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RESEARCH ARTICLE

Assessment of Physico-Chemical and Bacteriological Quality of Jar Water Marketed In Kathmandu Metropolitan City

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Highlights

- Quality of different brands of jar water samples marketed in Kathmandu metropolis were assessed.
- Physico-chemical parameters (pH, EC, TDS, TA, TH, Ca^{2+}, Mg^{2+}, Cl^{-}, NO_3^{-} and Fe) were analyzed.
- The bacteriological quality was assessed by using MTFM for total coliform count.
- Except pH of some brands, physicochemical parameters in all brands comply NDWQS and WHO standards
- 50% of the brands of jar water were found to be contaminated with coliform bacteria.

Abstract

Samples of water supplied in 20 litre jars under ten different brand names were collected randomly from several places of Kathmandu metropolitan city. Analyses of various physico-chemical parameters of water conducted. Water from each jar is analysed for physical parameters (pH, electrical conductivity (EC) and total dissolved solids (TDS)) and chemical parameters (total hardness (TH), calcium, magnesium, total alkalinity (TH), chloride, nitrate and iron) and for bacterial contamination. These analyses assess jar water suitability in Kathmandu district, revealing some company must improve processors and enhance hygiene and comply with NDWQS and WHO standards.

Keywords: *Jar water, Physico-chemical, Bacteriological, Kathmandu Metropolitan City*

Introduction

Water is a basic human need that is necessary for drinking, supporting hygiene and sanitation, and maintaining life and health. Only 3% of water on Earth is fresh water and it is estimated that 8% of worldwide water use is for domestic purpose which include drinking, cooking, personal hygiene and other domestic purposes etc. [1]. Water that is clean enough and meet the quality standard so that it can be used for drinking purpose without the threat of negative consequences is known as drinking water. Although global access to safely managed drinking water has steadily progressed in recent years, there are still about 2 billion people around the world without access to safely managed drinking water services [2].

The demand of drinking water in Kathmandu valley is 470 million litres per day, while the daily water supply is only 80 million litres in dry season and 106 million litres in wet season [3]. In addition, an increasing number of outbreaks of waterborne diseases have been connected to issues with public water distribution systems. Due to the scarcity of potable tap water and fear of contamination, people are compelled to find alternatives to tap water using bore well, jar water etc. The latter is popular as it is conveniently found on local shop for Rs. 50 for 20 litres and people trust that water quality is safer for consumption. Additionally, consumers also believe that the taste and flavor of jar water is better than tap water.

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According to Nepal Bottled Water Industries Association, around 550 water bottling plants are in operation nationwide, 150 of which are located in the Kathmandu valley alone [4]. There are variety of sources of jar water, and many of these are from the same sources as tap water. Sometimes the water supplied in jar is just regular tap water that has undergone some sort of enhancement such as modifying its mineral content. Therefore, the quality standards of processed water are not necessarily better and/or different than water available from municipal systems. According to the latest study carried out by the Epidemiology and Disease Control Division of Ministry of Health and Population, Government of Nepal, nearly a quarter of the drinking water being used in Kathmandu has been found contaminated with fecal coliform, and most of the tested samples were taken from bottled water [5].

Several studies on quality of bottled water had been done in the past in Nepal and other parts of the world some of which are presented in table 1.

Table 1. Some previously reported investigations on physicochemical and microbial parameters of bottled water

