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ASSESSMENT OF DRINKING WATER QUALITY IN KATHMANDU, KIRTIPUR AND SIRAHA, NEPAL

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ABSTRACT

In the present study, the assessment of the water quality of tap water from the spring source, hand pump, and well water from Kirtipur, Siraha, and Kathmandu, respectively, was carried out by determining the physicochemical and microbial characteristics of water samples. Three water samples, one from each source, were collected and analyzed using the standard method of APHA 2017. The different water quality parameters, such as temperature, pH, Electrical Conductivity (EC), Total Hardness (TH), turbidity, iron, ammonia, aluminum, arsenic, and major anions such as Nitrate (NO_3^-), Chloride (Cl^-), Sulphate (SO_4^{2-}), Fluoride (F^-) as well as microbial parameter were determined. The physicochemical parameters of the water samples were within the permissible limits of the NDWQS standard. The pH of the studied water samples was slightly basic in nature, ranging from 7.3 to 7.7. In comparison with tap water and hand pump, well water sample from Kathmandu was with high EC, turbidity, TH, Cl^-, iron, ammonia, NO_3^-, SO_4^{2-} and arsenic (As) with value 1167 µs/cm, 1.5 mg/L, 422 mg/L, 135.6 mg/L, 0.11 mg/L, 1.2 mg/L, 17.7 mg/L, 10 mg/L and 0.01 mg/L, respectively. The prevalence of the anions in the water samples was in the order $Cl^- > NO_3^- > SO_4^{2-} > F^-$. The water from the hand pump and well was free from microbial contamination. However, *E coli* was detected in tap water from Kirtipur, exceeding the NDWQS limit, which indicates the potential risk to public health on direct consumption of water. Regular and strict monitoring of water sources and public awareness on water pollution are highly encouraged.

Keywords: Water quality, Siraha, Kirtipur, Kathmandu, physicochemical and microbial parameters, NDWQS

INTRODUCTION

Water is an essential element for the sustainability of life on Earth. It is an integral component for all living things as well as inanimate objects (Pandey, 2012). Therefore, the establishment of a stable community requires the presence of a safe and dependable source of water. Water makes up one-third of the Earth's surface. However, only 0.3% is suitable for human consumption. Water that satisfies national drinking water quality standards (NDWQS) or WHO guidelines in terms of microbiological, chemical, and physical characteristics is considered safe drinking water (WHO, 2007). Both natural and man-made activities affect the quality of water. The natural water quality becomes unfit for use and is referred to as contaminated or polluted water if such activities change.

According to WHO estimates, poor sanitation, pollution, or a lack of water supply are responsible for up to 80% of all illnesses and diseases worldwide. Many deaths and morbidities are caused by water-borne illnesses and contaminated drinking water (Prasai, 2007). Since human health and well-being are directly related to the quality of the water used, safe water quality is a significant concern in terms of public health importance (Sharma, 2005). Nearly two million children die from diarrhoea each year, and more than 884 million people worldwide lack access to clean water. This is also true in Nepal, where 5.5 million people lack access to clean drinking water and 10,500 children die as a result of water-borne diseases every year in Nepal (Shrestha, 2012).

Determining whether the available drinking water is safe and appropriate for human consumption is the goal of water quality assessment. Regular and periodic water quality assessment is very crucial for a healthy life and ecosystem. Such evaluation assists in identifying contaminants that may present health risks, such as dangerous bacteria, heavy metals, or excessive concentrations of chemicals and salts, by examining physical, chemical, and biological parameters. Additionally, it offers crucial data for efficient water resource management, assisting communities, health authorities, and legislators in guaranteeing access to safe and clean water.

Because it prevents waterborne illnesses and improves public health, routine assessment is particularly crucial in areas that are polluted or have inadequate treatment facilities.

