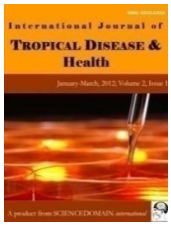

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Physico-Chemical and Thermotolerant Fecal Coliforms Analysis of Commercial Bottled Water in Dar es Salaam City in Tanzania

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Authors' contributions

This work was carried out in collaboration between all authors. Author CSMK conceived the study, wrote the protocol, corrected and analyzed data and drafted the manuscript. Author HMM reviewed the study design and protocol and supervised data collection and analysis. Authors LY and JAS did the analysis and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Background: There is currently an increased demand and consumption of bottled water in Tanzania especially among the middle and high income earners as it is generally perceived to be pure, clean and of good quality. This has led to the sale of different brands of bottled water on the Tanzanian market. Due to increased demand and consumption of bottled water in Tanzania, there has been a growing concern about the microbiological quality of this product. The objective of this study was to assess the physico-chemical quality parameters and microbial contamination level with thermotolerant fecal coliform bacteria commercial bottled water Dar es Salaam city in Tanzania.

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Materials and Methods: This cross sectional study was done in randomly selected ten different commercial brand of bottled water available in commercial market of Dar es Salaam city in Tanzania. Tap water from Dar es Salaam Water Supply Company (DAWASCO) was also sampled for comparison. Fecal coliform were enumerated by the membrane filtration and commercial field testing DelAgua®kit. The physicochemical examination of the water samples was done to determine pH, turbidity and Total Dissolved Solids (TDS) of the water samples using a Hach spectrophotometer (Hach Company, Loveland, Colorado, USA).

Results and Discussion: All samples of bottled water (100%) analyzed did not show the presence of thermotolerant faecal coliform bacteria and thus meet the World Health Organization (WHO) acceptable value of zero cfu/ml. All the surveyed brands of bottled water were safe for drinking as they were devoid of any thermotolerant fecal coliforms bacteria. Tap water from DAWASCO revealed thermotolerant fecal coliforms contamination with mean CFU counts of 4.0/100ml. Coliform organisms found in tap water in this study were above the recommended levels by regulatory agencies such as Tanzania Bureau Standard (TBS), International Bottled Water Association (IBWA), Food and Drug Administration (FDA), United States Environmental Protection Agency for (USEPA), World Health Organization (WHO) and the European Community (EC).

The overall mean results of the physicochemical parameters of bottled water brands and tap water studied were within the recommended limits by TBS and WHO.

Conclusions: The absence of thermotolerant fecal coliform bacteria in the bottled water is indicative of safety for public consumption. Tap water from DAWASCO is unfit for human consumption and it needs to be treated to render it safe for human drinking. Physicochemical parameters revealed that the pH, TDS and turbidity were within the required levels by TBS and WHO. This indicates that, the manufacturers of bottled water brands and DAWASCO are conforming to the TBS and WHO standards on physicochemical requirements for drinking water.

Keywords: Bottled water; thermotolerant; fecal coliforms; E. coli.

1. INTRODUCTION

Bottled water can be defined as any potable water that is manufactured, distributed or offered for sale, which is sealed in food-grade bottles or other containers and intended for human consumption [1]. Bottled water is increasingly perceived as pure, clean, of good quality and protected [2]. Sales of bottled water have increased dramatically in recent years largely because of the public perception of purity and safety and public concern about the quality of tap water [3]. However, consumers need to be made aware that bottled water is not necessarily safer than tap water. Bottled and municipal water may contain the same microorganisms since both can originate from the same environmental contaminants [1]. Under improper processing, handling and/or prolonged storage of bottled water, bacteria can grow to levels that may be harmful to human health [1]. Consequently, when offered for sale to the consumer, bottled water should comply with all of the regulations as set by the Tanzania Bureau of Standards (TBS). According to TBS any harmful bacteria must be absent. Water from surface sources, wells, boreholes, municipal supplies, bottled water and other sources are known vehicles for enteric pathogens such as bacteria, parasites and viruses [4]. Bottled water has previously been implicated as the source of outbreaks of cholera, typhoid fever as well as traveller's disease in countries such as Portugal and Spain [1,5,6]. However, in Tanzania little is known about the microbiological quality of bottled water.

