Quality appraisal of drinking water from different sources in Nepal

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Abstract: This research was investigated to evaluate the quality assurance of water from different sources. All together 250 water samples (135 well water, 48 boring water, 50 treated water, and 17 tap water) were received from different parts of Nepal from December 2019 to April 2020. The physicochemical parameters of water samples were performed according to the standard methods for the examination of water and wastewater. The membrane filtration technique was applied for the determination of Total Coliform bacteria. The measurements of water quality parameters were compared with the upper and lower limits of the National Drinking Water Quality Standards (NDWQS), 2005. Out of 135 well water samples, pH (1.48%), conductivity (2.22%), turbidity (42.96%), total hardness (4.44%), iron (54.07%), ammonia (48.88%), and nitrate (2.22%) elevated values compared to National Drinking Water Quality Standards, 2005. Likewise, 2.08%, 6.25%, 64.58%, 4.1%, 47.91%, and 58.33% of boring water samples showed higher values than the National Drinking Water Quality Standards for pH, conductivity, turbidity, total hardness, iron, ammonia, respectively. Conductivity, total hardness, chloride, and iron were found below the standards for both treated and tap water samples. Arsenic concentration was found within the standard for all water samples while 0.74% of well water samples showed a higher concentration of chloride compared to the standard. Results revealed that the minimum and maximum concentrations of some parameters were found to vary among the water sources. Among the total water samples, 94.8% well water, 76.4% tap water, 56.0% treated water, and 14.6% boring water samples showed the presence of coliform bacteria. This concludes that most of the water sources were polluted with fecal contamination and without proper purification may lead to the risk of waterborne diseases. Therefore, systematic and regular monitoring of water sources should be implemented to maintain water quality.

Keywords: Water sources; Physico-chemical parameters; Microbiological parameter; NDWQS.

Introduction

Human lives excessively depend on water for several inevitable purposes. However, its safety, and ease of availability are still questionable concerning scenarios in different cities. In developing countries like Nepal, water is a scarce resource, and around the world, 663 million individuals don't approach safe water[1]. Safe drinking water is a crucial element for human wellbeing, which affects the socio-economic development of a country[2]. Due to rapid urbanization and anthropogenic activity, Earth's natural environment has been depleted and it has negatively impacted human health. In Nepal, the major sources of water are acquired from surface sources, waterways,

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streams, and lakes. These drinking water sources are mostly polluted with direct disposal of domestic and industrial wastes without proper treatment and cause various sorts of irresistible infections due to the presence of various sorts of microorganisms in water.

Appropriate water supply service is one of the most essential indicators of good public health index and wellbeing3. Globally, around 2 billion individuals use unsafe drinking water defiled with defecation. Due to contaminated drinking water, 4, 85,000 diarrheal deaths occur each year[4]. Fe, As, Zn, Ni, Co, contamination in drinking water also have a serious health impact because many of them are highly toxic to human physiology, bio-accumulative in nature, and remain in the environment for a longer period[5]. People get exposed to these metals which cause serious health issues like cancer, and diabetes. Hence, heavy metal polluted water has also resulted in high death rates globally[6].

For human consumption drinking water should be free from contamination with pathogenic microorganisms and a water distribution system must ensure the supply of drinking water of health standards. The presence of E.coli, Klebsiella, Citrobacter, and Enterobacter species in water is a possible sign of the presence of pathogenic organisms. Clostridium perfringens, Salmonella, and protozoa which cause diarrhoea, giardiasis, dysentery, and gastroenteritis, are normal among provincial tenants of non-industrial nations[7, 8].

For the assessment of water quality, the water quality measures are compared with the tested samples. Physical, chemical, and biological factors should be persistently checked to get information about the water and set guidelines for the planned reasons. Only by comparing with the specified criteria, judgment can be made about the acceptability of water for a particular purpose[9]. Hence, the main purpose of this research was to examine the current status of microbiological parameters in the water from different sources and to assess its adequacy for drinking with respect to NDWQS, 2005.

