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Analysis of Water Quality Using Physico-Chemical Parameters in District Shangla, Khyber Pakhtunkhwa, Pakistan

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Declaration
Authors' Contribution
The current research was designed by MS, AAK and IU. All the data was collected by MS and AAK and laboratory experiments were conducted by MS, AAK, KK, IA and MU. Manuscript was written by MS and SMUD. The study was supervised by IU.

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ABSTRACT

Water is a universal solvent and an important component of life. Water is said to be polluted when its composition or quality changes due to direct or indirect disposal of wastes and other human activities. There are three water quality parameters; physical, chemical and biological. These parameters serve as essential indicators for assessing the safety and suitability of water for consumption, encompassing various aspects to ensure compliance with health and environmental standards. Physicochemical parameters, which include both physical and chemical play an important role in determining the fitness of water for drinking purposes. A comprehensive study was conducted in district Shangla, Khyber Pakhtunkhwa (KPK), Pakistan to evaluate the quality of drinking water in four tehsils: Puran, Chakisar, Besham, and Alpuri. The water samples were collected from three different source including tube wells, springs, and tap water. A total of twelve water quality parameters were meticulously examined, comprising three physical parameters and nine chemical parameters. The physical parameters assessed were total dissolved solids, pH, and electrical conductivity. The chemical parameters were total hardness as calcium carbonate (CaCO3), the concentration of chloride (Cl), sulphate (SO4), sodium (Na), nitrite (NO2), calcium (Ca), magnesium (Mg), and potassium (K) and total alkalinity. The results showed significant variations in four tehsils but all the values fall within the WHO and PSQCA recommended limits except magnesium (Mg). The amount of total dissolved solids (TDS) varied greatly, ranging from 80 to 412 mg/L.

INTRODUCTION

Water is an essential component of life, supporting the growth and survival of all organisms on Earth (Taiwo *et al*., 2012; Corcoran *et al*., 2010). Despite covering over 70% of the Earth's surface only 2.8% are fresh water primarily stored in rivers, lakes, and groundwater (Stephens *et al*., 2020). This scarce resource is vital for human health, food production, and economic development (Swaminathan and Bhavani, 2013). However, water resources facing significant challenges such as pollution, contamination, and mismanagement, which threaten ecosystems and human well-being (Boretti *et al*., 2019). These challenges are further compounded by the complex interplay of chemical, physical, and biological characteristics that define water quality (Spellman, 2017). In which further parameters include are pH, total dissolved solids (TDS) and concentration of chloride, sulfate and nitrates and electrical conductivity (Omer, 2020). Each of these has distinct health implications (Spellman, 2017).

Understanding the relationships between water quality and human health is crucial for developing effective conservation and management strategies (Araújo *et al*., 2015). Contaminated water has significant health issues, contributing to waterborne diseases such as diarrhea, skin infections, and even death, particularly among children under five (WHO, 2023; Li *et al*., 2022). Poor hygiene and inadequate water access further exacerbate these issues, creating a cycle of health and environmental challenges (Mapingure *et al*., 2024). Addressing these problems requires a comprehensive approach that integrates scientific research, sustainable practices, and policy interventions to ensure the availability of safe drinking water and the preservation of freshwater ecosystems (Mujtaba *et al*., 2024).

In Pakistan, access to clean and safe drinking water remains a major issue, with millions of people relying on contaminated sources due to limited water treatment facilities and poor sanitation practices (Qamar *et al*., 2013). The lack of reliable infrastructure particularly in rural areas, including many parts of Khyber Pakhtunkhwa (KPK) exacerbates the problems and leading to widespread waterborne diseases and health risks (Atif *et al*., 2024). Shangla is a less developed district in Northern region of Khyber Pakhtunkhwa, where many communities facing significant barriers in accessing clean water, often relying on untreated and unsafe sources (Ishaque *et al*., 2024).

The contamination from sewage, insufficient chlorination, and lack of proper water filtration systems, highlight the urgent need for effective water management interventions in the region (Salam *et al*.,2024). This current study has been designed to assess the quality and physico-chemical parameters of drinking water in District Shangla, Khyber Pakhtunkhwa, Pakistan, to address these critical challenges and implement sustainable water management practices.