S. N.	Selected Area	Sample size	Parameters studied	Ref.
1.	Kathmandu	15 brands of jar water	Bacterial count	[6]
2.	Kathmandu valley	30 brands of bottled water	Total coliform and heterotrophic bacteria	[7]
3.	Dharan Municipality, Nepal	76 tap water samples and 24 bottled water samples	Bacteriological quality	[8]
4.	Kathmandu, Lalitpur, Bhaktapur	9 sample of 20 mL jar water	temperature, pH, chloride, dissolved oxygen (DO), TH, TA and free carbon-dioxide, total coliform and fecal coliform	[9]
5.	Bhaktapur Municipality	100 Bottle water from 10 different brands	pH, EC, TDS, TH, Cl^-, NH_3, NO_2^- and coliform	[10]
6.	Kathmandu valley	50 water sample	Physical and Chemical parameters, fecal coliform and total coliform.	[11]
7.	Eastern Alabama	Twenty-five brands of bottled waters	pH, conductivity, alkalinity, Cl^-, NO_3^-, NO_2^-,SO_4^{2-}, PO_4^{3-}, Total carbon (TC), inorganic carbon (IC) Total organic carbon (TOC) and 27 elements	[12]
8.	Turkey	15 brands of bottled mineral water	pH, EC, SO_4^{2-}, HCO_3^-, Cl^-, K^+, Si, Na^+, Mg^{2+}	[13]
9.	Chittagong City, Bangladesh	38 drinking jar water samples	pH, TDS, Fe, As, Pb, and Cr, identification of bacteria, fecal coliform and total coliform.	[14]
10.	7 cities of Italy (Rome, Turin, Genoa, Trieste, Pisa, Florence and Cagliari)	37 bottled water samples and 15 tap water samples	57 dissolved inorganic components	[15]
11.	Hungary	492 samples of domestic and imported brands of carbonated and non-carbonated mineral waters.	Bacteriological quality	[16]
12.	Jaipur city, India	15 bottled water and 5 sachets	Bacteriological evaluation	[17]
13.	Alexandria Govermorate, Egypt	Fourteen bottled water brands	pH, EC, TDS, anions, essential elements, and heavy metals	[18]

14.	Gonabad, Iran	9 brands of bottled water	Microbial quality	[19]
15.	Romania	14 brands of bottled water	12 physico-chemical parameters, 9 metals and metalloids and 17 heavy metals	[20]
16.	Pretoria, South Africa	12 brands of bottled water samples	TDS, EC, SO_4^{2-}, NO_3^-, PO_4^{3-}, pH, trace elements.	[21]
17.	Sumaru Community, Nigeria	15 brands of sachet water	pH, EC, TDS, DO, BOD, Cl^-, NO_3^-, PO_4^{3-}, Ca^{2+}, Hardness	[22]
18.	Colombo, Sri Lanka	26 brands of bottled water	Microbial quality	[23]

These studies have revealed the noncompliance with standards of water quality in terms of physico-chemical parameters and contamination of bottled/jar water with various microbial agents. Therefore, this study was conducted to assess the quality of jar water marketed in Kathmandu metropolitan city by examining physicochemical and bacteriological parameters.

Materials and Methods

Out of about 50 different brands of jar water available in Kathmandu metropolitan city, only 10 brands (*viz*. Aqua Abha, Aqua Demand, Aqua O_2 life, Aqua Peace, Aqua Pratik, Aqua Pure, Aqua Sulav, Fresh Drop, Gosaikunda and KGK) were selected by lottery method for the study. The jar water samples were collected from the stores from different localities of Kathmandu Metropolitan City from April to May. The samples were collected in 1-2 liter PVC bottles and transported to the laboratory within 4 hours in an icebox, and maintained there at a temperature of around 4 °C until analyses were done.

