Water Practice & Technology

IWA PUBLISHING

Water Practice & Technology Vol 18 No 6, 1500 doi: 10.2166/wpt.2023.095

Detailed evaluation of physicochemical properties and microbial activities of Hanna Lake and Spin Karez

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ABSTRACT

Access to clean drinking water is a major issue in many regions of the world, particularly in areas where groundwater is scarce. This study aims at determining the water quality of two lakes. Some parameters in this investigation were found to be above the WHO limit, while most were within the limit. For instance, the average value of electrical conductivity in Hanna Lake was 537.4 μS/cm, while it was 758.9 μS/cm in Spin Karez, which was above the WHO limits (>500 μS/cm). Turbidity in Hanna Lake was 4.17 nephelometric turbidity units (NTU), within the WHO limits (<5 NTU), while in Spin Karez, it was 9.5 NTU above the WHO limits, and dissolved oxygen concentration average values were 9.06 mg/l in Hanna Lake and 8.86 mg/l in Spin Karez, above the permitted limits provided by the WHO (6.5–8 mg/l). The study also found that both lakes had high concentrations of microbial colonies, with 65 CFU/100 ml in Hanna Lake and 56 CFU/100 ml in Spin Karez. Based on these findings, an efficient water treatment technique should be adopted to remove these highly concentrated parameters in both lakes for purified water and future water demands.

Key words: Hanna Lake, microbial activities, NEQS, physio-chemical parameters, Spin Karez, WHO

HIGHLIGHTS

- Detailed evaluation of all parameters.
- Clean drinking water.
- Microbial activities.
- Climate change.
- Lakes.

LIST OF ABBREVIATIONS

As	Arsenic
B	Boron
Ba	Barium
Ca	Calcium
Cd	Cadmium
CFU	Colony forming unit
Co	Cobalt
Cr	Chromium
Cu	Copper
DO	Dissolved oxygen
EC	Electrical conductivity
E-coli	*Escherichia coli*
Fe	Iron
GPS	Global Positioning System
ICP-MS	Inductivity coupled plasma mass spectroscopy
K	Potassium
Mg	Magnesium

Mg/L	Milligrams per litre
Mn	Manganese
Mo	Molybdenum
Na	Sodium
NEQS	National Environmental Quality standards
Ni	Nickel
NTU	Nephelometric turbidity unit
Pb	Lead
PCRWR	Pakistan Council of Research and Water Resources
pH	Power of hydrogen
PHED	Public Health Engineering Department
Se	Selenium
TC	Total coliforms
TDS	Total dissolved solids
TH	Total hardness
WHO	World Health Organization
Zn	Zinc
μS/cm	micro-Siemens per centimeter

1. INTRODUCTION

A key element that is essential to supporting life on our planet is water. It is not only necessary for the continued existence of every living being but also it can to create a conducive habitat for life to flourish (Westall & Brack 2018). As the population in the cities and the municipal areas are increasing with each passing day, so is the need to attain fresh potable water to accommodate the public (Liyanage & Yamada 2017). Since water is one of the basic amenities of life, its supply is even more adamant. The precipitation in the Quetta region is very low, and the nature of the atmosphere is mostly dry throughout the year (Khan *et al.* 2013). The water table of Quetta is about 2,000 feet below the ground level, and according to one study, it is decreasing even more by about 4.5 feet every year. Due to the scarcity of fresh water, the ratio of waterborne diseases is increasing with each passing day (Durrani *et al.* 2018).

The water from Hanna Lake is not suitable for drinking purposes because the concentration of coliforms is high (Aziz *et al.* 2013). The microbial parameters including total coliform, total fecal coliforms, and total fecal streptococci in Hanna Lake were higher than the permissible limits of the WHO in 2016 (Aamir *et al.* 2017). Among the most well-known diseases associated with consuming feces-contaminated food and water are cholera diarrhea and typhoid (Osiemo *et al.* 2019). People get most of the diseases from recreational places from microbial organisms, and about 80% of people in the United States get Giardia disease by swallowing the water from these places, and these organisms in water create the symptoms of cramps and nausea (Gyamfi *et al.* 2012; Yoder *et al.* 2012), as Hanna and Spin Karez are also used for recreational purposes so there is a high chance of getting diseases such as skin infections, diarrhea, cholera, and many more. Spin Karez is about 8 miles east of Quetta city and is currently used for watering the trees and plants in the Quetta Cantonment area. The stagnant water in both lakes is the major cause of the increasing waterborne diseases among the public. The sources of water contamination are agricultural and industrial pollutants, and soil conditions, and these are further classified as organic and inorganic microorganisms meaning microbial and physio-chemical parameters in higher concentrations cause water undrinkable (Panhwar *et al.* 2022). Heavy metals concentration increases in lakes due to anthropogenic activities and the consumption of heavy metals become a threat to the lake's living organisms and to people who eat these living organisms (Sibal & Espino 2018). In this research, the results of each sample will be compared with the guidelines and standards set by the WHO and National Environmental Quality Standards (NEQS). The entry of the chemicals into the fresh water contaminates it, and water becomes unsuitable for drinking purposes and poses a threat to human health. The lack of fresh water supply has greatly increased the number of patients in the city. The underground water is mostly contaminated, according to a study in 2020 (Rasheed *et al.* 2021). Seventy-six water samples were collected from different sources in Baluchistan, and of those 76 samples, 57% were polluted with total coliforms, *E. coli*, fluoride, chloride, TDS, and hardness. The public is not aware of the contaminants in the water, due to which people are exposed to waterborne diseases, and many young children are affected by this which also increases the risk of inappropriate mental growth of the kids (Ahmed *et al.* 2020). Physio-chemical parameters including temperature and turbidity are also linked to the lake ecosystem. This will be a comprehensive study of the water quality of both the reservoirs and the physio-chemical and microbial

parameters that are affecting it. To measure multiple elements in water samples, the Varian 820 ICP-MS (inductively coupled plasma mass spectroscopy) coupled with a Varian SPS 3 auto-sampler was employed (Louie *et al.* 2012). Direct nebulization ICP-MS was used to measure the total chromium and selenium concentrations in the test samples (Bednar *et al.* 2009). ICP-MS can be used to trace a wide range of elements, including both metals and nonmetals. In the present study, the Perkin Elmer NexION 350Q model of ICP-MS was used to measure the concentrations of various elements in water samples in a very sensitive and precise manner. The water sample was inoculated onto a growth medium that had already been sterilized and hardened, and the colonies that emerged on its surface were counted (Yasin *et al.* 2015). To evaluate bacterial colonies in water samples, the current study utilized bacterial culture grown on Recipe Rapid E-coli 2 agar.

