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ORIGINAL RESEARCH ARTICLE

PHYSICAL, CHEMICAL AND MICROBIOLOGICAL ANALYSIS OF BOTTLED WATER IN POKHARA, NEPAL

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ABSTRACT

Background: Today possibility of rendering water non-potable by various types of contaminants (physical, chemical and biological) is of considerable importance. It is not only the microbial contaminants but also the physical and chemical contaminants, playing an important role in compromising our health in many ways. The aim of this study was to assess the physical, chemical and the microbiological quality of commercially produced bottled water in Pokhara city.

Methods: A study was conducted to assess the quality of bottled drinking water produced in Pokhara city. Total of 21 brands of bottled water was collected, first batch in monsoon season and second batch in pre-monsoon season, from the market. The physical, chemical and microbial assessment was carried out as per National Drinking Water Quality Standards, 2062. Coefficient of variation and t-test were applied where applicable.

Results: Better water quality was found in Pre-monsoon season than that of monsoon season, in regard to microbial assessment. None of the samples in first batch tested positive for coliform whereas in second batch 38.2% of samples tested positive for coliform. Coefficient of variation for pH and chloride content was, 8.9% and 6.1%, 35.6% and24.19%, in pre-monsoon and monsoon season respectively. Both were found to be statistically significant. While other tested parameters were within normal limits.

Conclusions: The quality bottled drinking water available for sale do not meet the standards given by National Drinking Water Quality Standards, particularly the microbial quality.

INTRODUCTION

Uninterrupted supply of safe drinking water is one of the important aspects of public health. Concern for safe drinking water in Nepal can be traced back to the early 19th century when in 1840 king Rajendra Bir Bikram Shah in his Royal proclamation to the people of Kathmandu ordered "use water for drinking only after filtering and boiling it, and then letting it become cool, as otherwise worms which exist in water eat up the liver causing death".[1] This royal proclamation reminds us of the long history of concern about the contamination of drinking water. Before the dawn of modern technology, people in Nepal used to drink water directly from natural sources[1] As globalization took precedent, concern for the contamination of natural water sources with various substances like fecal material, domestic and industrial sewage, etc. grew exponentially. In the mid-1980s, bottled drinking water was introduced. It was marketed as safe drinking water brought directly from natural sources.[1] Today market is inundated with a large number of brands of bottled water with no quality assurance.[2-3]

Pokhara, a tourist city, holds greater responsibility for safeguarding the health of its residents and the tourist as well. Local suppliers are, mostly, catering for the need of drinking water, especially for tourist and the residents as well. News of the detection of coliform in bottled water, in Pokhara, has also been there.[4-5] The study aimed to assess the physical, chemical and microbiological quality of bottled water only produced in Pokhara.

METHODS

This was a comparative cross sectional study design carried out in Pokhara city. After the approval from institutional research board, Manipal College of Medical Sciences, total of 19 brands of bottled water out of 23 brands produced in Pokhara and 2 international brands were randomly collected from the market, in two batches. Total 42 bottles (samples) of water, same 21 brands (bottles) in each batch, were collected from the market. Frist batch in pre-monsoon season and second batch in monsoon season, in the year 2019. Soon after being collected from the market, it was immediately transported to Kathmandu by air. Those samples were then delivered to laboratory at the same day and subsequently laboratory analysis were performed.

The analysis was conducted in the Environmental and Climate study laboratory, Nepal Academy of Science and Technology

(NAST). The water samples were examined for the physiochemical and microbiological quality as per the methods described in APHA (2005)[6] (Table 1). The samples were quickly analyzed, soon after arrival, for physiochemical and total coliform count test, in case of delay in analysis samples were preserved at 4°C. Estimates of Physicochemical and Microbiological (total Coliform count) quality of the samples was expressed as per National Drinking Water Quality Standards, 2062 (Table 2) and statistical analysis was carried out using SPSS 17.0. Coefficient of variation and t-test were applied where applicable.

Table 1: Test parameters, methods and instruments used [6]

S. No.	Parameters	Methods	Instruments
Physical			
1	Temperature	Thermometer	EC-210 Rocker Scientific Co.
2	pH	pH meter	EC-210 Rocker Scientific Co.
3	Conductivity (µS/cm)	Conductivity meter	HI 8633 HANNA
4	Turbidity (NTU)	Nephelometry	HI 98713 ISO Turbidimeter HANNA
Chemical			
5	Hardness (mg/L as CaCo3)	EDTA titration	Titration
6	Chloride (mg/L)	Argentometric titration	Titration
7	Iron (mg/L)	Phenanthroline Spectrophotometry	6715 UV/Vis Spectrophotometer JENWAY
8	Arsenic (mg/L)	Colorimetric kit method	QUANTOFIX® Arsenic 10 (Macherey-Nagel Germany)
9	Ammonia (mg/L)	Colorimetric kit method	VISOCOLOR® alpha Ammonium (Macherey-Nagel Germany)
10	Nitrate (mg/L)	Colorimetric kit method	VISOCOLOR® alpha Nitrate (Macherey-Nagel Germany)
Microbiological			
1	Total coliform count (0 cfu/100 mL)	Membrane Filtration (MF)	Membrane filter (0.45 µm)