Materials and methods

Altogether 250.0 water samples were received in the Environment and Climate Study Laboratory of Nepal Academy of Science and Technology (NAST), Khumaltar, Lalitpur from various locations in Nepal. The water sample was collected following the guidelines provided by APHA. The water samples were analyzed for physicochemical and microbiological (Total coliform count) parameters as indicated by the standard technique for the examination of water and wastewater[10]. Water samples were tested immediately after the arrival of the samples at the laboratory. In case of delayed analysis, the samples were preserved at 4 °C[11]. The findings of the research have been assessed by comparing each parameter with National Drinking Water Quality Standards, 2005[12].

Physicochemical analysis

All the physicochemical parameters were analyzed using the standards as described in Table 1.

Microbiological analysis

For the enumeration and identification of coliforms, a 100.0 mL water sample was filtered through a sterile membrane filter made of cellulose ester pore size 0.45 µm, which traps the microorganisms. Then, the filter paper was placed on M- Endo agar plate with the help of sterile forceps. The plates were incubated at 37.0 °C for 24.0 hours. Since, M-Endo agar is used for the detection of coliform bacteria. As an internal control, one extra M- Endo agar plate was cultured along with samples to validate the findings from water sources.

Results and discussion

A total of 250.0 water samples from various sources such as well, boring, treated, and tap water were received from different places in Nepal and were analyzed for ..physicochemical and microbiological parameters. Of the total samples tested (Figure 1), most of the samples 127.0 (50.8%) were from Lalitpur, followed by 84.0 (33.6%) from Kathmandu and 29.0 (11.6%) from Bhaktapur while 10.0 (4%) water samples were from other places (Kavre, Pokhara, Sindhuli, Sindhupalchowk, Siraha, and Udayapur)

Table 1. Methods applied for measurement of Physicochemical and micro biological parameters

Parameters	Units	NDWQS, 2005	Methods/ Instruments
Physical			
Temperature	°C		Thermometer
pH		6.5-8.5*	Benchtop pH meter (Thermo Scientific Orion Star A111)
Conductivity	µS/cm	1500.0	Conductivity meter (HI8633 HANNA 9)
Turbidity	NTU	5.0 (10.0)	Nephelometer (HANNA)
Chemical			
Hardness (as $CaCO_3$)	mg/L	500.0	EDTA Titration
Chloride	mg/L	250 .0	Argentometric Titration
Iron	mg/L	0.3 (3.0)	Phenanthroline Spectrophotometry (Agilent Technology Cary UV/Vis spectrophotometer)
Arsenic	mg/L	0.05	Colorimetric kit method (QUANTOFIX® Arsenic 10 (Macherey-Nagel Germany)
Ammonia	mg/L	1.5	Colorimetric kit method (VISOCOLOR® alpha Ammonium (Macherey-Nagel Germany)
Nitrate	mg/L	50.0	Colorimetric kit method (VISOCOLOR® alpha Nitrate (Macherey-Nagel Germany)
Microbiological			
Total coliform count	CFU/100 mL	0.0	Membrane Filtration (MF)

Maximum and minimum limit () Tolerable range

The majority of samples were received from the Lalitpur district. The minimum and maximum value of the temperature of all water samples was 12.0 °C and 23.0 °C (Table 2). The hydrogen ion concentration (pH) value of 1.5% of well water, 2.1% of boring water, and 4.0% of treated water samples was above NDWQS, 2005. The minimum and maximum value of pH of the tap water samples was 6.9 and 8.3 (Table 2), within the standard value. Although there is no direct relationship between human health and the pH of water, it affects many other water quality parameters. Hence, it should be considered a major factor to control corrosion of water pipes in the water distribution system. pH also affects the disinfection efficiency so any health-related problems could be due to increased consumption of metals from plumbing and pipes or deficient disinfection[13].