The average annual precipitation and average annual snowfall of Quetta are about 260 and 560 mm, respectively, and the highest annual precipitation was 928.9 mm in 1982 (Durrani *et al.* 2021). The elevation of the city is about 1,676 m from the sea level. The shape of the city is like a bowl. Both the lakes are surrounded by mountains. During the winter season, snow melts in the mountains, and the water is stored in the lakes. Most of the water volume is stored in the lakes in January and February because of greater precipitation, i.e., 60 and 50 mm, respectively (Durrani *et al.* 2021). Hanna Lake is located about 13 km from Quetta city and was built to save water in the British era. The latter is the main spot for recreational activities for families and get-togethers. Quetta City is groundwater dependent, and the annual precipitation is inadequate. With the continuous increment in the population and the depletion of groundwater, the city is facing great challenges (Dawood *et al.* 2021). Soon the city will no longer rely on groundwater because the discharge is more than recharge and the volume of water will be decreasing with time (Kakar *et al.* 2020).

The aim of this study is to examine the physicochemical and microbial properties of Hanna Lake and Spin Karez to determine their suitability as sources of potable water. Furthermore, the study aims to create awareness among the local populace and stakeholders regarding the significance of clean water and the hazards associated with consuming contaminated water. Previously, no significant research has been conducted on the Spin Karez. This study represents the first comprehensive investigation of this body of water. While there have been some earlier attempts to examine the physio-chemical and microbial parameters of Hanna Lake, this current research represents a more detailed study that covers both the Spin Karez and the Hanna Lake. The study includes 25 physio-chemical parameters and microbial colonies for both lakes, which have not been investigated before.

2. METHODOLOGY

2.1. Study area

Quetta is the largest city and capital of Baluchistan Province. The city is located at 30.1798° N, 66.9750° E. The sources of drinking water here are groundwater as well as surface water. Surface water is contaminated with coliforms, pesticides, and toxic metals (Leghari *et al.* 2011). The city is currently experiencing groundwater depletion and a daily decline in the water table level; as a result, the tube wells that were not properly planned are also drying up (Khan *et al.* 2013).

The study areas of Hanna Lake and Spin Karez Lake, which are 18 and 23 km from Quetta City, are depicted in Figure 1. The two lakes in Quetta are popular with tourists and are used for recreation. The area of Spin Karez Lake is approximately 60.8 hectares (150 acres), while the area of Hanna Lake is approximately 41.43 hectares (102 acres). Mountain ranges surround both lakes. The lake water comes from precipitation and melting snow. Water can be stored for up to 220 million gallons in Hanna Lake.

2.2. Sample collection and preservation

Taking into consideration sample collection protocols, the samples were collected at random from both lakes. Random sampling ensures that the results we get from the sample are comparable to those from the entire study area. Boats were used to collect the majority of the samples from Hanna Lake. The coordinates of various sample collection locations were recorded with the help of the GPS meter. In sampling bottles that had been rinsed and properly labeled, ten surface samples were taken at random from each lake, and the location is shown in Figure 2(a) and 2(b). Temperature, pH, turbidity, and electrical conductivity (EC) were the onsite parameters measured. The fresh samples were transported to the research laboratory for physical, chemical, and