With a population of 1.5 million, the Kathmandu valley is home to the nation's single largest urban economy. During the dry season, the current groundwater and surface water piped water supply ranges from 65 to 85 MLD. The supply only reaches 140 MLD, even during the rainy season (Khatiwada, 2002). As a result, groundwater supplies provide about half of the Kathmandu Valley's urban water supply and are extensively used for industrial, residential, and private purposes (Pant, 2010). The sources of groundwater are then under pressure as a result. The Kathmandu Valley's water quality is in poor condition and does not meet WHO standards (Prasai, 2007). This is brought on by sewage contamination, septic failure, open pits, leaching from landfills, latrines, and the open disposal of industrial and household waste (Karn, 2001). Iron, nitrate, ammonia, arsenic, and pathogens are the main contaminants of drinking water sources. Therefore, such water is unfit for human consumption, and before using it, suitable treatment techniques must be used.

In recent years, rapid population growth, industrialization, and different anthropogenic activities have resulted in the degradation as well as intense pressure on the existing water resources. Water quality degradation causes a negative impact on the health of living organisms as well as the sustainability of the ecosystem. There is a lack of regular and periodic assessment of water quality in both surface and underground water sources. There are fewer studies regarding the drinking water sources in the Kirtipur and Siraha areas (Parajuli & Shrestha, 2017; Belbase *et al.,* 2024). The main objective of this study is to evaluate the water quality status of drinking water sources such as spring water, hand pump, and well in Kirtipur, Siraha, and Kathmandu by determining the different physicochemical and microbial parameters.

MATERIALS AND METHODS

Three water samples from various sources (tube well, excavated, and the spring source) in the Kirtipur, Kathmandu valley, and Siraha area of Nepal were examined. The water samples were collected in 1-liter sterile bottles using an aseptic approach, in accordance with the American Public Health Association (APHA, 1998) guidelines. Each water sample was analyzed in triplicate to ensure the reliability and reproducibility of results. Table 1 displays the test parameters, method, and tools utilized for physicochemical and microbial analysis of water samples.

Table 1

Test Parameters, Methods in APHA 23rd EDITION, and Instruments Used for the Analysis of Water Samples.

S.N.	Parameters	Unit	Method (APHA*, 23rd EDITION)	Name of the Instruments & Kits
	Physiochemical			
1	p^H	-	4500-H^+B.	pH meter Company name: Lutron Model no. BPH-231
2	Conductivity	µs/cm	2510B.	Conductivity meter Company name : Lutron Model no. BCT-4308
3	Temperature	^{0}C	2550 B.	Mercury thermometer
4	Turbidity	NTU	2130B.	Turbidity Meter Company name : Lutron Model no. BPH-231
5	Total Hardness	mg/L	2340 C.	EDTA Titration
6	Chloride	mg/L	4500-CL^- B.	Argentometric Titration
7	Iron	mg/L	3111 C.	Atomic Absorption Spectrophotometer Company name : GBC Model no. Savant-AA
8	Ammonia	mg/L	4500-NH_3F.	UV-Vis Spectrophotometer Company name: Peak Instruments Model no. C-7200A
9	Nitrate	mg/L	4500-NO_3B.	UV-Vis Spectrophotometer Company name: Peak Instruments Model no. C-7200A
10	Arsenic	mg/L	3114B.	Atomic Absorption Spectrophotometer Company name: GBC Model no. Savant-AA
11	Fluoride	mg/L	4500F^- D.	UV-Vis Spectrophotometer Company name: Peak Instruments Model no. C-7200A
12	Sulphate	mg/L	4500-SO_4.	Gravimetric
13	Aluminium	mg/L	3111D.	Photometer Company name: Palintest Model no. 7500
	Microbiological			
14	Faecal Coliform E.coli	(CFU/100ml)	9222D.	0.45 µm pore size Membrane Filtration Technique

APHA = APHA, 2017*

RESULTS AND DISCUSSION

The physical parameters (temperature, pH, electrical conductivity, turbidity) and chemical parameters (total hardness, chloride, ammonia, nitrate, iron, arsenic, aluminum, sulphate, and fluoride) of all the studied water samples were within the permissible limit of National Drinking Water Quality (NDWQS) guidelines value. The microbiological parameter (faecal coliform) of all water samples except for tap water (spring source) was under the safe limit of NDWQS. The results of the physicochemical as well as microbial parameters of the tested water samples, along with their comparison with the NDWQS standard, are depicted in Table 2.