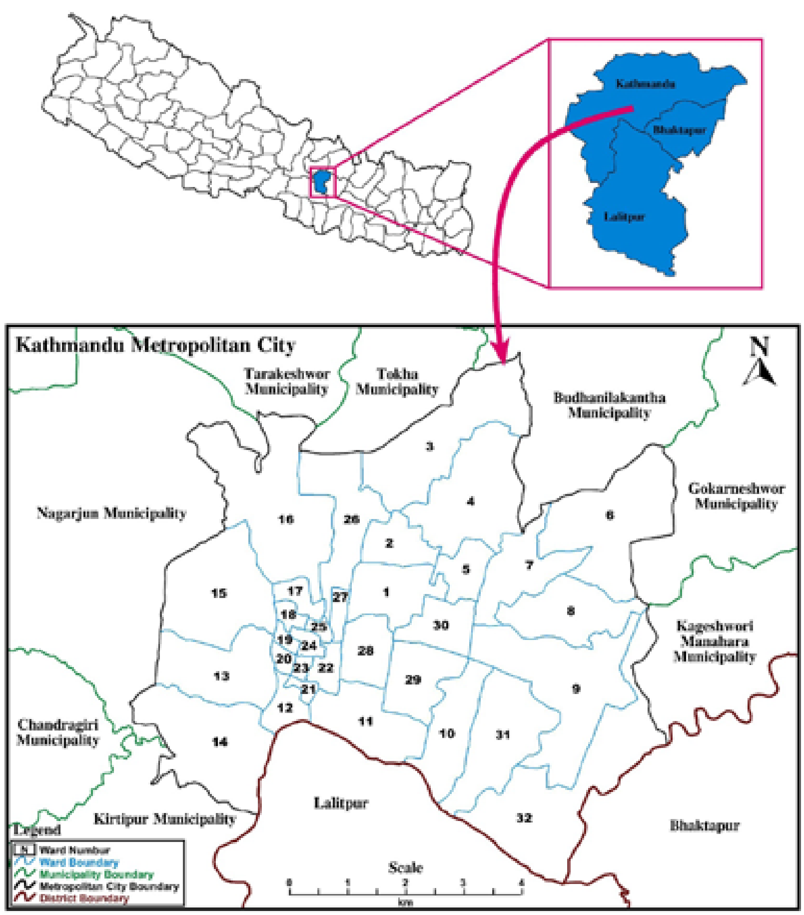

Fig 1. Location Map of Kathmandu Metropolitan City

Physico-chemical Analysis

Chemicals and solvents of analytical grade were purchased from local suppliers in Kathmandu. All physico-chemical parameters except nitrates and iron were analyzed according to methods described by Trivedi and Goel [24]. Measurement of pH and conductivity were done using digital pH meter (model no.: HI-98107 by Hanna) and conductometer (model no. HI-983003/304 by Hanna). Total dissolved solids (TDS) was determined by evaporation method. Total alkalinity (TA), chloride, magnesium, calcium and Total hardness (TH) were determined by titrimetric method [24]. Nitrate and iron were determined spectrophotometrically following APHA method 4500-NO_3 and APHA method 3500-Fe B using 1,10-phenanthroline respectively [25].

Bacteriological Analysis

Bacteriological analysis was carried out as described in APHA 9221 by enumerating total coliform using Multiple Tube Fermentation Method (MTFM) [25].

Results and Discussion

Table 2 lists the results of analyses of different physico-chemical parameters along with the Nepal Drinking Water Quality Standards (NDWQS) [26] and WHO Drinking Water Guidelines (WHO DWG) [27].

Table 2. Water quality analysis of different jar water samples

Sample code	pH	EC (μS/cm)	TDS (mg/L)	TH (mg/L) as $CaCO_3$	TA (mg/L)	Cl^- (mg/L)	NO_3^- (mg/L)	Mg^{2+} (mg/L)	Ca^{2+} (mg/L)	Fe (mg/L)
S1	6.4	262.09	162.14	14	20	72.42	0.29	5.99	8.02	<0.05
S2	5.8	143.04	105.84	12	20	59.64	2.55	2.4	9.60	<0.05
S3	6.6	184.21	131.46	10	25	89.46	2.15	7.6	2.40	0.15
S4	6.4	138.24	102.67	12	20	46.86	0.12	8	4.01	<0.05
S5	6.9	192.42	122.22	8	15	52.54	1.33	0.8	7.13	0.06
S6	6.5	207.24	130.15	8	25	126.38	0.77	2.4	5.61	0.13
S7	6.1	189.51	120.94	12	15	66.74	2.19	7.2	4.81	0.17
S8	6.5	244.93	170.80	26	20	79.52	0.57	13.18	12.82	<0.05
S9	6.9	223.33	138.23	16	35	53.96	0.28	10.4	5.61	0.14
S10	7.2	301.05	210.69	18	40	76.68	0.12	12.4	5.61	0.09
NDWQS	6.5- 8.5	1500	1000	500	NA	250	50	NA	200	0.3
WHO DWG	6.5- 8.5	750	<600	200	NA	250	50	<150	150-300	0.3

pH

Despite the fact that pH typically has no direct impact on consumers, it is one of the most important operational water quality parameters. According to NDWQS and WHO guideline the pH of drinking water must lie within the range 6.5–8.5 [26, 27]. Considering all the samples studied, the pH value was found to range from 5.8 for S2 to 7.2 for S10. Except for four brands of jar water viz. S1, S2, S4 and S7, the value of pH for all other samples were within the NDWQS and WHO standards. Differences in the levels of pH from these jar waters may suggest difference in the sources of the water. Our findings are similar to these reported by Shrestha et al. [28].