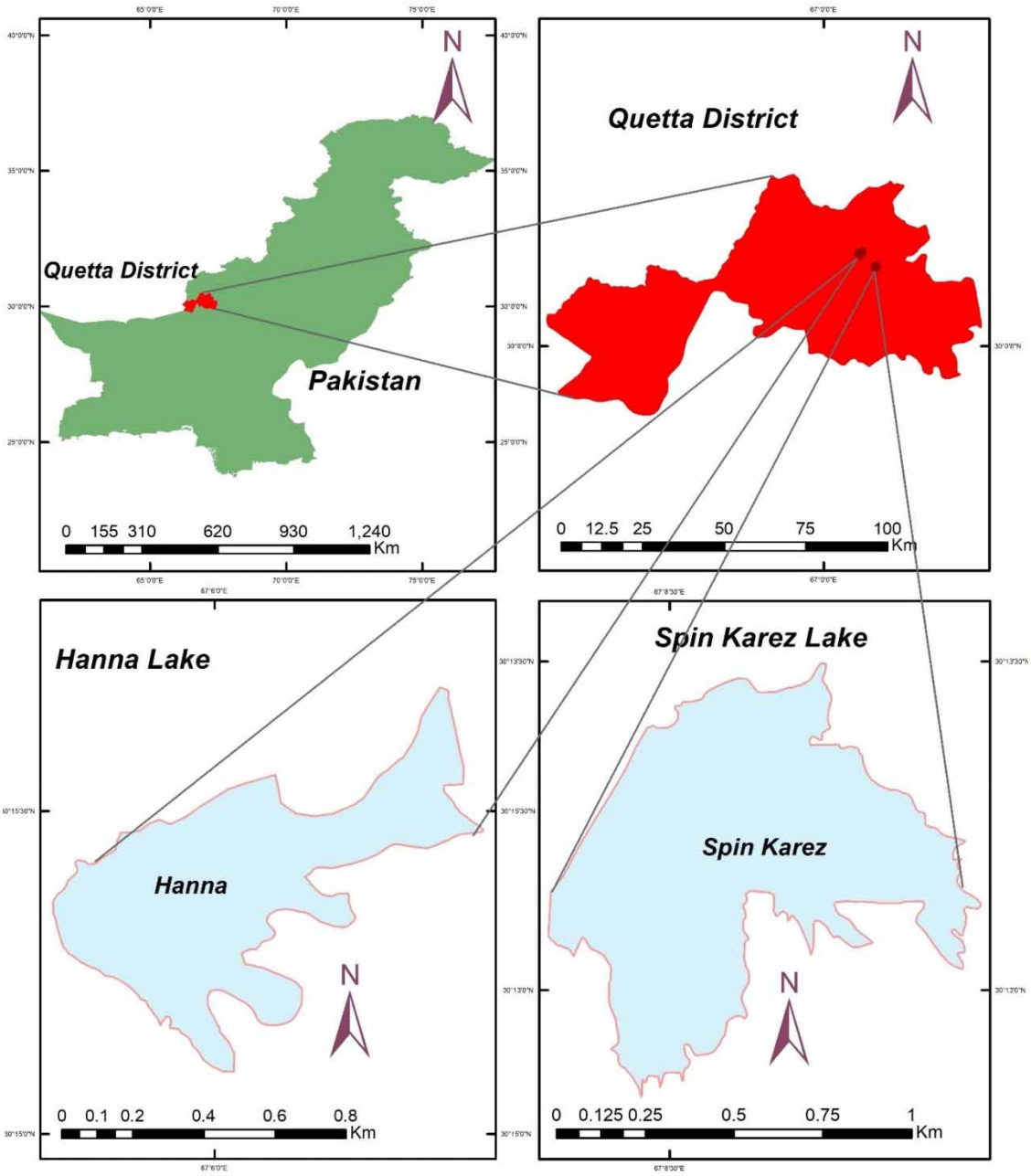

Figure 1 | Location of study area.

microbial analyses by US Environmental Protection Agency (US-EPA) (Clasen & Boisson 2006) sample collection protocols to discover additional parameters in the water. Microbial analysis was carried out on the same day that the samples were taken.

2.3. Sample analysis

Turbidity (nephelometric turbidity unit (NTU)), pH, dissolved oxygen (DO) (mg/l), and total hardness (mg/l) were measured with a turbidity meter, pH meter, DO meter, and total hardness meter, and the other chemical parameters like Mg (mg/l), Na (mg/l), K (mg/l), B (mg/l), Ba (mg/l), Se (mg/l), and Ca (mg/l), in addition with heavy metals including Pb (mg/l), Cd (mg/l), Ni (mg/l), Fe (mg/l), Zn (mg/l), Cr (mg/l), Co (mg/l), Cu (mg/l), As (mg/l), Mo (mg/l), and Mn (mg/l), were measured using the ICP-MS model (NexION 350Q, Perkin Elmer) (Kéri *et al.* 2018), a sensitive instrument having detection limit particles per trillion for many elements measurement.

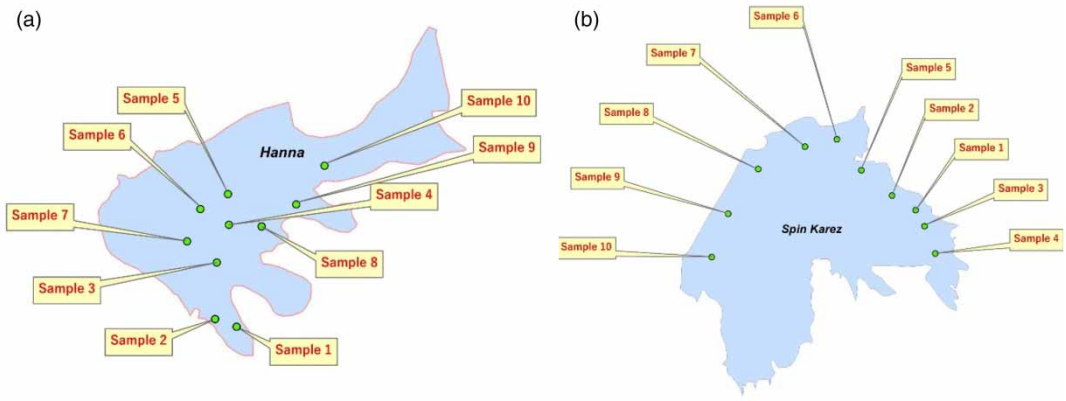

Figure 2 | (a) Sample collection points in Hanna Lake and (b) sample collection points in Spin Karez.

The bacterial colonies were observed on Recipe Rapid E-coli 2 agar (Gelose). Medium was prepared and then sterilized in an autoclave for 15 min at 121 °C, and then cooled in Petri dishes until it forms a soft gel, which supports a filter paper contaminated with microbes, and these Petri dishes were kept in an incubator for 24 h before examining bacterial colonies.

3. RESULTS AND DISCUSSION

Water pollution is a result of the activities caused by humans intentionally or unintentionally. Physical pollution is caused by the heat of the waste in water, mining sites, construction sites, eroded lake banks, and many other factors. Chemical pollution is caused due to the waste carried from factories, farms, and cities, while biological pollution is caused by animal wastes, human wastes, and the decay of organic matter in water. These kinds of pollution can harm human health, and that is why it is necessary to find the concentration of these pollutants in drinking water. This study assessed the water quality of Hanna and Spin Karez lakes, and water parameter concentration of Hanna Lake was different from that of Spin Karez.

