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Potability of Bottled and Jar Water in Kathmandu Valley: A Comparative Analysis

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Abstract

Access to safe and clean drinking water is recognized as a fundamental human right. Kathmandu faces a number of problems in drinking water distribution, packaging and its availability. Human right assures for safe drinking water for healthy and prosperous life. This research aimed to compare drinking water quality of bottled and jar water in Kathmandu Valley on which most people are dependent on. 15 samples of each bottled water and jar water were collected from Kathmandu Valley. Both the physico-chemical and bacteriological parameters were analyzed. The physico-chemical parameters of bottled and jar water were compared statistically. Weighted arithmetic water quality index (WQI) method was used to oversee the quality of the water samples providing weightage to each parameter based on their standard value provided by National Drinking Water Quality Standards (NDWQS). Seven samples from bottled water and three samples from jar water had iron concentration greater than the maximum permissible limit set by NDWQS. Similarly, five samples from bottled water had pH value less than 6.5. Most Probable Number (MPN) test indicated all samples to be free from microbial contamination. There were significant differences between bottled water and jar water in terms of temperature, pH, ammonia, phosphate and iron ($p<0.05$). Among the measured parameters, pH, iron, and ammonia were found to be key contributors influencing the WQI, highlighting their value deviation from standard value. Majority of the samples from bottled water did not comply with the standards with respect to pH and iron concentration. The WQI assessment and bacteriological test indicated that all sampled waters were of good quality for drinking purposes. However, regular monitoring is recommended to ensure the continued safety and quality of drinking water in Kathmandu.

Keywords: *Drinking Water, MPN Test, Suitability, Weighted arithmetic, WQI*

Introduction

Water is found everywhere and in different forms but only 2.5% is freshwater, the water that we are directly connected with (Chen et al., 2022). The actual amount of total renewable water resources in south east Asia was almost 11,632 m^3 per person per year in 2012 (Pandey & Shrestha, 2016). Only 18% of the total population in 2020 uses safely managed drinking-water services in Nepal, whereas 74% of the global population uses safely managed drinking water (UN-Water, 2021). In Kathmandu Valley, the average water production of Kathmandu Upathyaka Khanepani Limited (KUKL) is only 300.02 million litres per day (MLD), while the demand is 506 MLD (KUKL, 2023). The remaining demand is fulfilled by either unprocessed water like well, tube well and boring or by processed water like jar water and bottled water. Due to the lack of fulfillment of drinking water supply in Kathmandu Valley, demand of jar water is accelerating (Kharel, 2019). Out of 550 bottling plants in Nepal, 150 water bottling plants are based in Kathmandu Valley. Private water bottling plants fulfill almost 75% of water demand (Prasain, 2020). Due to the easy availability and accessibility of purified water, bottled water has gained popularity in the market (Rai et al., 2015). This has led to increasing bottled water consumption at sharp rates in Nepal alike all over the world (Fiket et al., 2007 & Rai et al., 2015).

Timilshina et al. (2013) revealed that in response to the increasing demand and consumption of bottled water in the Kathmandu Valley, concerns have been raised over water quality. In this study, conducted approximately a decade ago, revealed 90% of bottled water samples exceeded the acceptable limits for heterotrophic bacterial counts. Rai et al. (2015) reported 62.5% of samples of bottled water had heterotrophic count above acceptable range (<50 CFU/0.1 mL) and 75% crossed World Health Organization (WHO) guidelines (0 CFU/0.1 mL) and *Escherichia coli* was observed in 13 samples out of 25 analyzed samples in eastern Nepal. In contrast, Neupane et al. (2019) analyzed the quality of sealed bottled water of different brands with Nepal's Drinking Water Quality Standard (NDWQS) in Bhaktapur, and it was found that none of the samples was microbiologically contaminated; however, 69% of the samples did not comply with the standard pH limit.

Kambalagere & Puttaiah (2008) used a method where all the water quality parameters were provided individual weightage, that results to the single index indicating the water quality status. The method categorized the index value into 5 categories from 0-25, 25-50, 50-75, 75-100 and >100 resembling excellent, good, poor, very poor and unsuitable for drinking water, respectively. In this study, 'jar water' meant a 20-litre bottle of water and 'bottled water' meant a one-litre bottle of water that are commercially produced by water processing and filtering companies. These companies claim bottled water to be safe for drinking purpose. Therefore, this study aimed to compare the quality of bottled water and jar water in Kathmandu Valley (Kathmandu, Bhaktapur and Lalitpur districts). The results were also compared with the National Drinking Water Quality Standard (NDWQS), 2022 and WHO Guidelines.