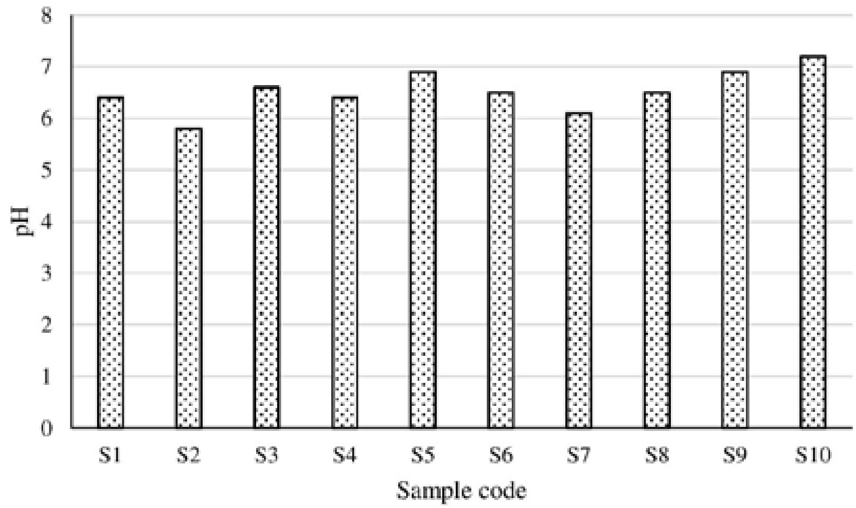

Fig 2: Variation of pH in Jar water samples

Electrical conductivity and total dissolved solids

The ability of water to conduct electrical current is measured by its electrical conductivity. The higher values of electric conductance might be due to higher amounts of dissolved gases, ionic salts and other chemicals in the water. So, electrical conductivity is related to total dissolved solids (TDS) present in water sample [29]. Above 400 µS/cm conductance values may affect the chemical quality of drinking water. The value of electrical conductivity ranges from 138.24 µS/cm for band S4 to 301.05 µS/cm for the brand S10. All these values lie within both the NDWQS limit (1500 µS/cm) and WHO limits (<600 µS/cm) [26,27].

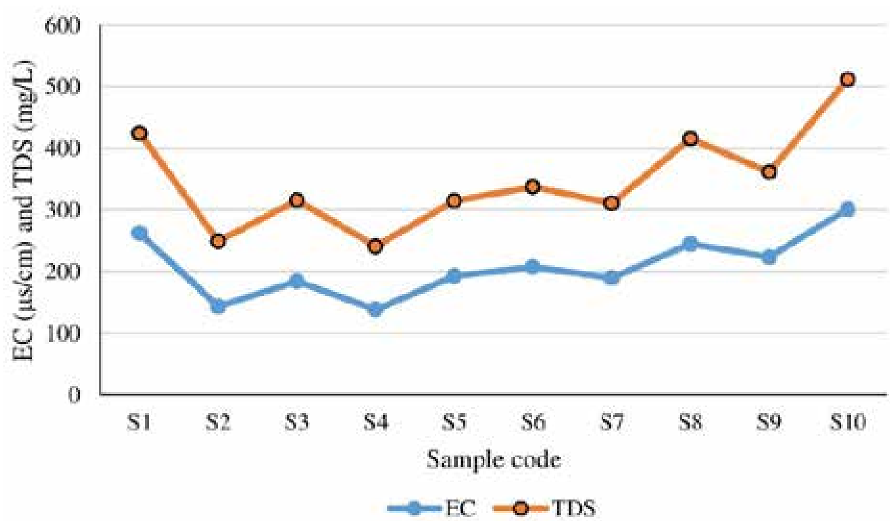

Fig 3. Variation of Electrical Conductivity and Total dissolved solids in Jar water samples

Total dissolved solids (TDS) increase turbidity and reduce the aesthetic value of water limiting the suitability of water for drinking purpose. So, TDS can be considered as a general water quality indicator. NDWQS and WHO permissible values for Total dissolved solids is 1000 µS/cm and <600 µS/cm respectively [26, 27]. The data presented in table 2 shows that TDS value is below the permissible value with the maximum TDS value of 210.69 mg/L for S10 and minimum TDS value of 102.67 for S4. The results of the electrical conductivity were similar to the findings of Maskey et al. [30] where the values obtained for EC ranged between 1.00 and 496 and were reported to be below the maximum guideline limit of 1500 µs/cm.

Anions (Cl^- and NO_3^-), and Total alkalinity

In all types of water there is presence of chloride since chlorination is done for disinfection of drinking water. A higher chloride concentration in water is a sign of organic contamination, and it also makes the water more corrosive and with bland taste [31]. According to the NDWQS and WHO, the permissible limit of chloride is 250 mg/L [26, 27]. All brands of jar water sample studied are found to comply with both NDWQS and WHO standards for concentration of chloride. The chloride content varies from maximum of 126.38 for S6 and minimum of 46.86 for S4.