RESULTS

Same brands of samples were collected and analyzed twice, first batch in pre-monsoon season and second in monsoon season. All the collected samples were found to have a sealed cap. Out of 21 brands of bottled water collected, five brands didn't have manufactured dates, two in first batch and three in second batch, three brands didn't have batch number and expiry date in the both batches but not the same brands. In two brands only batch number was not mentioned, which was in the first batch samples. Those were in the brands manufactured by local companies. All the other brands of bottled water where manufactured date was mentioned, were within a period of 6 months.

All the assessed parameters are in accordance to the standard set by National Drinking Water Quality Standards, except pH and total coliform. In first batch 5 (23.8%) samples' pH was found to be below the lower margin of standard. Whereas, in second batch 4 (19%) samples' pH found to be below the lower margin of standard. All were in the local brands, in both the cases. Two brands, in particular, had low pH in both instances. Statistical analysis showed a significant difference in the level of pH, turbidity and Chloride between two batches. Furthermore, the variability in the samples were more for conductivity and hardness, as expressed in terms of coefficient of variation (Table 2).

Table 2: Physio-Chemical parameters of bottled drinking water

Test parameters	$Range_1$ n=21	$Range_2$ n=21	$(mean \pm SD)_1$	$(mean \pm SD)_2$	CV_1	CV_2	t/z test value	p-value	Standards[#]
Temperature									
pH	6.08-8.30	5.8-7.5	6.9±0.62	6.5±0.4	8.90%	6.10%	2.817[a]	0.01	6.5-8.5*
Conductivity (µs/cm)	1.00-486	0.54-181	67.4±114.6	39.4±42.9	170%	108%	-0.224[b]	0.82	1500
Turbidity (NTU)	0.46-0.92	0.32-0.8	0.62±0.14	0.51±0.11	22.50%	21.50%	2.526[a]	0.02	5 (10)
Hardness mg/l	2-166	Apr-74	22.8±39.6	12.14±15.4	173%	126%	-0.827[b]	0.4	500 mg/l
Chloride mg/l	5.68-19.8	4.2-9.9	8.7±3.1	6.2±1.5	35.60%	24.19%	-3.181[b]	0	250mg/l
Iron mg/l	0	0	0	0	0	0	0	0	0.3mg/l
Arsenic mg/l	0	0	0	0	0	0	0	0	0.05mg/l
Ammonia mg/l	0	0	0	0	0	0	0	0	1.5mg/l
Nitrate mg/l	0	0	0	0	0	0	0	0	50mg/l

* There values show lower and upper limit

() refers the acceptable values only when alternatives is not available

1 results of analysis carried out before monsoon season

2 results of analysis carried out during monsoon season

a t-test values (paired t-test)

b z-test values (Wilcoxon sign rank test)

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In the microbiological analysis, coliform contamination was not detected in the first batch of samples. Whereas, the second batch of samples 38.2% (8) had coliform contamination, three of them had risk grade level D, here too, all in the local brands (Table 3).

Table 3: Total coliform risk of bottled drinking water

Total coliform cfu/100ml	Risk grade	Pre-monsoon samples (n=21)	Monsoon samples(n=21)
0	A (no risk)	0	13
1-10	B (low risk)	0	4
11-100	C (high risk)	0	1
101->1000	D (very high risk)	0	3

DISCUSSION

The physical qualities of water like pH, conductivity, and turbidity give us an idea about the possible contamination by a large variety of pollutants from industry, agricultural, and domestic practices. The pH of the water less than 6.5 can be acidic, naturally soft, and has a corrosive effect on pipes. There can be leakage of heavy metals like lead, zinc, and copper in drinking water which may have a very serious health consequence. On the other hand, the pH of the water more than 8.5 is an aesthetic concern, which may render water not pleasant to taste and also disinfection is less reliable at and beyond this point.[7-8] The result of this study found few brands of bottled water tested had pH less than 6.5 and there was also a significant difference in the pH level during Pre-Monsoon (range 6.08-8.30) and Monsoon (range 5.8-7.5) samples. In the study carried out in Kathmandu where the pH of drinking water from different sources was also not found to be within WHO standard,[9] which ranged from 4.11 to 7.58. Whereas the pH of drinking water in the study carried out in Visakhapatnam, India ranged from 7.1 to 8.5 during Pre-Monsoon and 7.3 to 7.6 during the Post-Monsoon season which didn't exceed the WHO standard.[10] Overall the pH of drinking water was found to be better during the Pre-Monsoon season than in the Post-Monsoon season which quite contradicting the result of this study.