Materials and Methods

Study Area

Kathmandu Valley, situated in central Nepal, is a tectonic basin surrounded by the green hills, with an average elevation of approximately 1,300 meters above sea level. The valley lies within the extent of 27°32'13" and 27°49'10" N latitudes and 85°11'31" and 85°31'38" E longitudes. It serves as the political, economic, and cultural hub of Nepal and encompasses three historically significant cities:

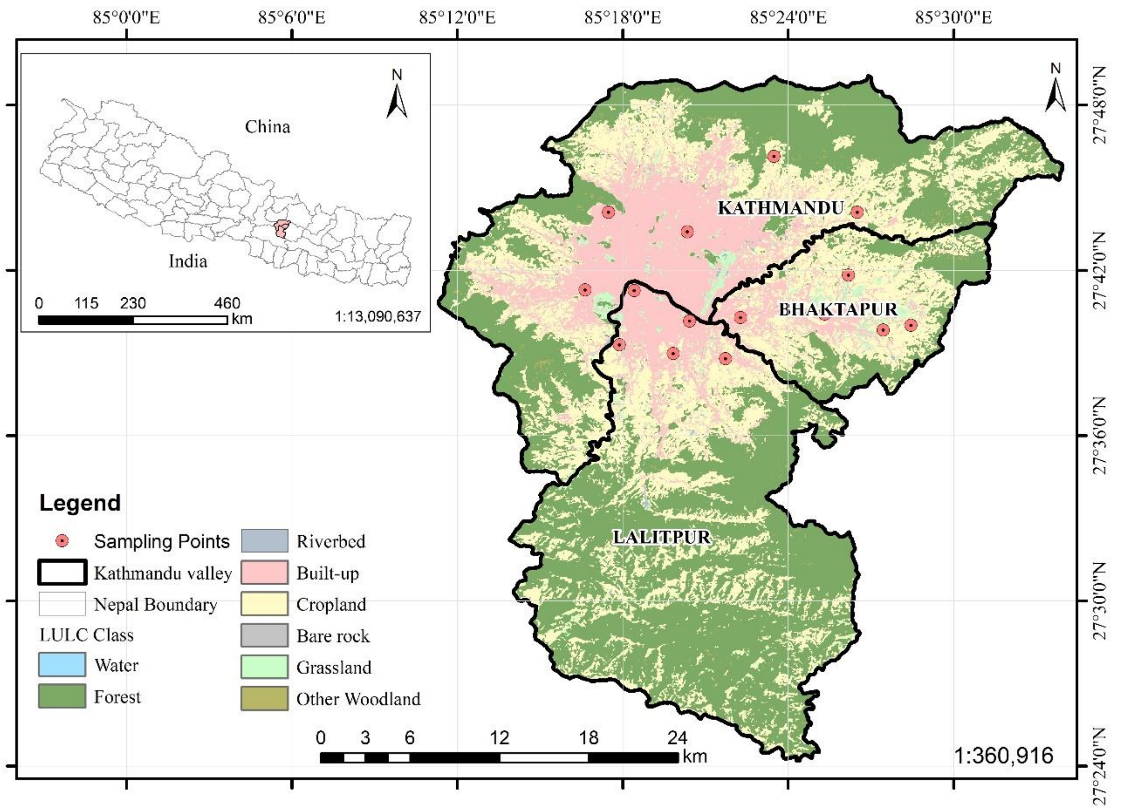

Figure 1: Sampling area in Kathmandu Valley including Kathmandu, Bhaktapur and Lalitpur districts

Kathmandu, Lalitpur, and Bhaktapur (Pandey et al., 2023). It covers a total of about 899 km^2 area and population of 3,025,386 (NSO, 2024). The major sources of drinking water in the valley are tap water, dug wells, shallow tube wells, deep tube wells, stone spouts (*dhunge dharas*), tanker truck water and processed water. These water are also used for domestic purposes (Sarkar et al., 2022). The valley is renowned for its rich cultural heritage, featuring several UNESCO World Heritage Sites that reflect the deep influence of Hindu and Buddhist traditions. Rapid urbanization has led to challenges such as environmental degradation, air pollution, and water resource depletion. Despite these pressures, the valley remains a center for academic research, tourism, and cultural preservation. The valley is traversed by the Bagmati River by mixing of various rivers such as Bishnumati, Manohara, Tukucha, Nakkhu, etc.

