INTERNATIONAL JOURNAL OF ENVIRONMENT

Volume-8, Issue-3, 2019 ISSN 2091-2854

Received: 1 May 2019 *Revised: 19 Sep 2019* *Accepted: 5 Nov 2019*

STUDY OF COMPLIANCE OF SEALED BOTTLED WATER WITH NEPAL DRINKING WATER QUALITY STANDARD: A CASE OF BHAKTAPUR MUNICIPALITY, NEPAL

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Abstract

Bottled water is generally considered safe for drinking. However, several studies have reported the substandard quality of bottled water. Physico-chemical assessment of ten different brands of bottled water distributed in Bhaktapur Municipality was carried out from January 2018 to March 2018. In total, one hundred bottled water samples consisting of ten different brands were collected randomly from various retail outlets. Eight selected physico-chemical and microbiological parameters were analysed following standard methods, and the results were compared with the Nepal Drinking Water Quality Standard (NDWQS) (2005). Out of one hundred samples, sixty-nine samples did not comply with the standard pH limit. Other physico-chemical parameters were found to comply with the standard though variations were observed in the concentrations among different brands. Microbial contamination was not found in any brands of the bottled water samples considered in this study. However, it is necessary to examine other contaminants such as heavy metals, minerals, and chemicals to know the overall quality of water. Moreover, the regulatory bodies are required to strictly monitor water processing companies for the maintenance of the quality of bottled water.

Key Words: Drinking water; Bottled water; Ground water; Coliform; Water treatment

DOI: http://dx.doi.org/10.3126/ije.v8i3.26613

Introduction

Clean water is very essential for humans to live a healthy life for longevity as water quality determines the health of individuals and whole communities. Safe drinkable water is highly linked with the health status and wellbeing of humans (WHO, 1997; Sharma, et al., 2005). Several studies conducted in the past at different parts of Nepal reported the substandard quality of drinking water due to exceedance of physical, chemical and biological agents above safe limits (Warner, et al., 2008; Pandey & Shakya, 2011; Shakya, et al., 2012; Aryal, et al., 2012; Koju, et al., 2014). More than 10,000 children under 5 years old lose their lives annually by consuming contaminated drinking water (WaterAid, 2011). In 2016/17 alone, 23,742 cases of water-borne diseases were reported in Nepal, out of which 270 cases resulted in death (Maharjan, et al., 2018). People in Nepal are exposed to severe health risks due to water contamination via sewage, agriculture, and industrial effluent leading to the risk of typhoid, dysentery, and cholera every summer (Khadka, 1993). These diseases account for 15% of all illnesses and 8% of total deaths. These numbers increase to 41% of all illnesses and 32% of all deaths in children up to 4 years of age (Sharma, 1990).

As far as Kathmandu valley is concerned, the demand for water is 366 million litres per day (ML/D) whereas the city supply is only between 69 and 115 ML/D in dry and wet seasons (Udmale, et al., 2016) and this supply is irregular and intermittent. Thus there is an acute shortage of water supply in the valley. Therefore, people in the Kathmandu valley depend upon underground water sources like shallow tube well, dug well and deep boring as the supplementary sources to fulfil their water demand. However, both the city and underground water sources are contaminated with biological agents (Diwakar, et al., 2008; Shrestha, et al., 2013; Malla, et al., 2018). Sewage lines, septic tanks, open pit toilets, leaching from landfill sites direct disposal of domestic and industrial waste are the causes of deterioration of ground water quality in Kathmandu valley (Pradhanang, et al., 2012). Drinking water supply comes to contact with faecal materials from humans or other warm-blooded mammals (Gleick, 2002). A recent study reported the contamination of underground water sources with physical, chemical and biological agents exceeding the NDWQS limits (Shrestha, et al., 2018).

