015) |
| 15.     | Bicarbonate                 | 0.04–0.12 mg/L 3.40 mg/L         | Giri (2018)                       |
|         |                              | 3.40 mg/L                        | Sarma et al. (2017)               |
|         |                              | 515.30 mg/L                      | Kumar et al. (2015)               |
| 16.     | Nitrate                     | 0.04–0.12 mg/L 3.40 mg/L         | Giri (2018)                       |
|         |                              | 3.40 mg/L                        | Sarma et al. (2017)               |
|         |                              | 515.30 mg/L                      | Kumar et al. (2015)               |
| 17.     | TOC                         | 0.92–1.07 mg/L 117.85 mg/L       | Giri (2018)                       |
|         |                              | 117.85 mg/L                      | Kumar et al. (2015)               |
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

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

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

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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

Fig. 5 Level of EC, TDS, and COD level in different sources of water from high-altitude region of India
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 were 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).
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 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 ARC (1980) | 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 DMARC (1980) | 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 DMARC (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 DMARC (1980) | 4 mg kg⁻¹ DMARC (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) |
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 7 | Some important metalloenzymes in livestock (adopted from Underwood and Suttle 2001) |
|---------|-----------------------------------------------------------------------------------|
| Metal | Enzyme | Function |
|--------|--------|----------|
| Iron | Succinate dehydrogenase | Aerobic oxidation of carbohydrates |
| Copper | Catalase | Protection against $H_2O_2$ |
| Copper | Cytochrome oxidase | Terminal oxidase |
| Copper | Lysyl oxidase | Lysine oxidation |
| Copper | Ceruloplasmin | Iron utilization: copper transport |
| Copper | Superoxide dismutase | Dismutation of superoxide radical $O_2^-$ |
| Zinc | Carbonic anhydrase | CO$_2$ formation |
| Zinc | Alcohol dehydrogenase | Alcohol metabolism |
| Zinc | Cytochrome oxidase A | Protein digestion |
| Zinc | Alkaline phosphatase | Hydrolysis of phosphate esters |
| Zinc | Nuclear poly(A) polymerase | Cell replication |
| Zinc | Collagenase | Wound healing |
| Zinc | Manganese | Pyruvate metabolism |
| Zinc | Superoxide dismutase | Antioxidant by removing $O_2^-$ |
| Zinc | Glycyl aminotransferases | Proteoglycan synthesis |
| Zinc | Xanthine dehydrogenase | Purine metabolism |
| Zinc | Sulfite oxidase | Sulfite oxidation |
| Zinc | Aldehyde oxidase | Purine metabolism |
| Zinc | Glutathione peroxidase | Removal of $H_2O_2$ and hydroperoxidase |
| Selenium | 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 |
| Calcium | Old: bone ↓ | Serum | Irritability ↓ | Convulsion |
| Magnesium | Young: bone ↓ | Serum | Irritability ↑ | Convulsion |
| Magnesium | Old: bone ↓ | Serum | Irritability ↑ | Convulsion |
| Copper | Liver ↓ | Serum | Disulfide bonds ↓ | Wool crimp ↓ |
| Cobalt | Liver $B_{12}$ ↓ | Serum | MMA ↑ | Inappetence |
| Cobalt | Serum $B_{12}$ ↓ | $< 350$ pmol $l^{-1}$ | | |
| Iodine | $T_4$ ↓ | Thyroid colloid ↓ | BMR ↓ | Goiter |
| Iodine | $T_3$ ↓ | Thyroid I ↓ | Thyroid hypertrophy | |
| Selenium | GSH-Px in erythrocyte ↓ | Serum Se ↓ | Serum creatine kinase ↑ | Myopathy gangrene of ear/tail |
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 hazard in a dairy herd (Wegener 2012). Hence, the priority must be to provide access to 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

| Chemical compounds | Abbreviation of compounds | Threshold level (mg/l) | Highest desirable limit (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
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.
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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