Sampling Design and Methodology

The drinking bottled and jar water samples were collected from the districts of Kathmandu Valley i.e. Kathmandu, Bhaktapur and Lalitpur from various shops, hotels, hospitals and shopping malls. The sampling was carried out by using stratified random sampling method in which a total of 30 drinking water samples were collected from the valley. It includes 15 bottled water and 15 jar water of different brands, five-five from each district. Sample collection was carried out in the month of December (Winter Season), 2020. Bottled water and jar water registered in Department of Industry under the Ministry of Industry, Commerce, and Supplies were only used. The samples collected were tested in the laboratory of Environmental Department of Tri-chandra Multiple Campus, Ghantaghar.

The temperature, pH, TDS, Electrical Conductivity were measured at the field. Later, the samples were stored in the ice cooled bag at very low temperature and other physicochemical and microbiological test were done within 48 hours of collection. The sampling bottle for collection of jar water were sterilized in the autoclave at 121°C for 15 minutes. The physical, chemical and microbiological quality of drinking water samples were examined as per the methods (Table 1) described in APHA (2017). Weighted arithmetic water quality index (WQI) method classified the water quality based on the purity level of parameters measured. It is calculated using the equation (i).

$$WQI=\frac{\Sigma q_i W_i}{\Sigma W_i} \quad \text{.......................(i)}$$

(Tyagi, Sharma, Singh, & Dobhal, 2013)

Where q_i is the quality rating scale and W_i is the unit weight of the i^{th} water quality parameter.

Data Analysis

The data were collected and stored in MS Excel 2013. The data thus obtained were compared with

Table 1: Tested parameters, methods and the instruments used for analysis

S.N.	Parameters	Methods	Instruments
1	Temperature (°C)	Thermometric	Thermometer
2	pH	Potentiometric	pH Meter
3	Electrical Conductivity (µS/cm)	Conductivity	EC 59 Milwaukee
4	Total Dissolved Solids (ppm)	TDS meter	EC 59 Milwaukee
5	Iron (mg/L)	Spectrophotometric (Phenonthroline method)	LI-285 Microprocessor UV-VIS Single Beam Spectrophotometer
6	Calcium Hardness (mg/L)	EDTA method	Glassware (Titration)
7	Total Hardness (mg/L as $CaCO_3$)	EDTA method	Glassware (Titration)
8	Chloride (mg/L)	Argentometric Titration method	Glassware (Titration)
9	Phosphate (mg/L)	Spectrophotometric (Stannous Chloride)	LI-285 Microprocessor UV-VIS Single Beam Spectrophotometer
10	Ammonia (mg/L)	Spectrophotometric (Phenate method)	LI-285 Microprocessor UV-VIS Single Beam Spectrophotometer
11	Total Coliform & Fecal Coliform (Cfu/100 mL)	MPN method	Test tubes, Autoclave, etc.

the WHO (2017) guidelines and NDWQS (2022). Also, the result of water quality parameters of bottled water and jar water were also compared with each other. Statistical analysis was carried out using Rstudio version 4.3.1 (R Core Team, 2023). The normality of the data was tested by Shapiro-wilk test. So, Student's t-test were applied where the p-value > 0.05 from Shapiro-wilk test and remaining were dealt with Mann-Whitney U test (p-value < 0.05). The level of significance for the statistical test was considered to be 5% (0.05).

Results and Discussion

The comparative analysis of bottled and jar water samples was carried out where physical and chemical parameters were analyzed along with total coliform and *E. coli* as biological parameters.

The analysis during the study showed that the temperature of bottled water was in the range of 9.2°C to 12°C whereas 11.8°C to 12.9°C for jar water. Temperature of samples were measured during the time of collection and they were stored in the room temperature at the site of sample collection. The optimum temperature required for water is 25°C. The reason behind low temperature of water samples might be the low temperature of surrounding as the sample collection was carried out during winter season based on heat transfer equation (Malasri et al., 2015). Though there is no direct effect of temperature over the drinking water, there is no such variations in temperature of bottled and jar water. The pH value for neutral water is 7.5 at 0°C, 7 at 25°C and 6.5 at 60°C (APHA, 2017). Thus, temperature plays the key role in determining pH and change in water temperature effects the other water parameters such as TDS, EC as well as the microbial growth and development. Although the temperature of bottled and jar water was within the optimum temperature range, there is a significant difference between their temperature.