Therefore, the residents of the valley are compelled to use processed drinking water in the form of sealed jars and bottles as alternative sources of water supply, which are considered to be safe and easily available. Increased demand for processed water has resulted in the establishment of several water processing companies for the production and distribution of sealed jars and bottled water. There are more than 200 license bottled water manufacturers in the Kathmandu valley, and daily consumption of bottled water in the valley is estimated to be approximately about 3 million litres (Kathmandu Today, 2016). Though processed water is considered to be safe for drinking, their quality standards are questioned frequently. The Department of Food Technology and Quality Control (DFTQC), Nepal has already taken actions against different bottled water companies for not maintaining the hygienic condition as well as for not following the standard production practices (Kathmandu Post, 2016; Kathmandu Post, 2018). Several studies done in the past in Nepal (Timilshina, et al., 2012; Pant, et al., 2016) and other parts of the world (Bharath, et al., 2003; Cidu, et al., 2011; Varga, 2011; Gangil, et al., 2013) have revealed the contamination of bottled water with various physico-chemical and microbial agents. The processing plants are designed to remove a broad range of contaminants such as biological agents, dissolved gases, turbidity, iron, ammonia, arsenic, colour, and different chemical compounds. The various treatment procedures used for the packaged drinking water at the factory include filtration by sand, carbon and micron cartridge filter (to remove suspended and colloidal particles), filtration with ultra- membrane filter (to remove fine suspended solids, protozoa, bacteria), activated carbon filter (to remove organic impurities), ozonisation (to eliminate bacteria), ultraviolet treatment (to inactivate bacteria), silver ionization, ion exchange and reverse osmosis (to remove dissolved solids, heavy metals, fluoride and pesticides/fertilizer residue), and procedures like demineralization and remineralization to meet the prescribed quality standard (Joseph, et al., 2018). Despite these treatment methods, there is still a chance of contaminating water at various stages of production. Therefore, periodic examination of the quality of packaged drinking water is essential to maintain the quality of water for users. Regular monitoring ensures not only the maintenance of water quality standard but also help to prevent diseases and stop further pollution of water resources (Jayana, et al., 2009). The main purpose of this study was to assess the quality of bottled waters distributed in Bhaktapur Municipality.

Materials and Methods

Study area

This study was conducted in Bhaktapur Municipality, which lies to the east corner of the Kathmandu valley, about 13 kilometres from the capital city. The municipality has ten administrative wards and occupies an area of 6.89 square kilometres with a population of 81,728 (Census, 2011).

Sampling

A walkover survey was carried out in Bhaktapur Municipality for sampling. A total of ten different brands of sealed bottled water were found to be distributed within the municipality. Before collecting samples from the market, the water bottles were properly inspected for any tampering, damage of protective seal and cap. The brand name, manufacture and expiry date were also inspected in the collected samples.

Bhaktapur Municipality has ten wards. Therefore, to cover all the municipal territory in the sampling process, at least one sample of each brand of bottled water was collected from each ward. A simple random sampling technique was used to choose a particular retail outlet such as a department store, grocery shop, restaurant, and canteen. A total of one hundred number of bottled water samples (ten samples from each brand) were collected from January 2018 to March 2018. Out of 100 samples, 75 samples were collected from department stores, grocery shops and restaurants (25 samples from each); 15 and 10 samples were respectively collected from college and office canteens. These samples were tested at Khwopa College Laboratory, Bhaktapur. Three physical parameters, viz., pH, electrical conductivity (EC), total dissolved solids (TDS); four chemical parameters, viz., total hardness (TH), ammonia (NH_3), chloride (Cl), nitrate (NO_3); and a bacteriological parameter were investigated in all the brands of water samples following the standard procedures (Table 1) (APHA, 2005; Bain, et al., 2009; Aryal, et al., 2012). The results were compared with the NDWQS (2005). Standard deviation and boxplot diagram were used to check the variability of the measured parameters. The correlation matrix was constructed to test the association between the variables by calculating the correlation coefficient of different parameters.