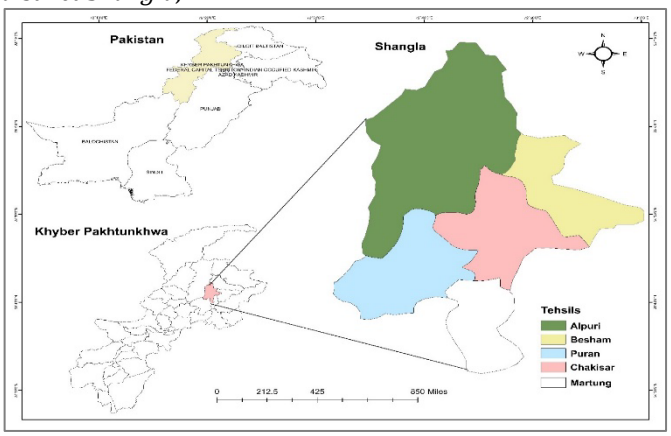
MATERIALS AND METHODS

Study area

The current study was conducted in district Shangla, located in Northern region of KP, Pakistan. The district is situated between 34°31' to 34°33'08'' N latitude and 72°33' to 73°01' E longitude with elevation of 3,164 meters above sea level and covers 1,586 Km2 area. There are five administrative tehsils in Shangla; Alpuri, Puran, Besham, Chakisar and Martung. At the top of mountains snow glaciers are present throughout the year and rive Indus cross the district through Besham Tehsil.

Figure 1

Study area map showing sampling Tehsils with color in district Shangla, KP.



Water Samples Collection

The water samples (n = 12) were collected from three different sources: tape water, spring water and well water in a 1000 ml sterile bottle and shifted to the Zoology Laboratory of Shangla Sub-Campus University of Swat for physico-chemical analysis. Three samples were collected from each of the four tehsils (Fig 1).

Parameters Tested

A total 12 water quality parameters for each sample were tested and compared with World Health Organization recommended standard (WHO, 2001) and Pakistan Standard Quality Control Authority (PSQCA) drinking water standards, 2010. These parameters were categorized into three physical parameters and nine chemical parameters. The physical parameters included total dissolved solids (TDS), pH and electrical conductivity. The chemical parameters tested were total hardness as calcium carbonate ($CaCO_3$), the concentration of chloride (Cl), sulphate (SO_4), sodium (Na), Nitrite (NO2), Calcium (Ca), Magnesium (Mg), and potassium (K), and total alkalinity.

RESULTS

Total Hardness ($CaCO_3$)

Results of physico-chemical parameters are shown in Table 1. It represents the total hardness values of water samples from various locations and sources as expressed in milligrams per liter (mg/L) of calcium carbonate ($CaCO_3$). The results show significant variability in hardness levels across samples of different locations. Notably, Besham tap water (BT) exhibited the highest hardness value (366.99±3.33) whereas Alpuri tap water (AT) recorded the lowest value (60.74±3.33). No form evidences have been suggested by WHO and PSQCA that drinking hard water has any warned health issues. In all the samples hardness were in the acceptable range.

Total Dissolved Solids (TDS)

The highest TDS value was found in the Besham spring water (BS) which was 412.33±2.30, while the lowest TDS value was observed in the Alpuri tap water (AT) which was 80.00±2.30. The Table 1 provides a comprehensive overview of the TDS levels in the water samples across the study area, by comparing the recorded TDS values with the desirable limit of 1000 mg/L of WHO and PSQCA. It was confirmed that the water samples meet the recommended standard of WHO and PSQCA.

Chloride (Cl)

In the study area, the concentration of chloride ranged from 10.72 mg/L in the Alpuri tap water sample (AT) to 48.22 mg/L in the Puran tap water sample (PT). All the samples had chloride concentrations below the recommended WHO and PSQCA standards which is favorable for health perspective. The chloride concentrations in the different samples are shown in the Table 1.

Table 1

Total hardness of Calcium carbonate ($CaCO_3$), chloride (Cl), total dissolved solids (TDS), World Health Organization (WHO) and Pakistan Standards and Quality Control Authority (PSQCA) standard, 2010.