3.1. Physical parameters in water samples

3.1.1. EC

The rate of water solubility is determined by EC and the conductivity of water tends to increase when it is heated. The amount of dissolved salts also affects the conductivity of water, and the higher the concentration of dissolved salts, the higher will be the conductivity. The presence of phosphate, chloride, and nitrate would increase the EC of the lake water because of a sewage system failure (Bhateria & Jain 2016). The concentration of dissolved ions also affects the EC of water. The EC of the samples collected from Hanna Lake was observed to be 537.4 μS/cm on average (Table 1), and 7 out of 10 samples have EC more than 500 μS/cm, which is more than permissible limits and the samples from Spin Karez had a conductivity of about 758.9 μS/cm on average (Table 1), and all the samples have EC more than 500 μS/cm, which is more than permissible values. These values are not under the guidelines established by the WHO (Meride & Ayenew 2016) and NEQS (Daud *et al.* 2017).

3.1.2. Turbidity and color

The suspended particles in the lake water, such as plant debris, silts, organic and inorganic matters, and clay, causes cloudiness or muddy nature. The turbidity of Hanna Lake in all samples was within the WHO limits with a mean value of 4.17 NTU (Table 1), while the turbidity in Spin Karez in all samples was above the WHO limits with a mean value of 9.5 NTU (Table 1). Because of the higher turbidity range in samples of Okara, the color of the water changed to light yellow or brownish (Sunday *et al.* 2014). The samples collected from Hanna Lake were colorless, while the samples from Spin Karez were slightly cloudy.

3.1.3. Temperature

The solubility of water and the rate of organic activity are heavily influenced by temperature (Adbarzi *et al.* 2020). The temperature of the samples collected in the winter season from Hanna Lake was 14.6 °C on average, and the

Table 1 | Physical parameters in Hanna Lake and Spin Karez Lake

	Sample	EC (μS/cm)	Turbidity (NTU)	Temperature (°C)	TDS (mg/l)
Hanna Lake	1	584	4.22	15.3	224
	2	552	4.39	15.6	277
	3	463	4.35	14.2	213
	4	490	3.97	14.2	275
	5	522	4.46	14.6	324
	6	559	3.68	14.3	297
	7	624	4.37	14.1	286
	8	588	4.58	14.3	308
	9	513	3.73	14.5	267
	10	479	3.95	14.9	282
	Mean	**537.4**	**4.17**	**14.6**	**275.3**
Spin Karez Lake	1	734	9.32	14.2	284
	2	807	10.5	15.2	301
	3	702	9.51	16.3	356
	4	718	9.75	14.3	246
	5	715	10.04	14.6	298
	6	795	8.84	14.9	314
	7	821	9.53	14.1	303
	8	763	9.31	14.8	278
	9	788	8.58	14.3	259
	10	746	9.62	15	277
	Mean	**758.9**	**9.5**	**14.77**	**291.6**
	WHO limits	**500**	**< 5 NTU**	**12–25°C**	**< 1,000**

samples from Spin Karez were about 14.77 °C (Table 1) within permissible limits. Cold water is mostly preferred because warm water helps the growth of microorganisms.

3.1.4. TDS

In both lakes, TDS values were within the WHO standards having a mean value of 275.3 mg/l in Hanna Lake and 291.6 mg/l in Spin Karez (Table 1).

3.2. Chemical parameters in water samples

3.2.1. pH

The pH of the water does not directly affect human health, but it is closely linked to other aspects of water quality that are potentially hazardous to human health (World Health Organization 2010). The pH of the samples collected from both lakes was between 7.39 and 7.48 (Figure 3(a) and 3(b)), the pH range is under the guidelines established by the WHO (Meride & Ayenew 2016) and NEQS (Daud *et al.* 2017), which is 6.5–8.5.

3.2.2. DO

For aquatic organisms, the amount of DO is very important. Numerous chemical reactions in water and its products are also influenced by DO. Algae growth is aided by the high DO content of the water, which in turn raises the biological oxygen demand (Thompson *et al.* 2022). The Hanna Lake and Spin Karez DO averages were approximately 9.06 mg/l and 8.86 mg/l, respectively, which is more than the acceptable limit of 6.5–8 mg/l.

3.2.3. Ca

Ca causes hardness when present in water. The guidelines provided by the WHO are as follows: below 60 mg/l is soft, 60–120 mg/l is moderately hard, 120–180 mg/l is hard, and above 180 mg/l is very hard (Kozisek 2020). The water obtained from Hanna Lake had Ca of about 31.5 mg/l, and water samples taken from Spin Karez had about 43.5 mg/l of Ca within permissible levels.