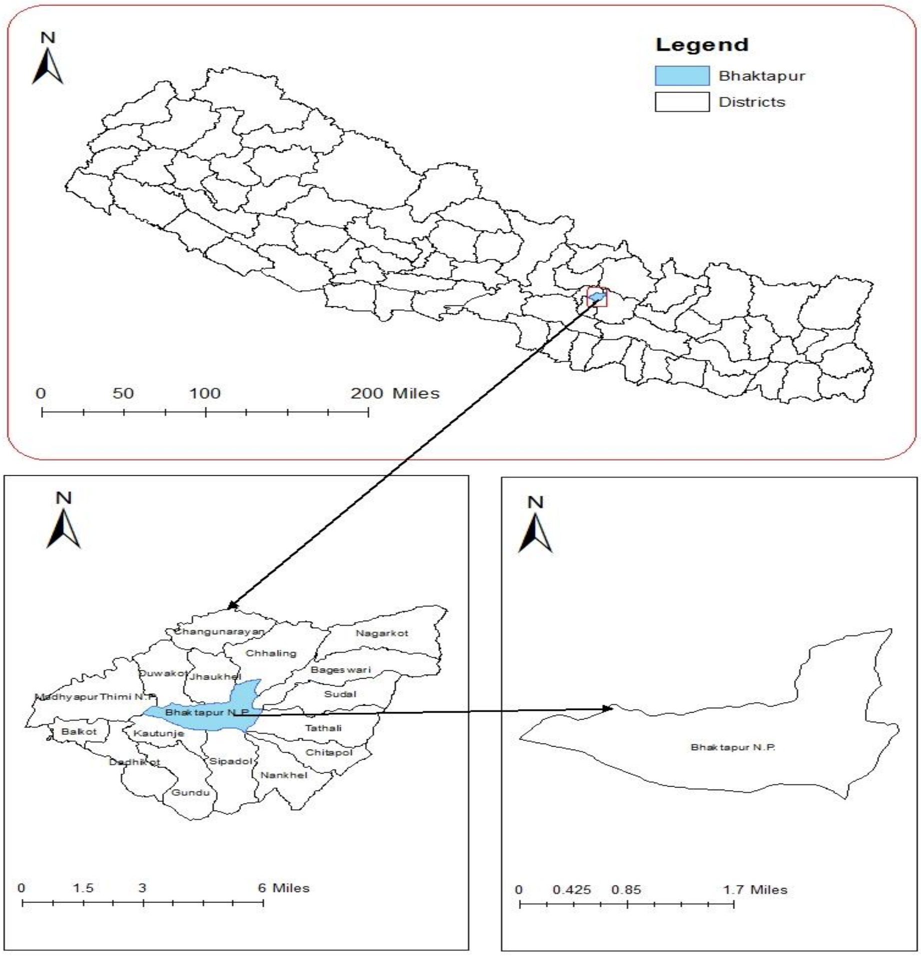

Figure 1 . Map of Nepal showing study area

Table 1. Test Methods employed to investigate water quality

S.N	Parameters	Unit	Test Methods	NDWQS (2005)
1	pH	-	pH meter	6.5-8.5
2	Conductivity (EC)	µs/cm	Conductivity meter	1500 µs/cm
3	TDS	mg/L	TDS meter	1000 mg/L
4	Hardness (TH)	mg/L	EDTA method	500 mg/L
5	Chloride (Cl)	mg/L	Argentometric method	250 mg/L
6	Ammonia (NH_3)	mg/L	Colorimetric method	1.5 mg/L
7	Nitrate (NO_3)	mg/L	Brucine method	50 mg/L
8	Coliform	MPN/100ml	Membrane filter method	0

Results

The brand name, manufacturing and expiry date of the collected samples are presented in Table 2. Out of hundred samples of bottled water assessed in the laboratory, drinking water quality parameters of all the samples were found to be within the limit of NDWQS (2005), except pH parameter.

The pH value of drinking water ranges from 6.5 and 8.5 (Table 1). The laboratory test (Table 3) shows that the pH values of all the samples are in between 5.2 to 6.8, which is slightly acidic. Table 3 further shows that all ten samples from Crystal brand of bottled water have pH between 6.6 and 6.8, which are within the allowable limit although these values are on the lower side of the standard. Only one sample (S3) from the Aqua Ice brand has pH value within the standard. Likewise, five, four, four, two, two, two and one samples respectively from Aqua Seven, Water King, Aqua Ruis, Aqua 77, Kinley, Liberty and Aqua Fresh brand have pH within the standard. However, none of the samples from Aqua New Pabitra brand complies with the standard. Thus out of 100 samples, 31(31%) samples only complied with the standard, and 69(69%) samples failed to comply with the standard.

Table 4 shows the test results of TDS for all ten brands of bottled water samples. The standard value of the TDS prescribed by NDWQS (2005) is 1000 mg/L. The test result presented in Table 4 shows that the values of TDS range from 7 - 54 mg/L, which are well within the standard. Likewise, the maximum allowable level of electrical conductivity is 1500 µs/cm as per the NDWQS (2005). As shown in Table 5, the measured values of electrical conductivity of all the samples (Table 5) are in the range of 8 to 60 µs/cm, which are within the limit of the standard.

Table 2. Sample number and characteristics of collected sample of sealed water bottle (Total sample water bottle = 100)

Characteristics	Number	Percentage
Brands		
Crystal, Aqua Ice, Aqua Seven, Water King, Aqua Fresh, Aqua 77, Kinley, Aqua New Pabitra, Aqua Ruis, Liberty	Each brand 10	Each brand 10%
Date of Manufacture		
January 2018	33	33%
February 2018	33	33%
March 2018	34	34%
Period of Expiry (n = 100)		
Within the next 6 months	100	100%
Beyond 6 months	0	0%
Site of Selection		
Department Store	25	25%
Grocery Shop	25	25%
Restaurants	25	25%
College Canteen	15	15 %
Office Canteen	10	10%