Table 2

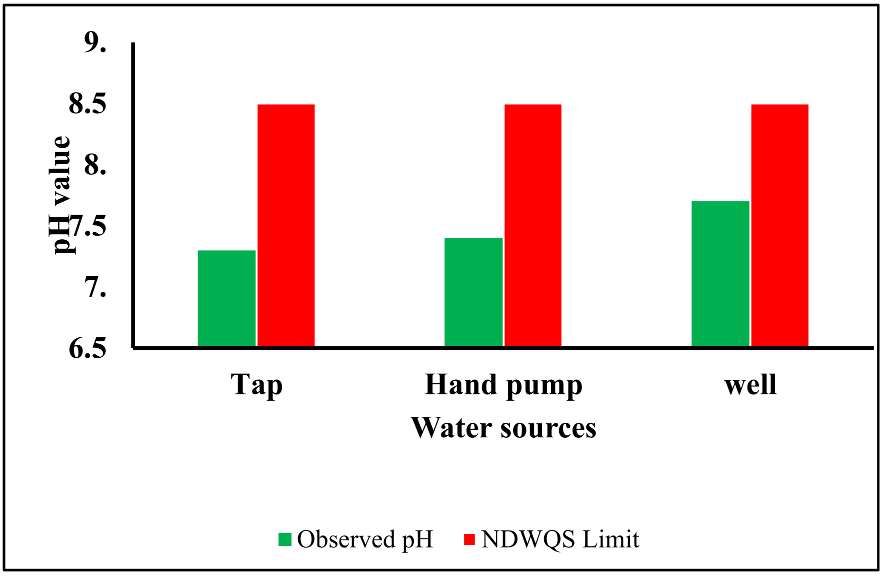
The Physicochemical and Microbial Parameters of the Water Samples from Different Sources Under Study.

S.N.	Parameters	Units	Observed Values of source of sample			NDWQS limit	Sample Source exceeding NDWQS
	Physiochemical		Tap	Hand Pump	well		
1	pH	-	7.7	7.3	7.2	6.5-8.5	No
2	Electrical conductivity(EC)	µs/cm	263.0	660.0	1167.0	1500	No
3	Temperature	^{0}C	16.0	16.0	16	-	No
4	Turbidity	NTU	<0.2	<0.2	1.5	5	No
5	Total Hardness (TH)	mg/L	126.0	300	422	500	No
6	Chloride	mg/L	<5	<5	135.6	250	No
7	Iron	mg/L	0.01	<0.01	0.11	0.3(3)	No
8	Ammonia	mg/L	<0.2	<0.2	1.2	1.5	No
9	Nitrate	mg/L	<5	<5	17.7	50	No
10	Arsenic	mg/L	<0.01	<0.01	0.01	0.05	No
11	Fluoride	mg/L	<0.1	<0.1	<0.1	0.5 - 1.5	No
12	Sulphate	mg/L	10	<5	5	250	No
13	Aluminum	mg/L	<0.01	<0.01	<0.01	0.2	No
	Microbiological						
14	Faecal Coliform E.coli	(CFU/ 100 mL)	06	0	0	0	Yes (Tap)