The value of electrical conductivity (EC) of 2.2% of well water samples and 6.2% of boring water samples were above NDWQS, 2005 (Figure 2). In the study, the minimum

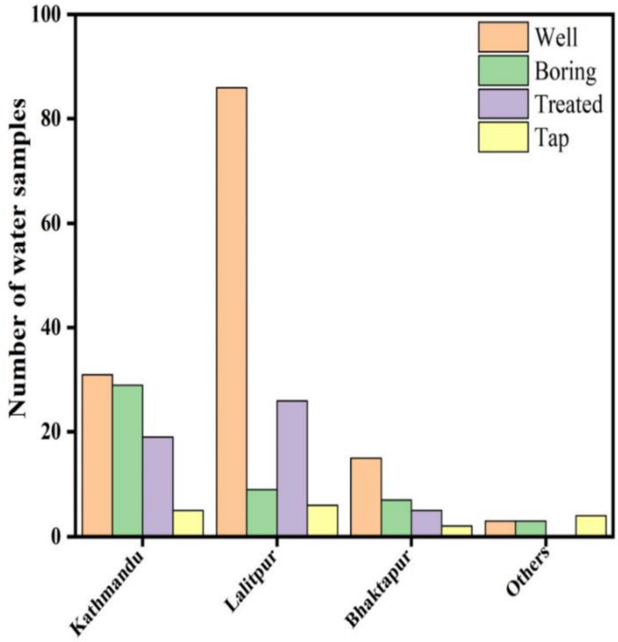

Figure 1: Water samples collected from different places of Nepal

and maximum values of electrical conductivity of well water and boring water were 66.0 µS/cm and 1767.0 µS/cm, and 37.0 µS/cm and 2250.0 µS/cm respectively (Table 2). Electrical conductivity (EC) indicates the presence of the total amount of dissolved matter in water[13]. High EC in water is due to the presence of metallic ions and dissolved salts [14]. High conductivity lowers the aesthetic value of the water by giving a mineral taste to the water. Water with high conductivity may cause corrosion of the metal surface of equipment such as boiler[13].

Turbidity of 42.9% well water, 64.6% boring water, 4.0% treated water, and 5.88% tap water samples with maximum values of 618.0 NTU, 226.0 NTU, 7.6 NTU, and 10.3 NTU (Table 2) were above NDWQS, 2005. Turbidity can interfere with the disinfection process and also impacts hydraulic problems in the distribution systems [15, 16]. The presence of calcium and magnesium ions in the water is responsible for the hardness of the water. The study revealed that the total hardness of 4.4% of well water samples and 4.1% of boring water samples were above standard whereas treated and tap water samples were within the standard with minimum and maximum values of 8.0 mg/L and 446.0 mg/L, and 20.0 mg/L and 340.0 mg/L respectively (Table 2). However, the total hardness hardness was within the standard limit in the previous valley[17]. The hardness of drinking water is connected with cardiovascular disease, growth retardation, reproductive failure, and other health problems. Not only had this, but a high concentration of hardness in water also caused a laxative effect[18].