Table 3. Test result of pH parameter in different brand of bottled water samples

Sample Water Brand	Sample Number									
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
Crystal	6.7	6.8	6.7	6.6	6.6	6.7	6.6	6.8	6.7	6.8
Aqua Ice	6.2	6.15	6.5	6.3	6.2	6.1	6.2	6	6	6.12
Aqua Seven	6.4	6.41	6.5	6.49	6.55	6.6	6.5	6.4	6.4	6.5
Water King	6.2	6.3	6.4	6.41	6.33	6.5	6.6	6.5	6.2	6.5
Aqua Fresh	5.61	5.65	5.61	5.7	5.5	5.7	6.1	6	6.5	5.4
Aqua 77	6	6.2	5.5	5.6	5.5	6.5	6.4	6	6.5	5.4
Kinley	6.5	6.5	6.4	5.9	5.5	5.9	5.4	5.9	5.4	5.5
Aqua New Pabitra	5.5	5.6	5.8	5.9	5.6	5.9	5.8	6.2	5.6	6.4
Aqua Rius	6	6.2	5.9	6.6	6.7	6.5	6.5	5.5	5.5	5.2
Liberty	5.9	6.2	6.3	6.5	6	6.1	5.9	5.8	6.2	6.6

Total hardness and ammonia were detected in none of the samples during the laboratory test. According to NDWQS (2005), the maximum permissible limit of chloride concentration in the drinking water is 250 mg/L. Its concentrations in the samples were found to be in the range of 4.1 to 12.5 mg/L (Table 6), which is within the limit of the standard. Likewise, the nitrate concentrations were found to be in the range of 0 to 1.6 mg/L (Table 7) in all the samples which lies within the maximum allowable limit (50 mg/L) set by NDWQS (2005). Table 8 shows the summary of the statistical analysis of chloride and nitrate concentrations. This table shows the minimum, maximum, mean and standard deviations of chloride and nitrate concentration for all the brands of bottled water samples.

Table 4. Test results of TDS parameter (mg/L) in different brand of bottled water samples

Sample Water Brand	Sample Number									
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
Crystal	52	50	54	50	50	50	44	50	50	50
Aqua Ice	40	43	45	40	46	45	47	44	45	45
Aqua Seven	15	10	13	18	13	12	15	14	14	16
Water King	10	9	7	8	9	7	7	8	7	8
Aqua Fresh	9	9	7	8	9	8	7	7	8	8
Aqua 77	10	15	12	10	11	11	10	9	10	12
Kinley	25	30	32	30	31	27	31	28	25	21
Aqua New Pabitra	7	9	10	8	8	9	7	9	7	6
Aqua Rius	30	31	32	28	31	30	25	28	28	27
Liberty	30	36	35	32	30	32	35	37	36	37

Table 5. Test results of conductivity (µs/cm) in different brands of bottled water samples

Sample Water Brand	Sample Number									
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
Crystal	60	55	58	60	57	59	56	55	50	50
Aqua Ice	55	50	40	45	47	50	52	46	47	48
Aqua Seven	18	23	20	22	21	17	20	20	19	20
Water King	19	19	17	16	18	21	22	17	21	20
Aqua Fresh	10	10	15	15	14	14	14	15	16	17
Aqua 77	20	20	22	22	21	23	25	27	25	25
Kinley	47	45	40	40	50	50	52	48	50	48
Aqua New Pabitra	15	15	9	8	10	10	13	12	10	8
Aqua Rius	35	35	40	40	45	45	42	45	50	53
Liberty	50	55	57	55	52	58	54	55	60	54

The box plot diagram of pH (Figure 2a) shows that the Aqua Ruis brand has the highest variability followed by Aqua 77 and Kinley. The Aqua Seven brand samples have the lowest variability followed by Crystal. Figure 2b shows that the Aqua Fresh brand has the lowest variability of TDS followed by Water King and Aqua New Pabitra. Likewise, Kinley brand has the highest variability of TDS followed by Crystal and Aqua Ice. As shown in Figure 2c, the Aqua Rius brand has the highest variability of conductivity followed by Aqua Ice and Kinley. The Aqua Seven brand has the lowest variability of conductivity followed by Aqua Fresh and Water King.

Table 6. Test results of chloride (mg/L) in different brands of bottled water samples

Sample Water Brand	Sample Number									
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
Crystal	7.3	7.2	7.1	6.8	7.5	6.9	7.1	7.2	7.2	6.7
Aqua Ice	12.1	10.7	9.5	11.5	11.4	11.2	11.9	12.1	11.4	11.8
Aqua Seven	8.4	8.2	8.1	8.8	8.7	8.7	8.2	8.1	8.5	9.5
Water King	6.9	7.1	7.5	7.5	7.2	7.2	7.2	7.1	6.5	6.8
Aqua Fresh	7.5	6.1	6.8	7.5	7.2	7.7	7.6	7.6	6.5	6.5
Aqua 77	12.5	11.8	10.5	10.7	11.2	11.2	12.1	11.2	11.5	10.9
Kinley	8.1	8.2	8.1	9.1	8.6	7.5	8.6	8.3	9.4	9.3
Aqua New Pabitra	4.1	4.1	4.2	4.5	4.1	4.5	4.7	4.1	4.2	4.1
Aqua Rius	9.1	9.4	8.5	8.4	8.6	8.5	8.9	7.8	8.2	7.8
Liberty	4.1	4.2	4.3	4.8	4.4	4.2	4.1	4.1	4.3	4.1