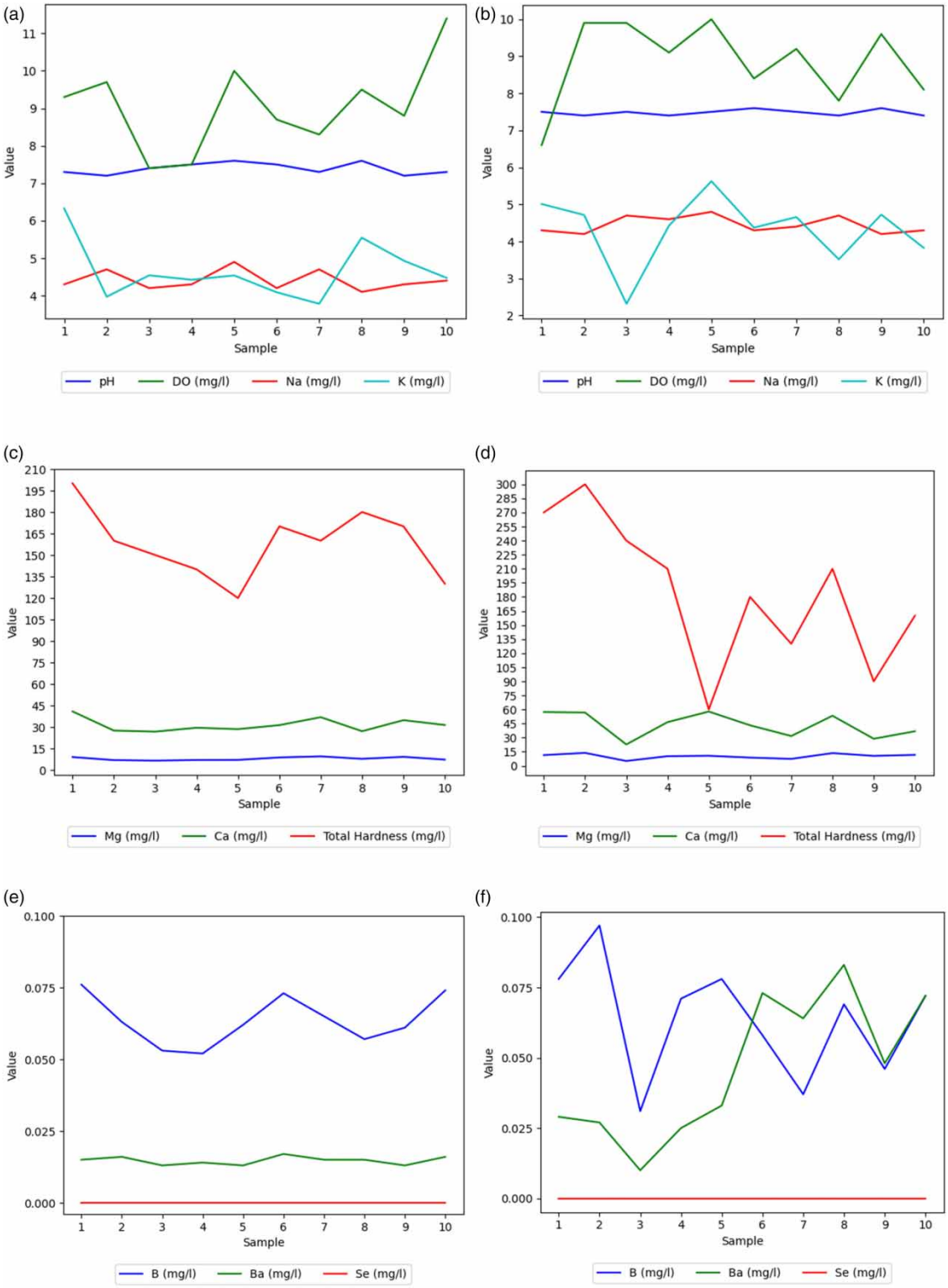

Figure 3 | (a, c, e) Chemical parameters in Hanna Lake. (b, d, f) Chemical parameters in Spin Karez.

3.2.4. Mg

Mg generally has a very slow reactivity, but the amount of DO affects it. The average Mg content found in the samples from Hanna Lake was about 7.9 mg/l, while the samples from Spin Karez had an Mg content of 10.3 mg/l, which lies inside the guidelines provided by the WHO (<50 mg/l).

3.2.5. Total hardness

The total amount of dissolved Ca^{+2} and Mg^{+2} in water is referred to as the total hardness. On average, the total samples collected from Hanna Lake lie around 158 mg/l, and the samples collected from Spin Karez were about 185 mg/l, which is well under the limit of <500 mg/l.

3.2.6. Sodium

The average range of Na concentration in the samples was determined to be approximately 4–5 mg/l, and the concentration of Na in both lakes was within the permissible standard range. Noting that excessive amounts of Na might have negative impacts on human health, including hypertension and cardiovascular illnesses, it is important to analyze the Na content in water samples.

3.2.7. Potassium

Potassium is a necessary mineral that is required for many body processes such as controlling heartbeat, preserving fluid balance, and supporting neuron and muscle functions. Although potassium is important, the body only needs a little quantity of it to function properly, and too much may be hazardous (Meride & Ayenew 2016). Average potassium values in Hanna Lake and Spin Karez are 4.6 and 4.3 mg/l, respectively.

3.2.8. Boron

Boron (B) enters the surface water by dumping wastewater or recharging through an underground water source. The average concentration of B observed from samples collected from Hanna Lake was 0.0636 mg/l and the average concentration of B observed from samples from Spin Karez was about 0.0637 mg/l on average. These are well under the guidelines established by WHO and NEQS.

3.2.9. Barium

This element enters drinking water through the recharge of underground water and industrial waste. The WHO specifies 1.3 mg/l as the acceptable limit. Ba observed on the samples collected from Hanna Lake is about 0.0147 mg/l and that on the samples collected from Spin Karez is about 0.0464 mg/l, which is significantly under the suggested maximum.

3.2.10. Se

It is a rare element that is used as a trace component in packaged food that is produced in factories. The minimum amount of Se allowed by the WHO is 0.01 mg/l. The Hanna Lake and spin Karez samples have Se of 0 mg/l.

3.2.11. Heavy metals

Heavy metals in water are higher as a result of anthropogenic activities such as mining, fertilizers, and the release of industrial wastes into the water (Dranga *et al.* 2017). Heavy metal concentrations are higher in surface water samples from Quetta city's dams, lakes, and ponds according to a study by Leghari *et al.* (2011), while the current study has found that heavy metals values were within the range set by the WHO.

3.2.12. Pb, Cd, Cr

If they get into the water, Pb, Cd, and Cr are harmful substances that can harm the kidneys and brain as well as cause serious health problems (Eldaw *et al.* 2020). According to the WHO guidelines, Cr metal in a specified range is required in drinking water to maintain nutrition and maintain normal human glucose metabolism (Mughal *et al.* 2022).