Nitrates are present in trace amounts in surface water but its higher concentration is hazardous to health. Drinking water with nitrate-nitrogen poses health hazard due to nitrite transformation, oxidizing iron in hemoglobin, resulting in methemoglobin lacking oxygen-carrying ability. Nitrate concentrations higher than 50 mg/L cause iodine absorption and hyperthyroidism and is also related to increased infant mortality, methemoglobinemia (blue baby syndrome), childhood diabetes, hypertension, cardiovascular disease, nervous problems, abnormalities, abortion, Alzheimer's disease and numerous types of cancer including gastrointestinal, oral, colon, bladder, and breast cancers [32]. The results of nitrate content were similar to the findings of Neupane et al. [10] where the values obtained for chloride ranged between 0 and 1.6 and were reported to be below the maximum permissible value of 50 mg/L.

The NDWQS guidelines for nitrate concentration in drinking water 50 mg/L as nitrate [26]. It should be less than 50 mg/L as nitrate or 11.3 mg/L as nitrate–nitrogen according to WHO [27]. The result of analysis shows only trace amount of nitrate present in all tested brands of jar water.

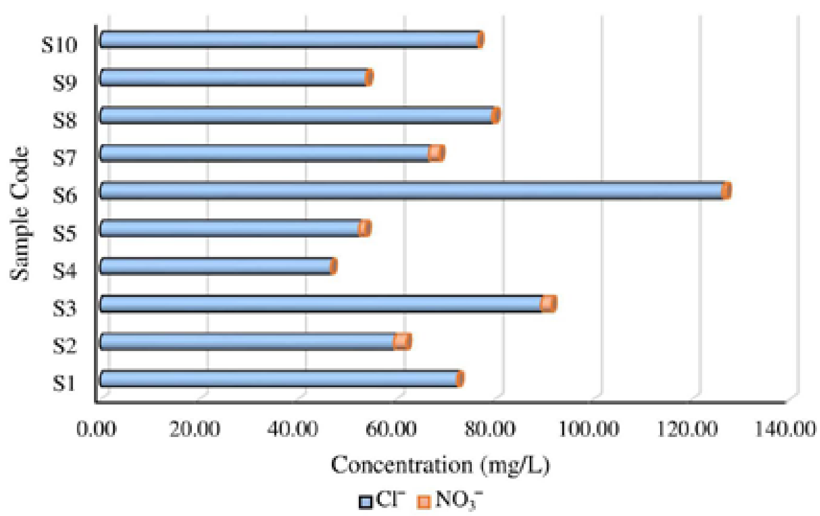

Fig 4. Variation of Cl^- and NO_3^- concentration in Jar water samples

Alkalinity of water is its acid neutralizing capacity and act as a pH neutralizer. Measurements of alkalinity are used to assess the buffering capacity of water. The recommended range for drinking water is 200 to 400 mg as $CaCO_3$/L. In the studied brands of jar water, the maximum value of alkalinity was found to be 40 mg $CaCO_3$/L (in S10) and minimum was found to be 15 mg $CaCO_3$/L (in S5 and S7).

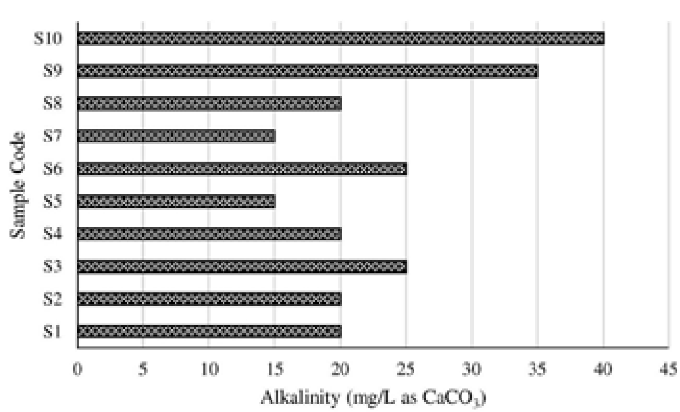

Fig 5. Variation of Total alkalinity in Jar water samples

Ca^{2+}, Mg^{2+} and Total hardness

In the tested samples of jar water magnesium concentration is found to vary from 0.80 mg/L in S5 to 13.18 mg/L in S8. The content of calcium differs from maximum value of 12.82 for S8 and minimum of 2.40 for S3. Both magnesium and calcium contents were found to lie within the permissible values for drinking water [26,27].