Table 7. Test results of nitrate (mg/L) in different brands of bottled water samples

Sample Water Brand	Sample Number									
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
Crystal	0.3	0.4	0.5	0.5	0.5	0.4	0.4	0.5	0.5	0.5
Aqua Ice	0.6	0.6	0.7	0.6	0.7	0.5	0.5	0.6	0.7	0.7
Aqua Seven	0.3	0.4	0.4	0.3	0.3	0.5	0.4	0.4	0.3	0.5
Water King	0.8	1.6	1.4	1.5	1.2	1.5	1.4	1.5	1.6	1.5
Aqua Fresh	0	0	0	0	0	0	0	0	0	0
Aqua 77	0.1	0	0	0	0	0.1	0	0	0	0
Kinley	0	0	0	0	0	0	0	0	0	0
Aqua New Pabitra	0.1	0.1	0.3	0.3	0.3	0.5	0.4	0.2	0.5	0.3
Aqua Rius	0.4	0.4	0.3	0.3	0.5	0.1	0.2	0.3	0.4	0.5
Liberty	0	0	0	0	0	0	0	0	0	0

Table 8. Statistics of chemical concentration in different brands of bottled water samples

S.N	**Sample Brand**	**Chloride (mg/L)**				**Nitrate (mg/L)**			
		Min	Max	Mean	SD	Min	Max	Mean	SD
1	Crystal	6.7	7.5	7.1	0.22	0.3	0.5	0.45	0.067
2	Aqua Ice	9.5	12.1	11.3	0.74	0.5	0.7	0.62	0.075
3	Aqua Seven	8.1	9.5	8.52	0.4	0.3	0.5	0.38	0.075
4	Water King	6.5	7.5	7.1	0.28	0.8	1.6	1.4	0.228
5	Aqua Fresh	6.1	7.7	7.1	0.54	0	0	0	0
6	Aqua 77	10.5	12.5	11.36	0.59	0	0.1	0.02	0.04
7	Kinley	7.5	9.4	8.52	0.57	0	0	0	0
8	Aqua New Pabitra	4.1	4.7	4.26	0.21	0.1	0.5	0.3	0.134
9	Aqua Rius	7.8	9.4	8.52	0.49	0.1	0.5	0.34	0.12
10	Liberty	4.1	4.8	4.26	0.2	0	0	0	0

The Aqua Ice brand has the highest variability of chloride concentration followed, by Aqua 77, and the Aqua New Pabitra brand has the lowest variability of chloride concentration (Figure 2d). Likewise, the boxplot presented in Figure 2e shows that the Water King brand has the highest variability of the nitrate concentration, whereas the Aqua Fresh and Kinley brand has the lowest variability.