Sample type and location	Total Hardness as $CaCO_3$ (mg/L)) and Chloride (mg/L)				Total dissolved solids (TDS) (mg/L)		
	$CaCO_3$	Chloride	WHO	PSQCA	TDS	WHO	PSQCA
Chakesar tape water	291.86±3.33	12.80±2.30	500	500	253.67±2.30	1000	1000

Chakesar spring water	299.76±3.33	13.10±2.30	500	500	292.67±2.30	1000	1000
Chakesar well water	256.85±3.33	21.43±2.30	500	500	237.00±2.30	1000	1000
Alpuri tape water	60.74±3.33	10.72±2.30	500	500	80.00±2.30	1000	1000
Alpuri spring water	314.57±3.33	33.64±2.30	500	500	379.33±2.30	1000	1000
Alpuri well water	248.89±3.33	12.15±2.30	500	500	247.00±2.30	1000	1000
Besham tape water	366.99±3.33	16.67±3.20	500	500	366.00±2.30	1000	1000
Besham spring water	352.10±3.33	26.49±2.30	500	500	412.33±2.30	1000	1000
Besham well water	251.86±3.33	22.32±2.30	500	500	334.00±2.30	1000	1000
Puran spring water	331.85±3.33	48.22±2.30	500	500	382.00±2.30	1000	1000
Puran well water	334.33±3.33	16.07±2.30	500	500	334.00±2.30	1000	1000
Puran tape water	317.04±3.33	24.41±2.30	500	500	361.33±2.30	1000	1000

Sulphate (SO_4)

In the study areas, the concentrations of sulfate ranged from 6.90 mg/L in the Alpuri tap water sample (AT) to 102.83 mg/L in the Besham tap water sample (BT). These sulfate concentrations are given in the Table 2. It is noteworthy that all the recorded sulfate values in the samples were within the WHO and PSQCA standard limit. Therefore, the concentrations of sulfate in the study area are considered safe and are not likely to be harmful to human health. This suggests that the sulfate levels in the water samples do not pose significant concerns.

Sodium (Na)

The concentrations of sodium were found divers ranged from 6.50 mg/L in Alpuri tap water (AT) to 27.70 mg/L in Chakisar well water (CW). Notably, all samples demonstrated sodium concentrations within acceptable limits of WHO and PSQCA standard, indicating no significant health risks associated with sodium intake from these water sources (Table 2).

Nitrite (NO_2)

Table 2 shows nitrite values for 12 samples, all complying with WHO (3 mg/L) and PSQCA (1 mg/L) guidelines. Neither nitrate was detected in all samples and nor any significant health related risk was detected.

Table 2

Total hardness of sulphate (SO_4), sodium (Na), nitrite (NO_2) World Health Organization (WHO) and Pakistan Standards and Quality Control Authority (PSQCA) standard, 2010.

Sample type and location	Sulphate (SO_4) (mg/L)			Sodium (Na) (mg/L)			Nitrite (NO_2) (mg/L)		
	SO_4	WHO	PSQCA	Na	WHO	PSQCA	NO2	WHO	PSQCA
Chakesar tape water	33.45±0	250	400	9.70 ±1.70	200	200	Nill	50	3
Chakesar spring water	23.58±0	250	400	9.00 ±1.70	200	200	Nill	50	3
Chakesar well water	21.42±0	250	400	27.70 ±1.70	200	200	Nill	50	3
Alpuri tape water	6.90±0	250	400	6.50±1.70	200	200	Nill	50	3
Alpuri spring water	14.23±0	250	400	24.77±1.70	200	200	Nill	50	3
Alpuri well water	14.60±0	250	400	9.80±1.70	200	200	Nill	50	3
Besham tape water	102.83±0	250	400	15.73±1.70	200	200	Nill	50	3
Besham spring water	15.32±0	250	400	17.00±1.70	200	200	Nill	50	3
Besham well water	32.40±0	250	400	8.60±1.70	200	200	Nill	50	3
Puran spring water	23.25±0	250	400	13.60±1.70	200	200	Nill	50	3
Puran well water	13.25±0	250	400	8.60±1.70	200	200	Nill	50	3
Puran tape water	64.63±0	250	400	20.10±1.70	200	200	Nill	50	3

Calcium ($CaCO_3$)

The highest calcium value was observed in the Besham tape water (BS) recorded 161.98 mg/L, while the lowest calcium value was found in the Alpuri tape water (AT) measure 34.07±2.47. All the recorded calcium values were in the tolerable range and WHO permissible limit (75mg/l).

Magnesium (Mg)

Magnesium concentrations varied significantly, ranging from 26.67 mg/L in Alpuri tap water (AT) to 242.96 mg/L in Besham tap water (BT) as given in the Table 3.

Potassium (K)

The lowest concentration of potassium was found in the Alpuri well water sample (AW) which was 1.10, while the highest concentration was detected in Alpuri Spring water (AS) with a value of 10.87. It is worth noting that the results of the study meet the WHO standards for potassium concentration in drinking water. This implies that the potassium levels observed in the samples were within acceptable ranges Table 3.