Heavy metals typically have lower concentrations in water than in the bed of lakes or sediments (Hou *et al.* 2013; Gülcü-Gür & Tekin-Özan 2015). Metals like Pb, Zn, Ni, Fe, and Cu were found in higher concentrations along the lake's shores and lower concentrations in the lake's center. This could be due to bioaccumulation (Sheikh *et al.* 2014).

3.2.13. Ni, Zn

Ni is carcinogenic if intake is more than the allowable limit, while Zn has not much effect on health, and the concentration of Ni and Zn may increase from the stainless-steel fittings and the pipes (Meride & Ayenew 2016). Iron, a naturally occurring metal found in the earth's crust (Eldaw *et al.* 2020), aids in the delivery of oxygen to our blood.

3.2.14. Co, Cu, Ar

To increase the production of red blood cells, a certain amount of Co is required; however, a concentration that is higher than the allowed limit is harmful to human health. (Zakir & Ihsanullah 2009). Cu concentrations in water rise as a result of pesticide use and industrial waste (Gyamfi *et al.* 2012). Ar can be found in the environment in both organic and inorganic forms, and consuming more than the allowed amount can cause lung and bladder cancer (Pál *et al.* 2022).

3.2.15. Mo, Mn

Molybdenum comes from mining areas and Cu and tungsten byproducts. Weathering can occasionally raise Mn levels in water in mountainous areas (Eldaw *et al.* 2020).

The results of heavy metals concentration of all the samples that were taken from Hanna and Spin Karez met the WHO and NEQS guidelines, as shown in Table 2.

Table 2 | Chemical parameters (heavy metals) in Hanna Lake and Spin Karez Lake

	Sample	Pb (mg/l)	Cd (mg/l)	Ni (mg/l)	Fe (mg/l)	Zn (mg/l)	Cr (mg/l)	Co (mg/l)	Cu (mg/l)	As (mg/l)	Mo (mg/l)	Mn (mg/l)
Hanna Lake	1	0.001	0	0	0.043	0.002	0	0	0.004	0	0.002	0
	2	0	0	−0.001	0.061	0.003	0	0	0.003	0	0.001	0.006
	3	0.002	0	−0.001	0.039	0.003	−0.001	0	0.003	0	0.001	0.001
	4	0	0	−0.001	0.049	0.003	0	0	0.003	0	0.001	0.001
	5	0	0	−0.001	0.027	0.002	0	0	0.003	0	0.001	0.001
	6	0.001	0	0	0.088	0.003	0	0	0.006	0	0.001	0.003
	7	0	0	0	0.053	0.003	0.002	0	0.004	0	0.003	0.001
	8	0.001	0	−0.001	0.021	0.002	0.001	0	0.003	0	0.001	0.003
	9	0.003	0	0	0.057	0.005	0	0	0.003	0	0.001	0.002
	10	0	0	0	0.059	0.002	0.001	0	0.004	0	0.002	0.001
Spin Karez Lake	1	0	0	0	0.024	0.003	−0.001	0	0.003	0	0.002	0.001
	2	0	0	0	0.048	0.003	0	0	0.003	0	0.002	0
	3	0	0	0	0.035	0.002	−0.001	0	0.001	0	0.001	0
	4	0	0	0	0.028	0.003	0	0	0.002	0.001	0.001	0.001
	5	0	0	0	0.019	0.004	0	0	0.003	0.001	0.002	0.001
	6	0	0	0	0.042	0.002	0	0	0.001	0	0.002	0
	7	0	0	0	0.034	0.002	0	0	0.003	0	0.001	0
	8	0	0	0	0.047	0.003	−0.001	0	0.003	0.001	0.002	0
	9	0	0	0	0.029	0.004	0	0	0.002	0.001	0.002	0.001
	10	0	0	0	0.034	0.004	−0.001	0	0.003	0	0.001	0.001
	WHO limits	**0.05**	**0.01**	**0.02**	**0.3**	**3**	**0.05**	**0.05**	**2**	**0.01**	**0.01**	**0.05**

Negative values show the concentration is the below detection limit, and the minimum detection limit for ICP-MS NexION 350Q, Perkin Elmer is 0.001 mg/L or 1 ppb.

3.3. Microbial activities in water samples

The concentration of microbial bodies in water is increased when deposits of feces and domestic waste are thrown away illegally (Panhwar *et al.* 2021). The extremely high concentration of bacteria in Hanna Lake would have devastating effects on the health of humans, plants, and animals (Luqman *et al.* 2022). According to the WHO and NEQS guidelines for bacteria, there should not be any bacterial colony detected within 100 ml of the water sample (Daud *et al.* 2017). According to the findings, a 100 ml sample from Hanna Lake contained approximately a total coliform of 65 CFU/100 ml of microbial colonies demonstrated in (Figure 4(a)), whereas in the sample from Spin Karez, the total coliform colonies were 56 CFU/100 ml as shown in (Figure 4(b)).

4. CONCLUSION

The aim of the study is to shed insight into Hanna Lake and Spin Karez's water quality. The results show that several parameters, including DO, EC, Ca, and turbidity, have concentration levels that are higher than the

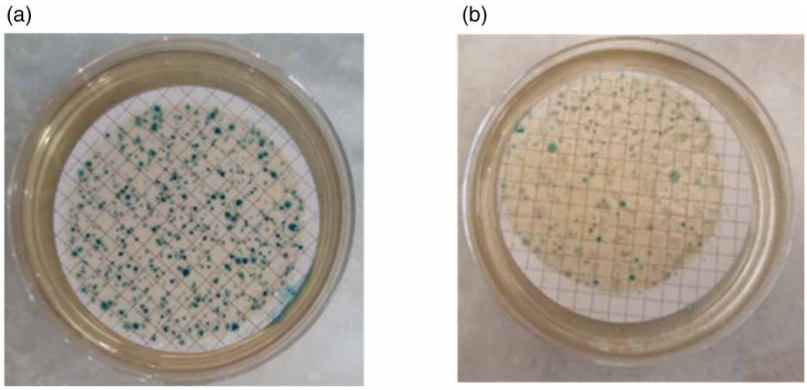

Figure 4 | Total coliform colonies observed in (a) Hanna Lake and (b) Spin Karez.