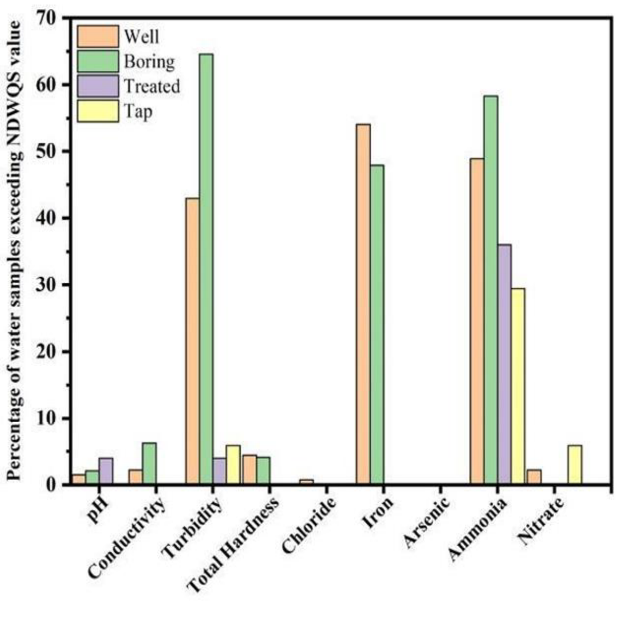

Figure 2: Percentage of water samples exceeding NDWQS value

Chloride is considered one of the major inorganic anions in water. The maximum concentration of chloride for boring, treated, and tap water samples were found to be 220.0 mg/L, 227.2 mg/L, and 10.3 mg/L respectively, indicating that the samples were within the standard (Table 1), which was in accordance with the study carried out in treated water of Kathmandu valley[19]. The chloride concentration is high in well water (0.7%) (Figure 2) with a maximum value of 541.02 mg/L (Table 2) because sodium chloride is a common particle of the diet that goes unaltered through the digestive system. Industrial effluents also result in the increment of chloride content[20]. The chloride concentration in water indicates sewage pollution which is also responsible for fecal contamination[21].

Among the water sources under the present investigation, 54.1% of well water samples and 47.9% of boring water samples (Figure 2) were intensely contaminated with iron with maximum values of 10.0 mg/L and 3.0 mg/L, respectively which corroborates with a study conducted in water samples where 66.7% of well water samples and 100.0% of boring water samples showed an iron concentration above NDWQS, 2005[22]. A high concentration of iron in water brings out changes in color, taste, and the odor of water, leaving smudges on garments and corroding water pipe lines[23]. Excessive iron content in water results in the deposition of slime layer in water pipelines which promotes the growth of iron bacteria[24].

Since the extraction and use of groundwater from deep boring and well water for drinking purposes has been overwhelmingly increased, the presence of arsenic is one of the arising issues in drinking water. In the present study, all the tested water samples were liberated from arsenic contamination. The maximum values of arsenic for well water samples were found to be 0.05 mg/L while boring, treated and tap water samples were found to be 0.01 mg/L (Table 2) showing that all the water samples had acceptable arsenic concentrations. But the studies carried out in the groundwater of Kathmandu valley, arsenic content was above the standard limit [25, 26]. Despite occurring naturally in water, arsenic can be distributed in higher amounts through volcanic activity, forest fires, and human actions [27]. Consumption of drinking water with an elevated arsenic concentration causes arsenicosis; also known as arsenic poisoning with indications of skin lesions like hyperpigmentation, hyperkeratosis, gangrene, and cancers in particular lung and bladder cancer11. Concerning ammonia pollution, 48.9% of well water samples, 58.3% of boring water samples, 36.0% of treated water samples, and 29.4% of tap water samples (Figure 2) showed higher ammonia concentrations compared to the standards. In a similar study, 41.0% of well water, 35.0% of boring water, and 8.8% of tap water samples were found to be contaminated with ammonia [28-30], which supports the finding of the present study. Sewage contamination and ammonification of organic matter in the water distribution system leads to a high concentration of ammonia in water, which also causes corrosion problems and aesthetic issues[31,32].

Table 2: Minimum and maximum values of physicochemical parameters of well, boring, treated and tap water.

Parameters	Well water		Boring water		Treated water		Tap water	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Temperature (°C)	12.0	23.0	12.0	23.0	12.0	23.0	12.0	23.0
pH	5.8	9.0	5.9	8.6	5.6	8.7	6.9	8.3
Electrical conductivity(µS/cm)	66.0	1767.0	37.0	2250.0	11.0	1451.0	46.0	839.0
Turbidity (NTU)	0.46	618.0	0.59	226.0	0.35	7.6	0.51	10.3
Hardness (mg/L)	4.0	930.0	20.0	766.0	8.0	446.0	20.0	340.0
Chloride (mg/L)	1.4	541.0	2.8	220.0	1.4	227.2	2.8	63.9
Iron (mg/L)	0.0	10.0	0.0	3.0	0.0	0.3	0.0	0.3
Arsenic (mg/L)	0.0	0.05	0.0	0.01	0.0	0.01	0.0	0.01
Ammonia (mg/L)	0.0	3.0	0.0	15.0	0.0	3.0	0.0	15.0
Nitrate (mg/L)	0.0	80.0	0.0	50.0	0.0	50.0	0.0	75.0