The pH of the studied water samples ranged from 7.2 to 7.7, with a high pH value observed for the tap water from Kirtipur. All of the tested water samples (100 %) were slightly alkaline in nature but within the permissible limits of NDWQS, which is shown in Figure 1. The pH values in the previous studies by (Ganiyu *et al.,* 2017) and (Bajracharya *et al.,* 2022) in dug well, (Parajuli & Shrestha, 2017) in tap and well water samples and (Sadeepa *et al.,* 2022) in spring water were in line with the present study in which water samples were observed alkaline in nature, However, Belbase *et al.* (2024) and Maharjan *et al.* (2020) reported 6.25 % and 3 % well water samples below 6.5 i.e. acidic in nature, which was in contrast with present study. Similarly, Hashim *et al.* (2018), Esi *et al.* (2013), and Nnorom *et al.* (2019) observed the water samples from groundwater sources to be acidic in nature, which deviates from the present study. The differences in the pH alter different physicochemical parameters of water, affecting the overall quality of water (Wetzal and Limnology, 1975).

Figure 1

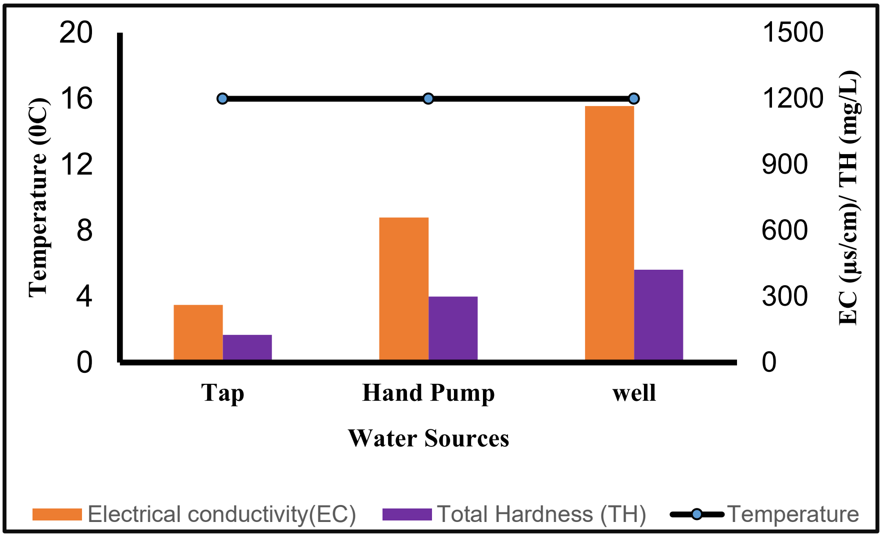
Comparison of Observed P^H Values in Water Samples with the NDWQS Standard



The maximum electrical conductivity of 1167 µs/cm was observed for the well water from Kathmandu district, whereas the minimum electrical conductivity was recorded for tap water (spring source) from Kirtipur with a conductance value of 263 µs/cm. The observed conductivity of all the water samples (100%) did not surpass 1500 µs/cm, the threshold limit of NDWQS, which is depicted in Figure 2. The higher electrical conductivity in well water samples was reported in the study of Belbase *et al.* (2024), in which 9.38% well water samples were above the NDWQS limit. Similarly, Shakya *et al.* (2019), Koju *et al.* (2014), and Bajracharya *et al.* (2022) observed higher conductivity in groundwater samples from Kathmandu and Lalitpur, respectively. However, Ganjyu *et al.* (2017) and Nnorom *et al.* (2019) found electrical conductivity of spring water samples in a range (409 - 892) µs/cm and (20 - 370) µs/cm, respectively, which was in agreement with the present study. The highest electrical conductance of 1870 µs/cm, 1474 µs/cm, and 1310 µs/cm was reported in a hand-dug well by Esi *et al.* (2013), spring water by Sadeepa *et al.* (2022), and a dug well by Silva & Udagedara (2013), respectively, which exceeded the conductance value in the present study.