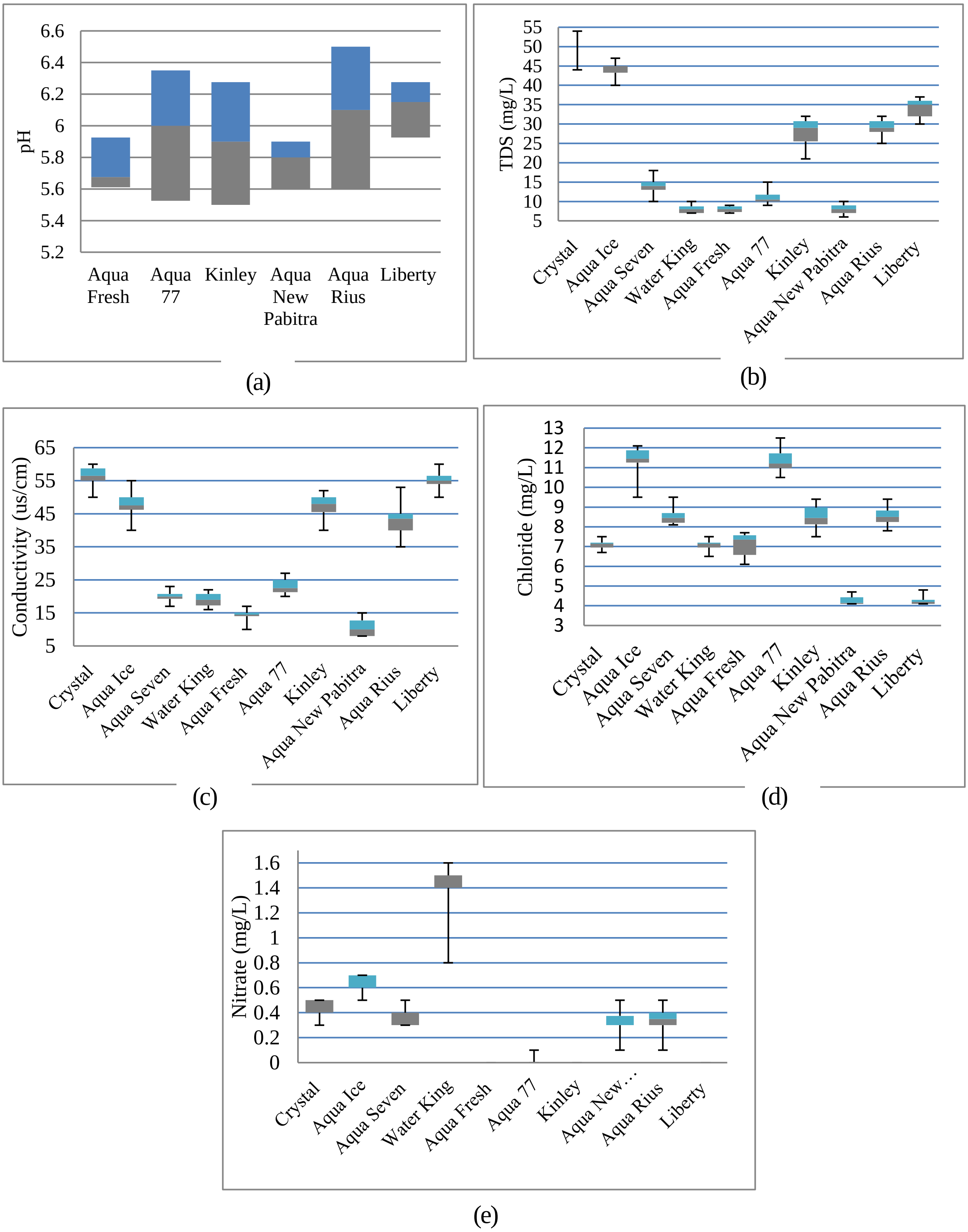

Figure 2. Boxplot diagram showing the variability of (a) pH, (b) TDS, (c) conductivity, (d) chloride and (e) nitrate in different brands of bottled water samples

The correlation between TDS and conductivity was found to be highly significant (Figure 3), but the correlation between chloride and nitrate was found to be very weak (r = 0.04, p = 0.90).

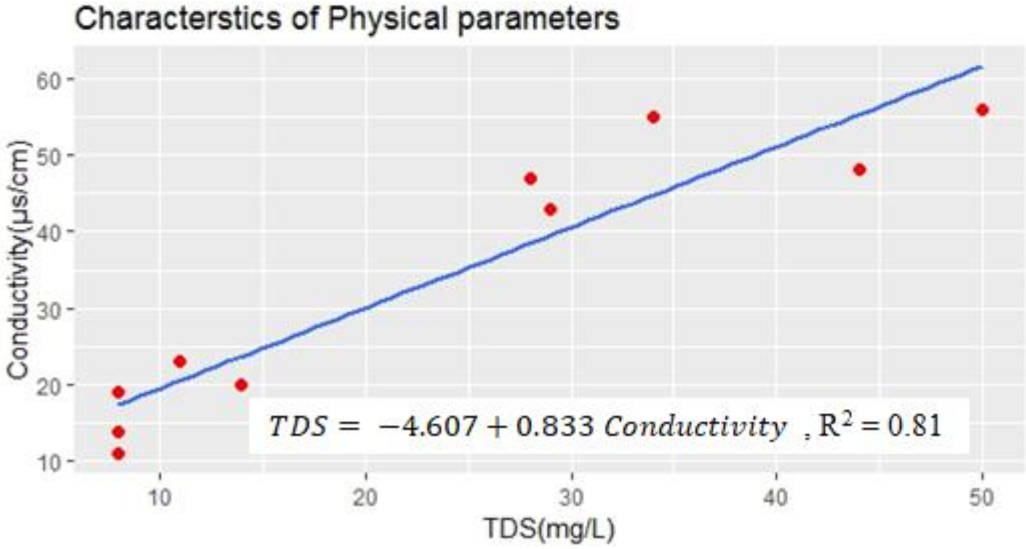

Figure 3. Relationship between TDS and Conductivity

The correlation matrix (Table 9) shows the relationship between various physico-chemical parameters. A significant positive correlation was found between TDS and conductivity. However, no significant correlation was observed between the physical and chemical parameter. No coliform was observed in any samples during the microbiological examination. In the absence of total coliform, the probability of the presence of *Escherichia coli* known as *E.coli* in water is very slim.