The high concentration of TDS was observed as 47 mg/L in bottled water and 125 mg/L in Jar water whereas the lowest concentration was 6 mg/L in bottled and 8 mg/L in jar water. All the water samples including both bottled water and jar water lie within the maximum permissible limit given by NDWQS making the water suitable for drinking. The TDS value below 300 mg/L is regarded as the excellent quality in terms of palatability of Drinking Water. Thus, all the water samples can be regarded as excellent in terms of palatability as their value lie below 300 mg/L (Fig. 2). However, the TDS means all sorts of ions dissolved in water including nitrates, arsenic, copper, iron, etc. which may possess the health risks also.

Similarly, there was a no significant difference between the TDS in the bottled water and the jar water. Statistically, we can say that the total dissolved solids in the bottled water and jar water are almost same. Hence, both sample water has no quality difference.

The highest value of electrical conductivity was observed as 93 µS/cm for jar water and 249 µS/cm for bottled water whereas lowest value was 12 µS/cm for bottled water and 16 µS/cm for jar water. The maximum permissible limit is 1500µS/cm given by WHO and NDWQS, and all the samples lie within the standard limit. As temperature, EC also has no direct influence on drinking water quality but it is an indicator of TDS. According to Selvaraj & Joseph (2009), the ratio of TDS to EC always lies within the range of 0.55 to 0.7.

The pH value of bottled water was in the range of 6-6.9 and the jar water were in the range of 6.8 - 7.9. According to the standard set by NDWQS, the range for pH for drinking water is 6.5 to 8.5. Hence, five samples of bottled water were below the acceptable limit. Neupane et al. (2019) & Maskey et al. (2020) also analyzed the bottled water quality of Bhaktapur and Pokhara valley respectively which found most of the sample water slightly acidic in nature. According to WHO, health effects are most pronounced in pH extremes. The pH below 4 can cause irritation and worsen existing skin conditions due to its corrosive effects whereas pH above 11 can causes skin, eye and mucous membrane irritation (WHO, 2017). pH value above 8 makes chlorine disinfection less effective. Both bottled water and jar water are treated with chlorine for disinfection and the effectiveness of chlorine will get reduced if pH is greater than 8. Likewise, the p-value ($p < 0.05$) shows that the bottled water and jar water have significant difference between their pH values.

The concentration of chloride in bottled water was in the range of 8.52 mg/L to 14.06 mg/L whereas jar water was in the range of 2.84 mg/L to 19.88 mg/L. The maximum permissible limit for chloride is set as 250 mg/L as per WHO guidelines and NDWQS, and all the water samples are within the acceptable range which shows the suitability for drinking purpose. In fact, the water samples contain relatively low concentration of chloride. Low to moderate concentration of chloride in the drinking water adds palatability in drinking water, however, excess concentration makes water unpleasant for drinking. Statistical analysis shows that the chloride in jar and bottled water have no any significant difference and ensure the sound quality.

Hard water requiring considerably more soap to produce a lather. Packaged water can exhibit diverse characteristics, including being naturally rich in minerals, naturally soft, or demineralized (WHO, 2017). The concentration of calcium was in the range of 2 mg/L to 26mg/L for bottled water and the range of 4 mg/L to 60 mg/L for jar water. The maximum permissible limit for calcium is 200 mg/L according to NDWQS. Its value is very low as compared to the standard. Higher the content of calcium in water, harder the water and higher hardness increases the unsuitability for drinking purpose. The total hardness of water is the measure of calcium and magnesium as $CaCO_3$ and $MgCO_3$. The total hardness of the ranges from 6 mg/L to 30 mg/L for bottled water and 6 mg/L to 50 mg/L for jar water. The maximum permissible limit for drinking water is 500 mg/L. Thus, all the water samples are safe for drinking. The p-value from the t-test shows that there is no significant difference between the jar and bottled water in terms of calcium hardness and total hardness.

Iron in water is present in both ferric and ferrous form. The iron content in bottled water ranges from 0.09 mg/L to 0.60 mg/L and from 0.01 mg/L to 0.32 mg/L for jar water. Seven water samples from bottled water and two water samples from jar water contained iron greater than the permissible limit set by WHO guidelines and NDWQS i.e., 0.3 mg/L. There is significant difference between the quality of jar water and bottled water with respect to the availability of iron in the water ($p < 0.05$). In addition, in the current research done by Burlakoti et al. (2020), the iron level on some jar water in Kathmandu Valley were above the permissible level however the average level was below 0.3mg/L. NDWQS (2022) clearly state that the iron concentration gets objectionable if it crosses the limit of 3 mg/L.