Of the total samples studied, 2.2% of well water samples and 5.9% of tap water samples had nitrate concentrations above the standard (Figure 2) whereas boring water samples and treated water samples had nitrate concentrations within the standard with a maximum value of 50.0 mg/L (Table 2). In a similar study18, 6.0% of well water and 8.0% of boring water samples had nitrate concentrations above NDWQS, 2005, which was similar to the results of the present study. Sewage and agricultural runoff might be the potential source of nitrate contamination in water. It is very hard to eliminate nitrate and the disinfection procedure might change it to a harmful form. Nitrate contamination may cause various kinds of health hazards such as methemoglobinemia[32].

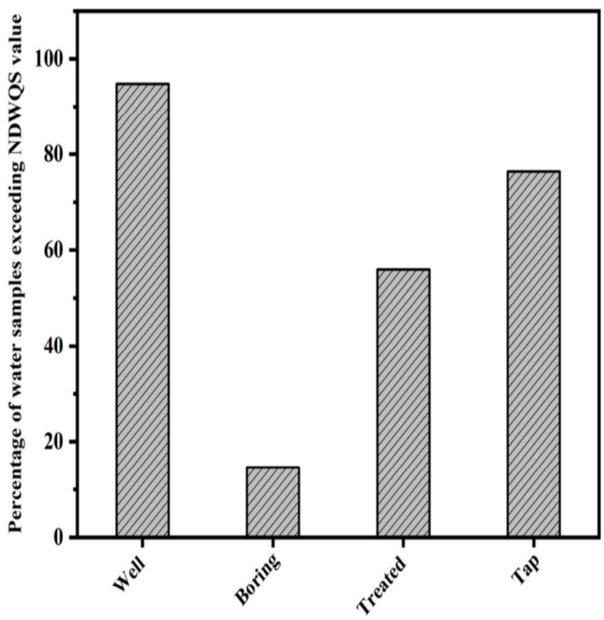

Figure 3: Presence of total coliform bacteria in water samples

In many developing countries like Nepal bacterial contamination of drinking water is a major issue. One of the most common waterborne diseases is diarrhea among children under five years[33]. Coliforms are the major indicators that represent fecal contamination of water. These microorganisms demonstrate the chance of the presence of other pathogenic organisms of fecal origin in drinking water. In the study, 94.81% of well water samples, 14.58% of boring water samples, 76.4% of tap water samples, and 56% of treated water samples contained coliform (Figure 3) indicating that these sources of water are not suitable for drinking purposes without applying any drinking water treatment procedure. Several similar studies were carried out in different places of Kathmandu and found consistent results on the contamination of coliform[34-36] which supports the finding of our study. The bacterial pollution in groundwater may be generally the most common way of dealing with sewage invasion, and drainage from the polluted river flowing, unhygienic practices such as unsanitary septic tanks constructed near the water sources[24].

Conclusion

The water quality assessment and continuous monitoring are crucial to understanding the status of drinking water pollution and the vitality of a safe drinking water supply chain in developing countries like Nepal. This study revealed that well water, boring water, treated water, and tap water were not appropriate for direct utilization due to the presence of both microbiological and inorganic pollutants. Fecal pollution reflected by the presence of coliform bacteria was a key problem in the majority of water sources and therefore, an appropriate technique for removal of microorganisms is recommended.

In conclusion, there is an imperative need for regular and systematic analysis, monitoring, and disinfection of water supplies to maintain the quality of water.

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