WHO and NEQ standards, rendering the water unfit for human consumption. The poor condition of Quetta's water distribution system exacerbates the depletion of water resources. The results of the study hold significance for both public health and environmental science. The effect of climate change and mountain erosion on the water quality in the area has not been thoroughly examined. Future studies could examine the link between these elements and the criteria governing Hanna Lake's and Spin Karez's water quality. In addition, it is proposed that quick action is required to solve Quetta's problems with water delivery and quality.

AUTHOR CONTRIBUTIONS

The draft was written by ZA and MB. The data were gathered by MBA, MSA, MB, and ZA. The data were interpreted by ZA and SP. SSH used the ICP-MS technique, SP, ZA, and MB cultured the bacteria, and SP and HS supervised this research work.

ACKNOWLEDGEMENTS

The staff of the Public Engineering Lab and Surveying Lab at NUST Baluchistan Campus, as well as the U.S.-Pakistan Center for Advanced Studies in Water (USPCAS-W), MUET Jamshoro, for assisting us with heavy metals detection, are sincerely appreciated by the authors.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

REFERENCES

Aamir, A., Khan, M. A., Shaukat, S. S., Khan, O. I. & Salman, Z. 2017 Appraisal of Hanna Lake water quality assessment, Balochistan, Pakistan. *Desalination and Water Treatment* **76**, 174–183.

Adbarzi, S. S. M., Tripathi, P., Choudhary, K. K., Kant, R. & Tripathi, V. 2020 Assessment of physico-chemical properties of pre and post-treated wastewater of Prayagraj region and its effect on nearby Ganges river. *Vegetos* **33**(2), 258–264.

Ahmed, J., Wong, L. P., Chua, Y. P. & Channa, N. 2020 Drinking water quality mapping using water quality index and geospatial analysis in primary schools of Pakistan. *Water* **12**(12), 3382.

Aziz, M., Sh, Z. & Jadoon, S. 2013 Pre and post Dryness evaluation of Hanna Lake water quality of Quetta. *Asian Journal of Research in Chemistry* **6**(4), 345–353.

Bednar, A. J., Kirgan, R. A. & Jones, W. T. 2009 Comparison of standard and reaction cell inductively coupled plasma mass spectrometry in the determination of chromium and selenium species by HPLC–ICP–MS. *Analytica Chimica Acta* **632**(1), 27–34.

Bhateria, R. & Jain, D. 2016 Water quality assessment of lake water: a review. *Sustainable Water Resources Management* **2**, 161–173.

Clasen, T. & Boisson, S. 2006 Household-based ceramic water filters for the treatment of drinking water in disaster response: an Q5 assessment of a pilot programme in the Dominican Republic. *Water Practice and Technology* **1**(2), 1–9.

Daud, M. K., Nafees, M., Ali, S., Rizwan, M., Bajwa, R. A., Shakoor, M. B., Arshad, M. U., Chatha, S. S. A., Deeba, F., Murad, W., Malook, I. & Zhu, S. J. 2017 Drinking water quality status and contamination in Pakistan. *BioMed Research International* **2017**, 1–18.

Dawood, F., Akhtar, M. M. & Ehsan, M. 2021 Evaluating urbanization impact on stressed aquifer of Quetta Valley, Pakistan. *Desalination and Water Treatment* **222**, 103–113.

Dranga, S. A., Hayles, S. & Gajewski, K. 2017 Synthesis of limnological data from lakes and ponds across Arctic and Boreal Canada. *Arctic Science* **4**(2), 167–185.

Durrani, I. H., Adnan, S., Ahmad, M., Khair, S. M. & Kakar, E. 2018 Observed long-term climatic variability and its impacts on the ground water level of Quetta alluvial. *Iranian Journal of Science and Technology, Transactions A: Science* **42**, 589–600.

Durrani, I. H., Adnan, S. & Aftab, S. M. 2021 Daily climate extremes of temperature and precipitation over Quetta Valley, Pakistan during 1961–2019. *International Journal of Environment* **10**(1), 20–48.

Eldaw, E., Huang, T., Elubid, B., Khalifa Mahamed, A. & Mahama, Y. 2020 A novel approach for indexing heavy metals pollution to assess groundwater quality for drinking purposes. *International Journal of Environmental Research and Public Health* **17**(4), 1245.

Gülcü-Gür, B. & Tekin-Özan, S. 2015 The investigation of heavy metal levels in water and sediment from Işikli Lake (Turkey) in relation to seasons and physico-chemical parameters. *Journal of Aquaculture Engineering and Fisheries Research* **3**(2), 87–96.

Gyamfi, E. T., Ackah, M., Anim, A. K., Hanson, J. K., Kpattah, L., Enti-Brown, S., Adjei-Kyereme, Y. & Nyarko, E. S. 2012 Chemical analysis of potable water samples from selected suburbs of Accra, Ghana. *Proceedings of the International Academy of Ecology and Environmental Sciences* **2**(2), 118.

Hou, D., He, J., Lü, C., Ren, L., Fan, Q., Wang, J. & Xie, Z. 2013 Distribution characteristics and potential ecological risk assessment of heavy metals (Cu, Pb, Zn, Cd) in water and sediments from Lake Dalinouer, China. *Ecotoxicology and Environmental Safety* **93**, 135–144.

Kakar, N., Kakar, D. M. & Barrech, S. 2020 Land subsidence caused by groundwater exploitation in Quetta and surrounding region, Pakistan. *Proceedings of the International Association of Hydrological Sciences* **382**, 595–607.