Table 9. Correlation matrix among various Physico-chemical parameters

Parameters	pH	TDS	EC	Cl	NO_3
pH	1				
TDS	0.45	1			
EC	0.35	0.93*	1		
Cl	0.03	0.14	0.08	1	
NO3	0.53	-0.05	-0.15	0.04	1

*Significant positive correlation

Discussion

In this study, we assessed the quality of ten different brands of bottled water samples based upon their physico-chemical and bacteriological parameters. All the examined parameters, besides pH, were found to be within the standard limits of NDWQS (2005). Similar results were obtained by Salehi et al. (2014) and Shams et al. (2019) in studies conducted on bottled water in Iran. In a study done by Yousefi et al. (2018) on bottled water distributed at supermarkets in the city of Sari, Iran, 100% compliance was found with the national standard and WHO guidelines. No microbial contamination was detected in any bottled water samples in a study done by Micheni et al. (2015) in Uganda. Likewise, the study done by Ajayi et al. (2008) in Nigeria showed the absence of microbial in all the bottled water samples. The finding of Rao et al. (2016) from Telangana, India agrees with our result. Singla et al. (2014) also obtained a similar finding on bottled water samples collected from different public places in Delhi, India.

Unlike our study, as reported in the previous studies done in Nepal, only 10% to 80% of the bottled water samples were free from microbial (Timilshina, et al., 2012; Rai, et al., 2015; Pant, et al., 2016; Maharjan, et al., 2018). In studies done in India, the acceptability of bottled water samples based on the bacteriological parameter ranged from 55% (Gangil, et al., 2013) , 60% (Jeena, et al., 2006; Jain, et al., 2012), 62.5% (Joseph, et al., 2018), 66.7% (Venkatesan, et al., 2014), 73.33% (Bency, et al., 2010), 83% (Sharma & Kaur, 2015) to even 100% (Singla, et al., 2014). In a study done in Saudi Arabia, no bacteria were detected in 94.64% of the bottled water samples (Mohammad & Sulaiman, 2016) while in a similar study done in Malaysia, only 81.81% of the bottled water samples were found unaffected with microbial (Praveena, et al., 2016). In another study done in Sri Lanka, none of the bottled water samples were found to comply with the Sri Lankan Standard (Sasikaran, et al., 2012).

The quality of the water source not only affects the treatment cost but also has a direct impact on the quality of the drinking water (Nsanze & Babarinde, 1999; Price & Heberling, 2018). In our study, two brands of bottled water companies were found using spring water, and the rest of the companies were found using groundwater as a source of water. However, the quality of the source water could not be verified in the present study. Disinfection of water is the most important part of the water treatment process to improve the quality of water as it inactivates pathogens from drinking water. The concentration of pathogens generally depends upon the disinfection of water at the factory (Nsanze & Babarinde, 1999; Pant, et al., 2016). In this study, all the companies were found using ultraviolet (UV), reverse osmosis (RO), and ozonisation in the treatment process.

The possibility of contaminating the bottled water with microbial cannot be ruled out in a long channel from the point of production, packaging, storage to distribution. No such evidence was observed in the present study, as this study was done taking a small number of sample sizes and brands. Such studies shall be carried out regularly taking a large number of sample sizes. Several studies show that there is a rapid growth of microorganisms during the bottling process (Leclerc & Moreau, 2002; Diduch, et al., 2016). Different factors like long-distance transport and the storage of water play a vital role in deteriorating the quality of water (Nsanze & Babarinde, 1999; Leclerc & Moreau, 2002; Omalu, et al., 2010; Shams, et al., 2019). The length of storage time and storing condition affect the growth of microbial quality of bottled water. Nsanze & Babarinde (1999) found that the storage of bottled water at 4 °C controlled the growth of microbial, whereas at 25-37°C, most microbes multiplied and at 42°C, most of them were killed. A similar result was found by Addo et al. (Addo, et al., 2016) in a study done in Ghana. Likewise, the growth of bacteria intensified in bottled water when exposed to indirect sunlight at room temperature (Shams, et al., 2019). The contamination of packaged water increases as the products move further down the distribution channel (Omalu, et al., 2010). Hence, the examination of the quality of packaged water is necessary not only during the production stages but also in the postproduction stages as well to ensure the quality of the product (Venkatesan, et al., 2014). Regulatory bodies and other concerned stakeholders are required to strictly monitor the manufacturing companies during production as well as the distribution of bottled water.