Figure 2

Temperature, Electrical Conductivity (EC), and Total Hardness (TH) of different water sources under study



Temperature is an important physical parameter that has an impact on dissolved oxygen and metal toxicity (Awofolu *et al.,* 2007). In the present study, a temperature of 16 ^{0}C was observed for the studied water samples from different sources (spring water, dug well, and hand pump), which is presented in Figure 2. In the study of Parajuli & Shrestha (2017), a high temperature of 30 ^{0}C was reported in tap and well water samples from Kirtipur. Similarly, Esi *et al.* (2013) reported the temperature in the hand-dug wells in Nigeria in a range of 23 - 25 ^{0}C. The temperature in the literature was higher than in the present study. Moreover, the minimum temperature of 15.7 ^{0}C reported in the study of Bajracharya *et al.* (2022) in dug wells was in good agreement with the present study.

The total hardness of well water, with a value of 422 mg/L, was comparatively higher than that of the tap and hand pump, with values of 126 mg/L and 300 mg/L, respectively. The reported hardness of water samples was within 500 mg/L, the NDWQS limit, which is well presented in Figure 2. According to the classification of water based on calcium carbonate hardness, water from tap water (spring source) was classified as moderately hard, as its hardness was below 150 mg/L. Similarly, hand pump and well water were categorized as hard water category since it's hardness was above 150 mg/L (Nduka & Orisakwe, 2009). The hardness value of 130 mg/L in spring water reported by Sadeepa *et al.* (2022) aligned with the present study. However, Esi *et al.* (2013) and Bajracharya *et al.* (2022) reported the maximum value of total hardness in the dug well as 132.13 mg/L and 198 mg/L, respectively, which was lower than the present study. The hardness value in the present study was in line with the previous studies by Belbase et al (2024), Maharjan *et al.* (2020), and Ghartimagar *et al.* (2020), in which the value of hardness was within the NDWQS limit. The dissolved calcium and, to a lesser extent, magnesium contribute to the hardness of water. Industrial effluents, sewage, and wastewater wastes are significant sources of magnesium and calcium (Belbase *et al.,* 2024). Hardness of water has no direct influence on human health, but may cause heart disease above its critical limit and primarily affects the scum formation and scale deposits, as well as the amount of soap needed to create lather (Schroeder, 1960).

Turbidity is the light scattering property of water due to the presence of colloidal as well as suspended particles such as clay, silt, organic matter, etc (Grobbelaar, 2009). The maximum turbidity in the present study was 1.5 mg/L in well water. However, the turbidity of water samples (tap water, well water, and hand pump) in the current study was beyond the maximum permissible limit of NDWQS. Gharti magar *et al.* (2020), Koju *et al.* (2014), Belbase *et al.* (2024), Maharjan *et al.* (2020), and Bajracharya *et al.* (2022) reported higher values of turbidity above NDWQS in their studies of groundwater samples, which was in contrast to the present study. The different natural and anthropogenic activities, such as soil erosion, industrial wastes, sewage, agricultural runoff, and algal bloom. etc, constitute high turbidity of water (Patel & Vashi, 2015). The high turbidity causes a negative impact on photosynthesis, depletes the dissolved oxygen as well, and degrades the colour, odour, and taste of water (Belbase *et al.*, 2024; Gómez *et al.,* 2017).

In the present study, the chloride concentration of 135.6 mg/L observed for well water was higher in comparison to the tube well and spring sources; nevertheless, it was still within the NDWQS recommended values. The chloride content in the present study was in alignment with the study of Maharjan *et al.* (2020), Ghartimagar *et al.* (2020), Bajracharya *et al.* (2022), and Belbase *et al.* (2024), in which chloride content was within the permissible limit of NDWQS. Ganiyu *et al.* (2017) reported a minimum chloride content to be 144 mg/L in spring and well water, which was in line with the present study. Natural sources, sewage, and industrial effluents, containing deionized salts, are the sources of chloride in water systems (Purandara & Varadarajan, 2003).