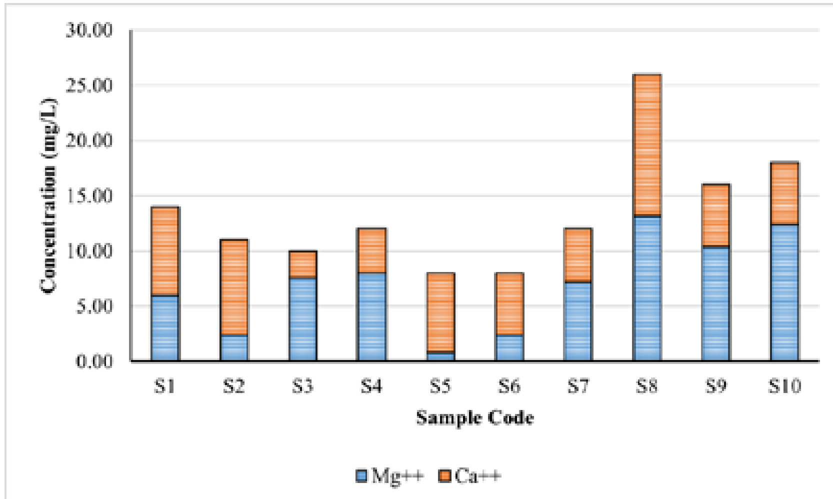

Fig 6. Variation of Calcium and Magnesium concentration in Jar water samples

Hardness, which is measured in terms of equivalent amounts of calcium carbonate, is mostly due to soluble salts of calcium and magnesium. Hard water is undesirable because it precipitates soap in the form of scum, causes scales in boilers when heated, and has a high boiling point, making it unfit for use in cooking and drinking [33]. According to NDWQS and WHO, the permissible values for hardness of water were 500 mg/L and 200 mg/L respectively. Higher concentration of hardness may be due to the mixing of soap molecules with Ca^{++} and Mg^{++} forming suds. As jar water is considered as a safe drinking water so water hardness must be much lesser so all the above jar brands have lower water hardness. The hardness of water differs from 26 of S8 for maximum value and 8 of S5 and S6 for minimum value. Maskey et al. also reported that the total hardness of bottled water samples is much lesser ranging between 2 – 166 mg/L compared to the upper limit of standard value of 500 mg/L [30].

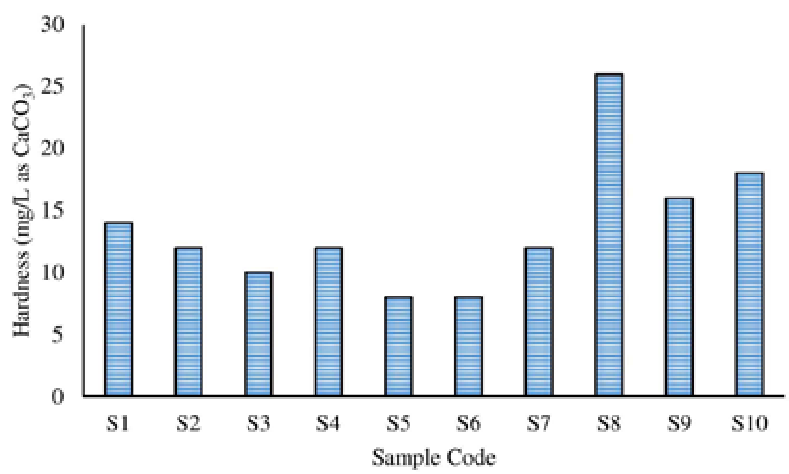

Fig 7. Variation of Hardness of water in Jar water samples

Iron

Iron is the common element found in earth crust and Iron pipes are also one of the sources of iron found in water. The problem that frequently occurs due to iron is the bacteria. Fatigue, weakness, and a lack of vitality are among the many signs of iron overload that are also observed in the case of iron deficiency. However, those who have hemochromatosis generally notice a darkening of their skin tone (“bronzing”), whereas those who have iron deficiency anemia will notice a pallor of their complexion. Both NDWQS and WHO set the permissible limit of iron to 0.3 mg/L [26,27]. Different jar water brands analyzed were found to contain iron in much lesser concentration than the permissible values.