The labelling of the bottled water with batch number, manufacture date, expiry period and processing technology is very important. In this study, manufacture date, processing technology, and expiry period besides a batch number were found to have mentioned on the label in all brand of the bottled water samples. The batch number helps to withdraw an entire lot of the products from the market in case if the faulty product is identified.

The pH value is one of the important water quality parameters which signifies the acidity and alkalinity of water. A sample with a pH of less than 7.0 and higher than 7.0 is respectively considered acidic and alkaline water. In this study, out of the 100 samples from ten different brand of the bottled water, 31 (31%) samples only complied with the NDWQS (2005) pH limit, and the value ranged from 5.2 to 6.8. Moreover, out of the ten different brands, all the samples from Crystal brand only complied with the standard. In a similar investigation in Kuwait, Al Fraij et al. (1999) found that about 44% of the samples had pH value higher than 8 and 8% of the samples had lower than 7. The study done by Salehi et al. (2014) and Yousefi et al. (2018) in Iran showed full congruence of the pH level with the standard.

In this study, electrical conductivity and TDS levels in the samples were found to be within the standard. The presence of dissolved solids such as calcium, chloride and magnesium in water increase electrical conductivity (Rahmanian, et al., 2015). The measured level of conductivity in the present study was in the range of 8 to 60 µs/cm, which is too low compared to the maximum allowable limit of 1500 µs/cm. RO removes dissolved solids, turbidity, and colloidal matters, which lower the conductivity. In the present study, all brands of bottled water companies were found using RO in the treatment process. Rahmanian et al. (2015) found a conductivity of 69.7 µs/cm in the RO treated water in Malaysia, which is in agreement with our findings. We obtained TDS value in the range of 7 to 54 mg/L. Moreover, we observed that the samples with the lowest conductivity value also have the lowest TDS value, and the samples with the highest conductivity value also have the highest TDS value. This situation shows the accuracy of the measurement (Alam, et al., 2017). The high coefficient of determination between conductivity and TDS further corroborates this situation in the present study.

In this study, total hardness and ammonia were not detected in any brand of the bottled water samples. The concentration of chloride in all brands of the bottled water samples were found to be within 5% of the maximum limit. In a similar study done in Bangladesh, the concentration of chloride in bottled water was below 10% of the maximum limit (Alam, et al., 2017), and in Indore city of India, it was 20% of the maximum limit (Prajapati & Choudhary, 2009). Ibrahim et al. (2014) in Egypt found the concentration of chloride as high as 45% of the maximum limit. In the present study, the concentration of nitrate was also below 5% of the maximum limit in all brands of the bottled water samples. Weyer et al. (2014) found the nitrate concentration below 1% of the maximum limit, whereas Alam et al. (2017) found the concentration as high as 6% of the maximum limit. The statistical analysis showed no correlation between nitrate and chloride. The variabilities of physico-chemical parameters have been estimated for all brands of the bottled water samples and found that some brands have high variability of concentration and some have low variability of concentration. Low variability is preferred because it signifies the consistent quality of the product. Variability means the extent to which the measured values in a statistical distribution or data set diverge from the mean value.

For a detailed investigation of water quality, it is necessary to conduct such a study on a large number of sample sizes. The minimum time for monitoring should be a year to collect a series of data or trends to confirm the reliability of the study (Rahmanian, et al., 2015). However, this study was carried out with limited resources taking a small number of sample sizes for a period of three months. This study analysed only a limited number of physico-chemical parameters. Minerals and heavy metals were not examined in the present study. The concentration of heavy metals in drinking water higher than a certain level can have a detrimental effect on human health (Ibrahim, et al., 2014).

Conclusion

Sealed bottled water has become a readily available source of water in urban areas and is generally considered a safe source of drinking water. However, several studies conducted in the past have raised the question about its quality. This study assessed the quality of bottled water distributed in Bhaktapur Municipality. Besides pH, physicochemical parameters such as conductivity, TDS, ammonia, hardness, chloride and nitrate were found to be within the recommended limits of NDWQS (2005). Microbial contamination was not found in any brands of the bottled water samples considered in this study. However, it is very important to investigate other potential water contaminants such as heavy metals, minerals, and chemicals to assess the overall quality of the bottled water. Such a study has to be done at least for a year to collect enough data to confirm the reliability of the study.

Moreover, bottled water needs to be labelled to provide information like manufacture date, expiry period, batch number, and treatment technology employed. Most importantly, concerned regulatory bodies need to strictly and periodically monitor the manufacturing companies to maintain the quality of bottled water.

Acknowledgements

We would like to acknowledge Ms. Sharmila Dangol, Ms. Nisha Shyaju, Ms. Suman Acharya and Ms. Roji Chawal for their kind help and support during laboratory test. The authors are grateful to anonymous reviewers and editors whose comments and suggestions helped to improve the manuscript.

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