The concentration limit for ammonia in drinking water is 1.5 mg/L as set by NDWQS. The value above 1.5 is unacceptable and regarded as unsafe for drinking. The ammonia concentration in bottled water ranged from 0.007 mg/L to 1.188 mg/L and from 0 mg/L to 0.22 mg/L in jar water. All the samples fall within the standard set by NDWQS. Skin corrosions, eye irritation, respiratory tract irritation, etc. are the probable health effects if ammonia concentration is higher. Statistically, there is a significant difference between the jar and bottled water ($p < 0.05$). In the study carried by Burlakoti et al. (2020), we can find the 48% of jar water samples had ammonia content greater than the permissible limit. It is also an indicator of water contamination, primarily due to sewage and animal waste (WHO, 2017).

The phosphate in drinking water is not provided in the NDWQS but it ranges from 0.003-0.08 mg/L in jar water and 0.03-0.10 mg/L in mineral-bottled water. Phosphate with its low concentration can affect the growth of algae in water (Yaakob et al., 2021). The t-test shows that there is a significant difference in jar and mineral-bottled water ($p < 0.05$).

Microbial test for water before packaging is indispensable (Joseph et al., 2018). According to NDWQS, the *E. coli* should be in 100% samples and total coliform should be 0 in 95% samples. However, all the water samples were carried out for MPN test and none of the samples showed positive result. Even in the confirmatory test, colonies were not formed after incubation in the agar solution. Both the bottled water and jar water were *E. coli* and total coliform free. This microbial test shows that both water samples were contamination free and safe for drinking.