Kéri, A., Kálomista, I., Ungor, D., Bélteki, Á., Csapó, E., Dékány, I., Prohaska, T. & Galbács, G. 2018 Determination of the structure and composition of Au-Ag bimetallic spherical nanoparticles using single particle ICP-MS measurements performed with Q6 normal and high temporal resolution. *Talanta* **179**, 193–199.

Khan, A. S., Khan, S. D. & Kakar, D. M. 2013 Land subsidence and declining water resources in Quetta Valley, Pakistan. *Environmental Earth Sciences* **70**, 2719–2727.

Kozisek, F. 2020 Regulations for calcium, magnesium or hardness in drinking water in the European Union member states. *Regulatory Toxicology and Pharmacology* **112**, 104589.

Leghari, S. U. K., Zadi, M. A., Sarangzai, A. M. & Shaheen, G. 2011 Physico-chemical composition of drinking water in and around the Quetta City. *Fuuast Journal of Biology* **1**(1), 63.

Liyanage, C. P. & Yamada, K. 2017 Impact of population growth on the water quality of natural water bodies. *Sustainability* **9**(8), 1405.

Louie, H., Wong, C., Huang, Y. J. & Fredrickson, S. 2012 A study of techniques for the preservation of mercury and other trace elements in water for analysis by inductively coupled plasma mass spectrometry (ICP-MS). *Analytical Methods* **4**(2), 522–529.

Luqman, M., Awan, M. U. F., Muhammad, S., Daud, S., Yousafzai, A. & Arooj, F. 2022 Microbial pollution in inland recreational freshwaters of Quetta, Pakistan: an initial report. *Journal of Water and Health* **20**(3), 575–588.

Meride, Y. & Ayenew, B. 2016 Drinking water quality assessment and its effects on residents health in Wondo genet campus, Ethiopia. *Environmental Systems Research* **5**(1), 1–7.

Mughal, A., Sultan, K., Ashraf, K., Hassan, A., Zaman, Q. U., Haider, F. U. & Shahzad, B. 2022 Risk analysis of heavy metals and groundwater quality indices in residential areas: a case study in the Rajanpur District, Pakistan. *Water* **14**(21), 3551.

Osiemo, M. M., Ogendi, G. M. & M'Erimba, C. 2019 Microbial quality of drinking water and prevalence of water-related diseases in Marigat Urban Centre, Kenya. *Environmental Health Insights* **13**, 1178630219836988.

Pál, L., Jenei, T., McKee, M., Kovács, N., Vargha, M., Bufa-Dőrr, Z., Muhollari, T., Bujdosó, M. O., Sándor, J. & Szűcs, S. 2022 Health and economic gain attributable to the introduction of the World Health Organization's drinking water standard on arsenic level in Hungary: a nationwide retrospective study on cancer occurrence and ischemic heart disease mortality. *Science of the Total Environment* **851**, 158305.

Panhwar, S., Aftab, A., Keerio, H. A., Sarmadivaleh, M. & Tamer, U. 2021 A novel approach for real-time enumeration of Escherichia coli ATCC 47076 in water through high multi-functional engineered nano-dispersible electrode. *Journal of The Electrochemical Society* **168**(3), 037514.

Panhwar, M. Y., Panhwar, S., Keerio, H. A., Khokhar, N. H., Shah, S. A. & Pathan, N. 2022 Water quality analysis of old and new Phuleli Canal for irrigation purpose in the vicinity of Hyderabad, Pakistan. *Water Practice & Technology* **17**(2), 529–536.

Rasheed, H., Altaf, F., Anwaar, K. & Ashraf, M. 2021 *Drinking Water Quality in Pakistan: Current Status and Challenges*. Pakistan Council of Research in Water Resources (PCRWR), Islamabad, pp. 141.

Sunday, J. J., Spencer, N. C., Kingsley, O., Edet, A. O. & Amaka, D. D. 2014 Physico-chemical and microbiological properties of water samples used for domestic purposes in Okada town, Edo state, Nigeria. *Int. J. Curr. Microbiol. App. Sci* **3**(6), 886–894.

Sheikh, J. A., Jeelani, G., Gavali, R. S. & Shah, R. A. 2014 Weathering and anthropogenic influences on the water and sediment chemistry of Wular Lake, Kashmir Himalaya. *Environmental Earth Sciences* **71**, 2837–2846.

Sibal, L. N. & Espino, M. P. B. 2018 Heavy metals in lake water: a review on occurrence and analytical determination. *International Journal of Environmental Analytical Chemistry* **98**(6), 536–554.

Thompson, D. A., Cwiertny, D. M., Davis, H. A., Grant, A., Land, D., Landsteiner, S. J. & Santillan, D. A. 2022 Sodium concentrations in municipal drinking water are associated with an increased risk of preeclampsia. *Environmental Advances* **9**, 100306.

Westall, F. & Brack, A. 2018 The importance of water for life. *Space Science Reviews* **214**, 1–23.

World Health Organization. 2010 *Hardness in Drinking-Water: Background Document for Development of WHO Guidelines for Drinking-Water Quality (No. WHO/HSE/WSH/10.01/10)*. Geneva, World Health Organization.

Yasin, M., Ketema, T. & Bacha, K. 2015 Physico-chemical and bacteriological quality of drinking water of different sources, Jimma zone, Southwest Ethiopia. *BMC Research Notes* **8**, 1–13.

Yoder, J. S., Gargano, J. W., Wallace, R. M. & Beach, M. J. 2012 Giardiasis surveillance – United States, 2009–2010. *Morbidity and Mortality Weekly Report: Surveillance Summaries* **61**(5), 13–23.

Zakir, S. N. & Ihsanullah, I. 2009 Effect of time intervals on levels of selected heavy metals in surface and ground waters in Peshawar basin. *Journal of the Chemical Society of Pakistan* **31**(5), 757–771.

First received 5 March 2023; accepted in revised form 4 June 2023. Available online 16 June 2023