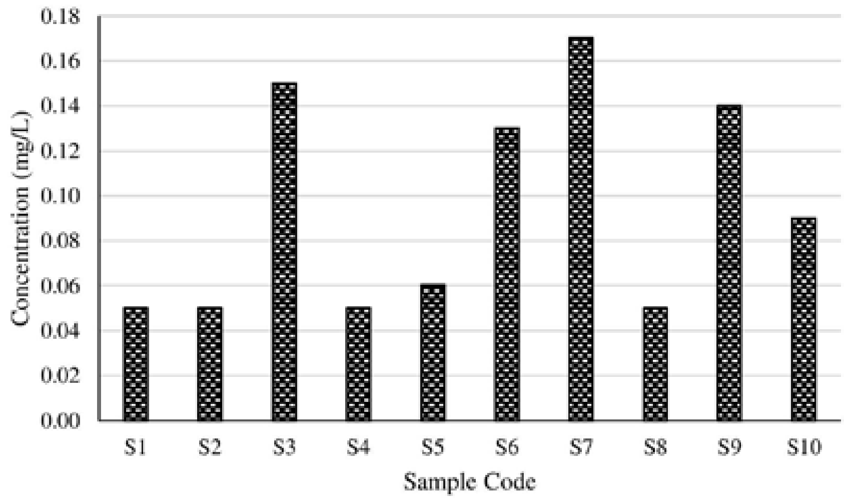

Fig 8. Variation of Iron concentration in Jar water samples

Total coliform count

Human and animal wastes are a primary source of bacteria in water [17]. Coliform bacteria may not directly cause disease, but they can serve as markers for pathogenic species that do. The latter may result in cholera, typhoid fever, hepatitis, dysentery, intestinal infections, and other diseases. The NDWQS and WHO guidelines for total coliform is 0 MPN/100 mL [26,27]. The results show that some of the jar water brands are contaminated with coliform bacteria. Total coliform count in S3, S5, S6, S7 and S8 are 11, 9, 11, 9 and 4 respectively. The results were similar to the findings of Gautam where 48% of samples found to be contaminated with total coliform [34].

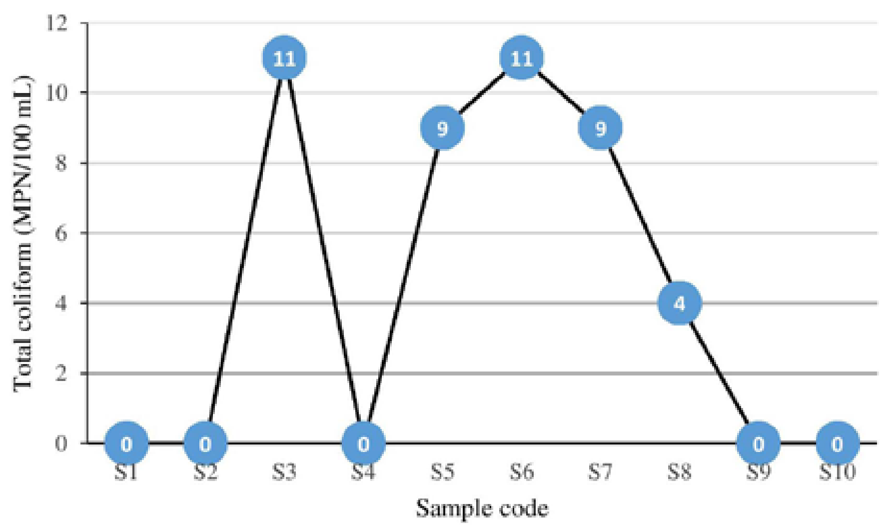

Fig 9. Amount of fecal coliform in Jar water samples

Conclusions

The study clearly showed that excepted for pH of some samples, the jar water marketed in Kathmandu's metropolitan city are fit for consumption on the basis of physico-chemical parameters as the parameters tested complies with NDWQS and WHO DWG standards. However, 50% of the jar water brands tested positive for pathogens making these unfit for drinking purpose. It is important that regulatory bodies step up their efforts to assure standard compliance in order to prevent risks to the public's health because the bacteriological quality of water is a hidden quality feature that has a significant impact on public health. In order to ensure the quality of the jar water, it is crucial that related regulatory organizations thoroughly and routinely supervise the manufacturing enterprises.

Acknowledgements

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