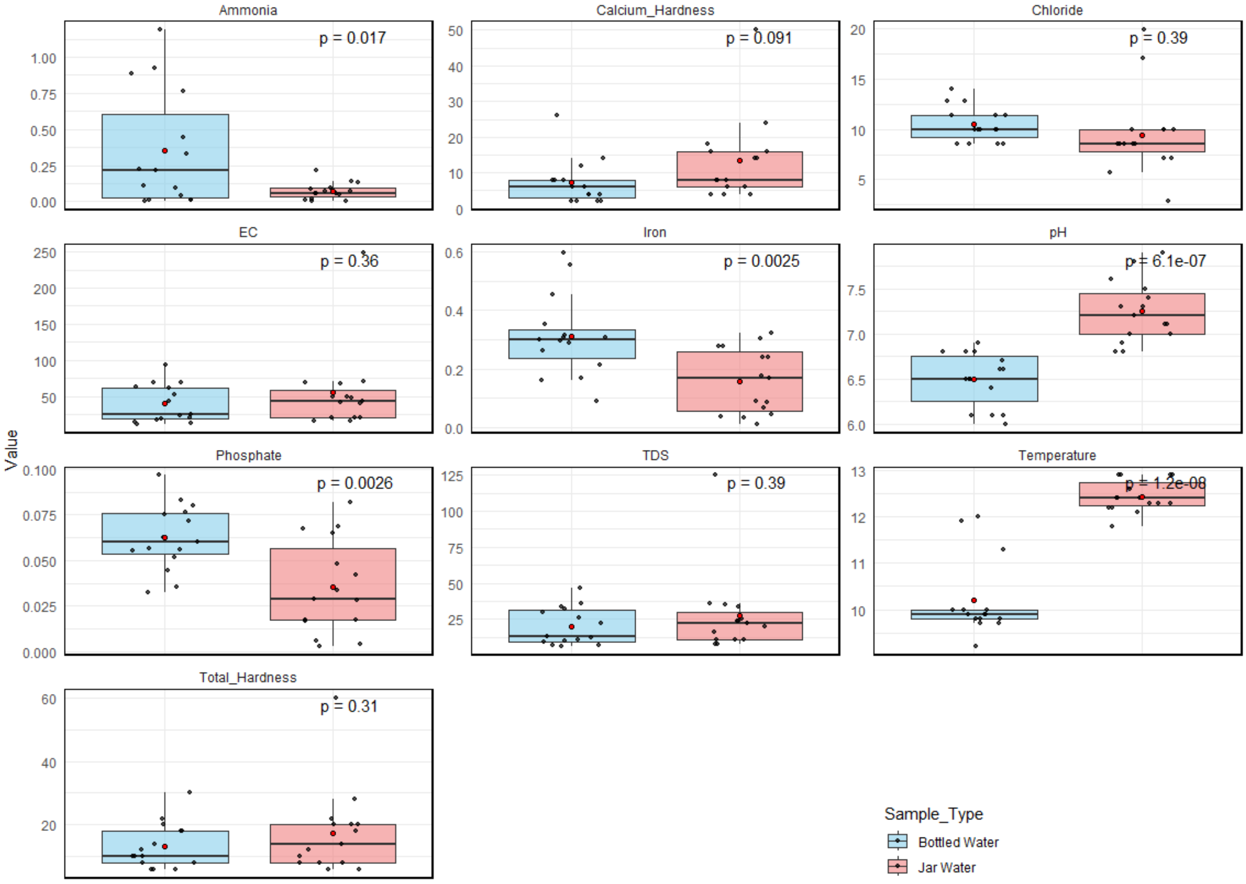

Figure 2: Comparison of physico-chemical parameters of both jar and bottled water

The study done by Neupane et al. (2019) and Yousefi et al. (2018) are comparable to the result of our analysis. None of the water samples were contaminated in those study also which were carried out at Bhaktapur and Sari (Iran) in bottled water respectively. Despite the result, the study carried by Maharjan et.al (2019) revealed that 92% of jar water were contaminated with Coliform bacteria. For a detailed investigation and comparison of water quality, it is necessary to conduct similar study with a large sample size. Rahmanian et al. (2015) on his study reported that one year should be given in minimum to collect the series of samples, analyze the trends and monitor the reliability of water. However, this study was done with a small sample size and only the limited physico-chemical parameters were studied.

The weighted arithmetic index can be influenced more by any parameters far above or far below the WHO guidelines, than that of just above or below the guideline value. The results of the weighted arithmetic water quality index were significantly influenced by parameters like pH, iron and ammonia concentration. The average WQI value is the cumulative result of all the given parameters that concluded both bottled water and jar water has good water quality with values 13.4 and 6.10 respectively (Fig. 3). However, on sample-wise calculation, all the jar water samples have WQI values less than 11 indicating excellent water quality. On the other hand, 4 bottled water samples have the WQI value ranging from 25-50 indicating good water quality and remaining eleven samples have WQI values less than 11 indicating excellent water quality. The result of weighted arithmetic WQI which is the cumulative result of each water quality parameter was good. Overall, the water quality of jar water was excellent (2.09 - 10.80) and bottled water was both excellent and good (2.02 – 48.47) as per the weighted arithmetic index method.

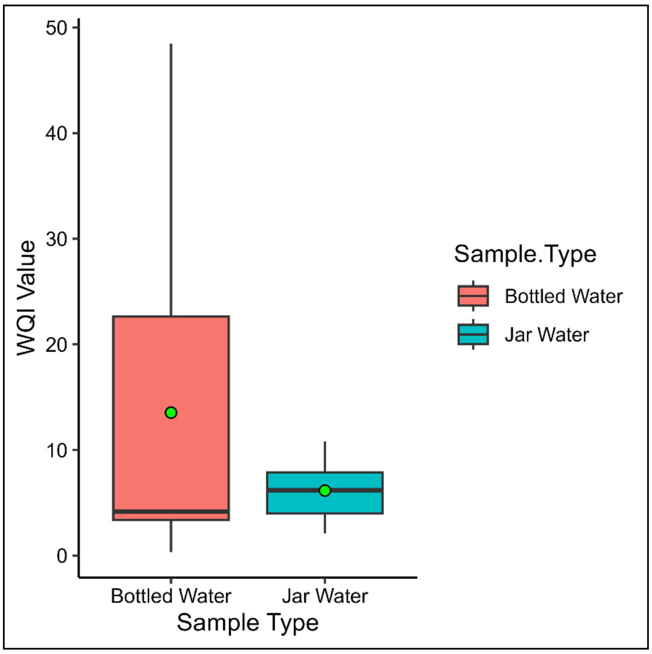

Figure 3: The WQI value of water samples of Jar and bottled water collected from Kathmandu Valley

Conclusion

Among the sampled bottled and jar water from the Kathmandu Valley, the values were found to be within the limits of NDWQS and WHO guidelines except for pH for bottled water and iron concentration in both jar and bottled water. Microbial test i.e., MPN test confirmed the absence of total coliforms in both the bottled and jar water. The Drinking Water Quality Index along with MPN test assures that both jar and bottled water were found to be safe for drinking in Kathmandu Valley. However, regular monitoring and assessment on available and assessable drinking water is necessary seasonally.

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