The maximum concentration of nitrate was observed as 17.7 mg/L in a well water sample, which exceeded the nitrate concentration in tap water and tube well. However, the level of nitrate in the present study was much lower than the maximum permissible limit of NDWQS, i.e., 50 mg/L. Bajracharya *et al.* (2022) and Shakya *et al.* (2019) reported the nitrate content in dug wells within the NDWQS, which was in good agreement with the present study. The nitrate concentration in the present study was higher than the studies of Ganjyu *et al.* (2017) and Esi *et al.* (2013), in which maximum nitrate was obtained as 5.33 mg/L and from 6.00 mg/L, respectively. The high concentration of nitrate in water sources is due to the leaching of septic tanks, sewage, chemical fertilizers, and animal wastes (Ganiyu *et al.,* 2017; Akinbile and Yusoff, 2011). The excessive level of nitrate in water samples causes methemoglobinemia or blue baby disease in infants as well as diarrhea, respiratory diseases, cancer, and lesions (Ward *et al.,* 2005; Nduka & Orisakwe, 2009; Nolan, 1998).

The ammonia content in well water was obtained as 1.2 mg/L, respectively, which was reported to be higher than tap water and tube well in the present study. The concentration of ammonia in all studied water samples (100%) did not cross the permissible limit of NDWQS. In contrast with the current study, higher values of ammonia were reported in the previous studies of (Belbase *et al.,* 2024), (Koju *et al.,* 2014), (Ghartimagar *et al.,* 2020), (Shakya *et al.,* 2019), (Bajracharya *et al.,* 2022), and (Maharjan *et al.,* 2020) in which groundwater samples above the NDWQS limit were 47.15%, 11%, 34%, 33.3%, 100% and 40%, respectively. The maximum content of ammonia reported as 0.42 mg/L in the study of Hashim *et al.* (2018) in well water was lower than present study. Since ammonia can be transformed to nitrate, which has a very negative impact on health when consumed, ammonia levels in water may be hazardous to health. The high content of ammonia in water results from agricultural fertiliser, as well as animal faeces and domestic sewage (Nurain & Ang, 2015).

Arsenic (As) is a toxic heavy metal that has been classified as a group 1 human carcinogen. The high levels of As in drinking water cause different health toxicities like skin cancer, gangrene, haematological poisoning, and cardiovascular and mental diseases (Dibyendu & Datta, 2007). In this study, (0%) none of the water samples contained As above the NDWQS safe limit. In the study by Belbase *et al.* (2024), 0.81% of groundwater samples contained As, which were above the NDWQS limit. Arsenic contamination in water sources occurs mainly from natural sources as well as anthropogenic sources such as mining, pesticides, industrial effluents, etc (Garelick *et al.,* 2008).

Iron (Fe) is one of the most abundant element on Earth's surface, which mostly exist as oxide in ferric state (Kamble *et al.,* 2013). It is important that micronutrients having significant role in physiological processes in living creatures (FAO/WHO, 1988). The maximum concentration of iron was 1.11mg/L, obtained for a well water sample from Kathmandu, whereas a low concentration of iron was observed for the dump well from the Siraha area. In the previous studies (Belbase *et al.,* 2024), (Ghartimagar *et al.,* 2020), (Shakya *et al.,* 2019), and (Maharjan *et al.,* 2020), high iron content above NDWQS was reported in the groundwater samples. Similarly, (Parajuli & Shrestha, 2017) and (Bajracharya *et al.,* 2022) reported the content of iron in well water samples within the NDWQS limit, which was consistent with the present study. The high iron concentration in water does not pose a risk to public health, but affects the color, taste, deposits, and turbidity of water. The main sources of iron in water sources are due to weathering and dissolution of rock and minerals containing iron, use of iron coagulants, use of steel and cast iron pipes in water distribution, landfill leachates, sewage, and industrial effluents (Ramteke, Moghe & Sarin, 1988; Parajuli & Shrestha, 2017).