Table 3

Total hardness of calcium (Ca), Magnesium (Mg), Potassium (K) and World Health Organization (WHO) and Pakistan Standards and Quality Control Authority (PSQCA) standard, 2010.

Sample type and location	Calcium (Ca) (mg/L)			Magnesium (Mg) (mg/L)			Potassium (K) (mg/L)		
	Ca	WHO	PSQCA	Mg	WHO	PSQCA	K	WHO	PSQCA
Chakesar tape water	88.89±2.47	75	200	202.97±0	150	150	5.47±0.64	12	10
Chakesar spring water	124.94±2.47	75	200	174.82±0	150	150	6.50±0.64	12	10
Chakesar well water	85.93±2.47	75	200	170.36±0	150	150	9.50±0.64	12	10
Alpuri tape water	34.07±2.47	75	200	26.67±0	150	150	1.40±0.64	12	10
Alpuri spring water	113.58±2.47	75	200	200.99±0	150	150	10.8±0.64	12	10
Alpuri well water	114.07±2.47	75	200	134.82±0	150	150	1.10±0.64	12	10
Besham tape water	118.03±2.47	75	200	242.96±0	150	150	5.43±0.64	12	10
Besham spring water	161.98±2.47	75	200	190.12±0	150	150	6.73±0.64	12	10
Besham well water	120.00±2.47	75	200	131.86±0	150	150	8.60±0.64	12	10

Puran spring water	158.52±2.47	75	200	161.48±0	150	150	6.10±0.64	12	10
Puran well water	111.11±2.47	75	200	220.74±0	150	150	8.60±0.64	12	10
Puran tape water	132.84±2.47	75	200	201.49±0	150	150	7.70±0.64	12	10

pH

Analysis indicates that the pH values of all collected samples align with the favorable thresholds outlined by both WHO and the Pakistan Standards and Quality Control Authority (PSQCA). This indicates that the pH levels of the water samples are considered suitable for consumption. The lowest pH value was observed in the Chakisar spring water sample (CS), which measured 6.97±0.18. On the other hand, the highest pH value was recorded in the Besham tape water sample, (BT) which measured 7.48±0.18 Table 4.

Total alkalinity ($CaCO_3$)

The results indicate that the highest alkalinity value was observed in the Besham tape water sample (BS), measured 225.63 mg/L, while the lowest alkalinity value was found in the Alpuri tape water sample (AT), measured 44.36 mg/L. All the recorded alkalinity values in the study area were below the WHO permissible limit. This show that the alkalinity levels observed in the samples are within acceptable ranges and are unlikely to cause health-related problems, even so further investigation is needed in this area (Table 4).

Electrical conductivity (EC)

The highest electrical conductivity value was recorded in Besham spring water sample (BS) which was 590.33± 2.32 and lowest in Alpuri tape water (AT) which was 119.00 ± 2.32. The results clearly indicated that the water in the study area exhibited considerably ionized characteristics and fall within the WHO and PSQCA standard limit (Table 4).

Table 4

Total hardness of PH, alkalinity, electric conductivity (EC) and World Health Organization (WHO) and Pakistan Standards and Quality Control Authority (PSQCA) standard, 2010.

Sample type and location	PH			Alkalinity(mg/L)			Eclectic Conductivity (EC) (mg/L)		
	PH	WHO	PSQCA	Alkalinity	WHO	PSQCA	EC	WHO	PSQCA
Chakesar tape water	7.29±0.18	6.50 – 8.50	6.50 – 8.50	137.57±3.27	500	600	366.00±2.32	400	1400
Chakesar spring water	6.97±0.18	6.50 – 8.50	6.50 – 8.50	175.49±3.27	500	600	426.67±2.32	400	1400
Chakesar well water	7.27±0.18	6.50 – 8.50	6.50 – 8.50	152.35±3.27	500	600	339.00±2.32	400	1400
Alpuri tape water	7.22±0.18	6.50 – 8.50	6.50 – 8.50	44.36±3.27	500	600	119.00±2.32	400	1400
Alpuri spring water	7.10±0.18	6.50 – 8.50	6.50 – 8.50	161.35±3.27	500	600	544.33±2.32	400	1400
Alpuri well water	7.39±0.18	6.50 – 8.50	6.50 – 8.50	150.42±3.27	500	600	313.00±2.32	400	1400
Besham tape water	7.48±0.18	6.50 – 8.50	6.50 – 8.50	163.92±3.27	500	600	528.00±2.32	400	1400
Besham spring water	7.25±0.18	6.50 – 8.50	6.50 – 8.50	225.63±3.27	500	600	590.33±2.32	400	1400
Besham well water	7.35±0.18	6.50 – 8.50	6.50 – 8.50	148.49±3.27	500	600	481.00±2.32	400	1400
Puran spring water	7.26±0.18	6.50 – 8.50	6.50 – 8.50	217.92±3.27	500	600	569.00±2.32	400	1400
Puran well water	7.30±0.18	6.50 – 8.50	6.50 – 8.50	94.82±3.27	500	600	481.00±2.32	400	1400
Puran tape water	7.27±0.18	6.50 – 8.50	6.50 – 8.50	175.49±3.27	500	600	518.00±2.32	400	1400