Contrary to general belief, the water is more turbid during monsoon season, [11]it was found to be opposite in the present study, with the mean turbidity level in pre-monsoon samples (0.62±0.14) and monsoon samples (0.51±0.11). But it was still within the normal limits in comparison to the quality of water which was more favorable in pre-monsoon season than in post-monsoon season in the study carried out in Visakhapatnam.[10] Similarly, the chloride content, which is also an indicator of pollution originating from sources like sewage, industrial effluents, and urban runoff containing saline intrusion,[8] was within normal limits but the statistically significant difference in the mean chloride content found between pre-monsoon (8.7±3.1) and monsoon season (6.2±1.5) was somehow difficult to explain. The studies carried out in different parts of Nepal also didn't find the chloride content in drinking water beyond normal limits.[12-13]

Studying the chemical composition of drinking water is not only helpful on understanding about the type of water, hard or soft, but also gives us an idea about how safe the water is for drinking purpose. Chemicals like iron, arsenic, ammonia, and nitrate are the important health concerns among, many others. The determination of these chemicals in this study was found to be normal (nil). Unlike in the study carried out in Kathmandu, where all but arsenic content of water samples crossed the WHO guideline value.[14] Arsenic is naturally present in groundwater in many countries. Long term exposure to arsenic from food and water can cause cancer, skin lesions, and many other health hazards like hypertension, diabetes. In children, it is associated with cognitive dysfunction and the increased deaths in young adults.[15]

At the same time, too much iron, ammonia, and nitrate than would have recommended is also not healthy. Iron can facilitate the growth of so-called iron bacteria while deriving energy from the oxidation of ferrous iron to ferric iron, increasing the depositing of a slimy coat on the pipe. Subsequently, increasing the chance of staining laundry and plumbing fixtures.[16] Nitrates and ammonia, on the other hand, indicates the possibility of bacterial, sewage and animal waste pollution as well as quantity of nitrate in groundwater is strongly linked to the amount of nitrogen applied in agricultural land, which indicates on the imminent health and ecological concern.[17] Studies carried out in many parts of Europe have found increasing nitrogen enrichment of groundwater resources, which is in contrast to the result of this study.[17]

Bacterial contamination of drinking water is a chronic problem in many developing countries. One of the most common waterborne diseases in Nepal is diarrhea. It is the second most common cause of hospitalization among the children below five years of age.[18-19] Coliform count and Heterotrophic plate counts are the widely used tests for regulating the microbial quality of drinking water. The presence of coliform species and heterotrophs in drinking water doesn't pose any health risk on itself but the presence of these bacteria indicates the possibility of the presence of other pathogenic organisms of fecal origin in drinking water.

In this study, a very stark difference in the coliform count during pre-monsoon and monsoon samples of bottled water has been noticed. With more than 38% of samples of bottled water in monsoon samples were contaminated with coliform bacteria against zero during pre-monsoon samples. It has always been a general understanding that the overall quality of water is better in the dry season than in comparison to the rainy season. The analysis of drinking water from different parts of Nepal also revealed the possibility of microbial contamination being not a distant reality. The studies carried out in different parts of Nepal also depicted a similar type of picture as was found in this study.[20-22]

Even though safe and clean drinking water has been categorized as basic human rights by the United Nation. The availability of safe drinking water, not least in developing countries, is still a distant reality. To achieve this goal, safe drinking water as basic human rights, all the concerned authorities, including governmental and non-governmental organizations, communities as well have to play a very proactive role. Water is life, we shouldn't forget this reality and we shouldn't stop working towards achieving this goal. The study was carried out on a small scale including only the commercially produced bottled water in Pokhara city. To know the true extent of contamination either it be physical, chemical or microbial quality of water, multiple samples from various sources of drinking water should have been included in this study.

CONCLUSION

The findings of this study point to the need for regular and systematic analysis and monitoring of drinking water, including commercially available, for mass consumption, bottled drinking water. As of now there is no treatment plant for drinking water in Pokhara. Quality of water is more compromised during monsoon. The findings of this study also confirmed the same notion to some extent. Clean and safe drinking water is a basic human right and it should be within the reach of general population

CONFLICT OF INTEREST: None

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