The sulphate (SO_4^{2-}) ion was high for the water sample from tap water, with a concentration of 10 mg/L; however, it was under the safe limit of NDWQS. The high SO_4^{2-} content of 116.5 mg/L and 13.78 mg/L was reported in tube well samples by Gyanju *et al.* (2017) and Esi *et al.* (2013), respectively, which exceeded the SO_4^{2-} concentration in the present study. All three water samples contained comparatively lower levels of the other chemical parameters, such as aluminum and fluoride, which were less than 0.01 mg/L and 0.1 mg/L, respectively, below the NDWQS standard. In the study of Nnorom *et al.* (2019) maximum value of aluminum in spring and well water sources was observed as 3.32 mg/L, which exceeded the level of aluminum in the present study. The occurrence of anions in the studied water samples followed the order of $Cl^- > NO_3^- > SO_4^{2-} > F^-$ in descending order, indicating Cl^- as the predominant anion and F^- as the least occurring ion in the examined water samples. The lower concentrations of anions ($Cl^- > NO_3^- > SO_4^{2-} > F^-$) and elements (Fe, Al, As) in the present study indicate less anthropogenic activities on the water sources in the present study (Paudel *et al.,* 2022).

According to microbiological characteristics, the hand pump and well water were free of faecal coliform; however, the spring source, or tap water, was contaminated with faecal coliform with a concentration of 6 CFU/100ml, exceeding the NDWQS limit of 0 CFU/100ml. Inoue *et al.* (2018) detected the prevalence of *E.coli* in spring water, shallow dug well, and dug tube well with maximum concentration of 5.1×10^1 CFU/100 mL, 1.2×10^5 CFU/100 mL, and 8.4×10^1 CFU/100 mL, respectively, in their study of microbial analysis of different sources of water in Kathmandu valley. The concentration of *E. coli* in the above study was higher than present study. Similarly, Bajracharya *et al.* 2022 and Koju *et al.* 2015 reported high microbial contamination of dug wells, which was in contradiction with the present study, as no microbial load was detected in the dug wells and hand pumps in the present study. The direct release of untreated sewage or municipal wastes into surface waters or into open spaces close to water sources may be the cause of microbial contamination in drinking water sources.

The present study deals with the assessment of water quality during a specific sampling period. However, the different temporal and seasonal changes and monsoon impacts have not been included, though they have a significant impact on water quality. Future studies are needed to incorporate the seasonal and temporal variation, as well as potential contamination risk during hydrological conditions, for the extensive analysis of water samples.

CONCLUSION

In the present study, the physicochemical and microbial characteristics of the water samples from the spring source (tap water), hand pump, and well of Kirtipur, Siraha, and Kathmandu were compared and analyzed. All the physicochemical parameters, such as temperature, pH, electrical conductivity, turbidity, total hardness, chloride, ammonia, nitrate, arsenic, iron, fluoride, sulphate, and aluminum, were within the safe limit of NDWQS. The maximum EC, TH, Cl^-, NH_3, SO_4^{2-} and NO_3^- content in studied water samples was obtained as 1167µS/cm, 422 mg/L, 135.6 mg/L, 1.2 mg/L, 5 mg/L and 17.7 mg/L, respectively. From the analysis of anions, Cl^- was the predominant ion in water samples under the present study. Additionally, it was observed that, except for the well water and dug well from Siraha and Kathmandu, the spring source in Kirtipur contained *E. coli* above the NDWQS limit. From physicochemical and microbial analysis, the water quality of the hand pump from the Siraha area is better in comparison with tap water from Kirtipur and well water from Kathmandu. It indicates that the water quality in Kirtipur, Nepal, is not highly satisfactory and directly fit for human consumption due to the presence of microorganisms. Depending on the flaws, the regular assessment of water quality, proper treatment methods, and suitable management of water sources should be encouraged to enhance the quality of water. Strict adherence to environmental protection laws and regulations is also necessary to preserve groundwater supplies and shield them from pollution. The continuous seasonal monitoring of water samples is highly recommended for future study to determine the temporal variability as well as potential contamination risk.

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