DISCUSSION

Hard water is defined as the water which is characterized by a high mineral content, primarily composed of calcium and carbonates, making calcium carbonate ($CaCO_3$) (Sengupta , 2013) The World Health Organization (WHO) and Pakistan Standards and Quality Control Authority (PSQCA) recommends the level of hardness should not surpass 500 mg/L. Consumers generally have a tolerance for water hardness levels that exceed 500 mg/L (WHO) and still can be considered acceptable for consumption by most individuals (WHO, 2011). The World Health Organization (WHO) and the Pakistan Standards and Quality Control Authority (PSQCA) recommend an optimal level of 1000 mg/L for Total Dissolved Solids (TDS) in drinking water (Daud *et al*., 2017). If the TDS concentration surpasses 1000 mg/L, it can lead to an evident change in taste (WHO, 2022). Water containing TDS concentrations below 1000 mg/ L is usually acceptable to consumers, although acceptability may vary according to circumstances (Akcaalan *et al*., 2022) However, the presence of high levels of TDS in water may be objectionable to consumers owing to the resulting change in taste and to excessive scaling in water pipes, heaters, boilers, and household appliances (WHO, 2011). Water with extremely low concentrations of TDS may also be unacceptable to consumers because of its flat, insipid taste; it is also often corrosive to water-supply systems (Owusu *et al*., 2024) In the current study, water samples from the research area underwent measurement and documentation of their TDS content by comparing the recorded TDS values with the desirable limit of 1000 mg/L, it can be stated that the water samples meet the recommended standard of WHO and PSQCA.

Chloride (Cl) is obtained from various sources and plays a significant role in physiological processes (Marunaka, 2023). Chloride is mainly derived from the dissolution or disintegration of salts containing hydrochloric acid, such as table salt (NaCl), sodium carbonate (NaCO2), as well as industrial waste, sewage, and seawater (Berend, 2012). Surface water bodies generally exhibit lower chloride concentrations compared to groundwater sources (Siraj *et al*., 2023). Chloride plays a crucial role in metabolic activities and other physiological processes within the human body (Berend and Gans, 2012) However, high chloride concentrations can lead to damage to metallic pipes and structures which can cause contamination of water (Zhang *et al*., 2024) According to the World Health Organization (WHO) and PSQCA standards, the concentration of chloride in water should not exceed 250 mg/L. The chloride concentrations in the different samples are depicted in the provided data however further research studies are necessary.

Sulfate (SO_4) primarily originates from the dissolution of salts containing sulfuric acid and is prevalent in

different water sources (Zak *et al*., 2021) Elevated levels of sulfate may arise due to oxidation and mine drainage of compounds like pyrite (iron disulfide) (Miao *et al*., 2012) In natural water, sulfate concentrations vary from a few to several hundred milligrams per liter (Zhou *et al*., 2024). Notably, sulfate in drinking water hasn't been linked to significant adverse effects on human health (WHO, 2011). Both the WHO and PSQCA have set a recommended upper limit of 250 mg/L for sulfate in drinking water (Awan et al.,2022). The concentrations of sulfate ranged from 6.90 mg/L to 102.83 mg/L. Therefore, the concentrations of sulfate in the study area are considered safe and are not likely to be harmful to human health. This suggests that the sulfate levels in the water samples do not pose significant concerns. The pH of water serves as a crucial operational parameter for assessing water quality (Dewangan *et al*., 2007). It gauges the concentration of hydrogen ions within water and is denoted on a scale spanning from 0 to 14 (Adeva *et al*., 2014). A pH level of 7 denotes neutrality, whereas values lower than 7 indicate acidity, and values above 7 indicate alkalinity (Hopkins *et al*, 2022) The values of pH were found in a normal range of 6-8.5 and water are suitable for consumption. Sodium (Na) is a metallic element with a silver-white appearance (Meride and Ayenew, 2016). Adequate levels of sodium in the human body play a crucial role in preventing various serious conditions such as headaches, kidney damage and hypertension, and in many countries, most water sources have a sodium concentration of under 20 mg/L (Grillo *et al*., 2019). The sodium concentrations in all the water samples from the study areas fall within acceptable limit and no significant risk associated were observed.