In Tanzania, it is mandatory that, manufactures have their water brands certified and registered by the Tanzania Bureau for Standards [7]. Currently, there are influxes by large number of bottled water brands into the market in Tanzania raising doubts for their quality. Bottled water has become the highest consumable commodity especially for the middle and high income social classes in urban and peri-urban areas, and since it is processed from various sources using different methods, it is important to examine its quality. There are no recent studies that have been done on the bottled water quality with regard to its microbiological and physico-chemical quality in the Dar es Salaam, city in accordance with TBS and other international standards. The aim of this study was to determine microbiological and physicochemical quality of bottled water brands and tap water from DAWASCO and to evaluate their suitability for drinking purposes, in accordance with the

Tanzania Bureau of Standards (TBS), WHO and other international standards for drinking water.

2. MATERIALS AND METHODS

2.1 Study Design

The study design is a laboratory based analytical study. The study was carried out in Dar es Salaam city at the National Institute for Medical Research (NIMR) laboratory. Water samples from different brands of commercial water were collected from different retail shops located in Dar es Salaam city. The collected water samples were checked for their values in four parameters known to be linked to water quality which are pH, hardness and turbidity as well as coli-forms.

2.2 Study Area

This study was conducted between July and October 2013 in Dar es salaam, Tanzania. Dar es Salaam is located at 6 48' south, 39 17'East (-6.8000, 39.2833). The city is situated on a massive natural harbor on the Indian Ocean coast of Africa, with sandy beaches in some areas .It is also the country's richest city and a regionally important economic centre. Dar es Salaam is actually an administrative province within Tanzania, and consists of three local government areas or administrative districts Kinondoni to the north, Ilala in the centre of the Region, and Temeke to the south. The Dar es Salaam Region had a population of 4,364,541 as of the official 2012 census. The city is a metropolitan and in some of its settings it is characterized by poor environmental sanitation, poor housing and poverty.

2.3 Sample Collection

One bottle from each of the ten bottled water samples were collected and examined in duplicates. Tap water from DAWASCO was collected from Mabibo area in Dar es Salaam city in Tanzania. The mouth and the outer parts of the tap were sterilized with the flame of a cigarette lighter for 2 minutes, and allowed to cool by running the water for about 1 minute before water collection. Water sample was collected using a clean one litre plastic bottle with a screw cap which was thoroughly washed with detergent, soaked with hydrochloric acid and rinsed with distilled water. At the point of collection, the container was rinsed three times with the water sample prior to collection. All of the collected water samples were immediately transported and stored refrigerated at 4°C in the laboratory prior to analysis to avoid microbial action affecting their concentration.

The ten brands of bottled water and tap water from DAWASCO examined are shown in Table 1 below.

Table 1. Bottled water brand description

Brand code	Package volume (L)
A	1.0
B	1.5
C	1.0
D	0.5
E	0.5
F	0.5
G	1.0
H	0.5
I	1.5
J	1.5
DAWASCO Tap water	1.0

2.4 Physico-chemical Examination

The physico-chemical examination of the water samples was completed within six hours of sample collection. The pH of each water sample was determined immediately after receiving the sample at the laboratory. The turbidity and Total Dissolved Solids (TDS) of the water samples were determined using a Hach spectrophotometer (Hach Company, Loveland, Colorado, USA).

2.5 Bacteriological Examination

Bacteriological examination of the samples was conducted by using a DelAgua method. The DelAgua method is a straightforward membrane filtration technique based on sample filtration and incubation to promote the growth of colonies which were then counted. A known quantity of undiluted sample (in this case, usually 100 ml) was passed from a HAWG047S6, 0.45µm, 47mm white gridded sterile filter paper leaving any bacteria present in the sample to the surface of the filter. The filter was then placed in a sterile Petri dish containing a sterile lauryl sulphate growth medium, and incubated at 44°C (+/-0.5°C, due to kit limitations) for 24 hours. Colonies of thermo-tolerant coliform (TTC) were counted and reported as TTC per 100 ml sample. The filtration apparatus was flame sterilized with methanol between samples to prevent any cross-contamination of samples.Samples were analysed within 6 hours after collection.