Nitrite (NO_2^-) and nitrate (NO_3^-) are ions are commonly present in our surroundings (Ma *et al*., 2018). Both are oxidized products of nitrogen (WHO, 2011). These ions can be derived from agricultural practices and bacterial activities (Souza *et al*., 2015) The concentration range from 0 to 18 mg/L and fall within a normal limit of WHO and PSQCA standard. Alkalinity in water refers to the presence of ions such as hydroxides, carbonates, and bicarbonates (Bozorg-Haddad *et al*., 2021). It represents the water's capacity to neutralize acids (Brandt, and Ratnayaka, 2017). In most water supplies, a modest concentration of alkalinity is satisfactory as it helps stabilize and counteract the corrosion which is caused by acidity (Taghipour *et al*., 2012). However, high alkalinity levels can lead to various health issues (Bozorg-Haddad *et al*., 2021). The World Health Organization (WHO) standards for alkalinity are expressed in terms of total dissolved solids (TDS) and set a limit of 500 mg/L (WHO, 2003). In the current study all the recorded alkalinity values in the study area were in the WHO permissible limit (500 mg/l) and in the acceptable range.

Calcium (Ca) ranks as the fifth most abundant element on the Earth's surface, important for body physiology and deficiency results various diseases such as rickets, impaired blood clotting, and bone fractures. Conversely, an excessive intake of calcium has been linked to cardiovascular issues (Shlisky *et al*., 2022) According to guidelines established by the World Health Organization, the acceptable range for calcium concentration in drinking water is 75 mg/L (WHO, 2009). However, the Pakistan Standards and Quality Control Authority (PSQCA) raised the limit to 200 mg/L in 2002. Notably, an adult typically requires 1,000 mg of calcium daily for optimal functioning. Given the WHO standards, it's vital to ensure that calcium levels in drinking water remain within the permissible range of 75 mg/L. It's important to acknowledge that the prioritization was placed on adhering to WHO's standards over those of the PSQCA. In the All the recorded calcium values in the study area were above the WHO permissible limit (75mg/L).

Magnesium, standing as the eighth most prevalent element within the Earth's crust, occurs naturally across all water varieties (Jahnen-Dechent and Ketteler, 2012). This essential element plays a pivotal role in facilitating the optimal operation of living organisms and is commonly found within minerals like dolomite and magnesite (Jahnen-Dechent and Ketteler, 2012). According to the standards set by the WHO and PSQCA the permissible range of magnesium in water should be 150 mg/L (Mehmood *et al*., 2013) All values were found in normal recommended limit. Similarly, WHO has established a permissible limit of 12 mg/L for potassium in drinking water and PSQCA 2010 standards give the permissible limit of 10 mg/l. It is worth noting that the results of the study meet the WHO standards for potassium concentration in drinking water. This implies that the potassium levels observed in the samples are within acceptable ranges.

Electrical Conductivity (EC) gauges a solution's capacity to carry an electric current (Saini *et al*., 2021). In its inherent state, pure water proves to be a weak conductor of electricity, functioning more as an insulator (Gapparov and Isakova, 2023). According to the WHO standards, the EC value of water should not exceed 400 µS/cm and PCQCA standards is 1400 µS/. The results clearly indicate that the water in the study area exhibited considerably ionized characteristics and had a higher level of ionic concentration with respect to WHO standards it is due to the presence of excessive dissolved solids. Consequently, the water demonstrated a fine conductor of electric current.

CONCLUSION AND RECOMMENDATIONS

All the samples of water collected from different locations among four tehsils within the study area have normal range of elements. No significant health related issues were observed and the water were found fit for consumption. Regular monitoring of water sources are necessary to avoid any health related issues. Proper cleaning and sewage practices is necessary. Addition of chlorine to water tank to maintain the proper level is recommended. Advance techniques should be adopted for treatment of water. Further, studies are necessary to access the exact range of physical and chemical parameters in maximum number of samples.

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