3. RESULTS

3.1 Registration and Certification Status of Sampled Bottled Water

Table 2 provides the list of ten bottled water brands and tap water studied in this investigation. Currently, the Tanzania Bureau of Standards (TBS) has issued a list of 47 bottled water brands which are registered and certified for human consumption in Tanzania. Though already in the market, among the ten sampled commercial bottled water brands, it emerged that three of them are not in the TBS list of certified and registered bottled water brands for human consumption in Tanzania [7].

Table 2. Bottled water classification

Brand name	Registration & certification by TBS
A	Yes
B	Yes
C	Yes
D	Yes
E	No
F	Yes
G	Yes
H	No
I	No
J	Yes
DAWASCO Tap water	No

3.2 Physicochemical Parameters

The overall mean results of the physicochemical parameters of bottled water brands and tap water studied are shown in Table 3.Mean pH of all eleven water samples ranged from 7.0 to 8.1which were within the set limits of TBS in Tanzania (6.5 – 9.2). In consideration of the WHO limit (6.5 – 8.0), one bottled water sample was an outlier [8]. The mean TDS value ranged from 30 to 150 mg/l and this was also within the recommended WHO specification of up to 500 mg/l. Mean turbidity values of studied water samples ranged between 0.16 to 4.81 NTU. The turbidity levels found in water samples were within the TBS recommended limit (5 – 25 NTU) and still within the recommended values by WHO of 5 NTU.

3.3 Microbiological Quality

In the present study the mean thermotolerant fecal coliform bacteria CFU counts /100 ml were not found in all ten bottled water brands sampled and investigated in this study (Table 4). The numbers shown are the average measurements of the two replicates for each of water brand. However; tap water from DAWASCO showed contamination with mean CFU counts of 4.0/100ml which is higher than the acceptable levels by TBS and international organization guidelines on bottled drinking water.

Table 3. Physico-chemical parameters of the bottled drinking water brands and tap water with comparison to the TBS and WHO limit values

Bottled water brand	Mean pH	Mean TDS (mg/L)	Mean turbidity (NTU)
A	7.3	126.7	0.24
B	7.2	113.3	0.33
C	7.0	46.7	0.17
D	7.5	146.7	0.17
E	7.6	70.0	0.17
F	8.1	30.0	0.22
G	7.7	30.3	0.18
H	7.9	20.0	0.26
I	7.3	110.0	0.16
J		70.0	0.21
DAWASCO Tap water	7.4	150.0	4.8l
Standards			
1. TBS	6.5 – 9.2	-	5 – 25
2. WHO	6.5 – 8.0	500	5

Table 4. Levels of fecal coliform bacteria in water samples

Bottled water brand	Colony forming units per 100 mls (CFU/100 mls)		
	Measured value 1	Measured value 2	Mean
A	0/100	0/100	0/100
B	0/100	0/100	0/100
C	0/100	0/100	0/100
D	0/100	0/100	0/100
E	0/100	0/100	0/100
F	0/100	0/100	0/100
G	0/100	0/100	0/100
H	0/100	0/100	0/100
I	0/100	0/100	0/100
J	0/100	0/100	0/100
DAWASCO Tap water	5/100	3/100	4/100

4. DISCUSSION

Outbreaks of waterborne diseases, often of epidemic proportions have been occurring if human wastes that are contaminated with pathogens enter water supplies. These include cholera, typhoid fever and dysentery. Because it would be practically impossible to test for each of the wide variety of pathogens that may be present, microbiological water quality monitoring is primarily based on tests for indicator organisms. The coliform bacteria count is a reliable indicator used to test water for contamination by microorganisms. Coliform bacteria (*Escherichia coli*) live naturally in the human intestinal tract and the average person excretes billions of them in feces each day[9]. The term "coliform bacteria" refers to a group of gram negative bacteria that have a long history of being good indicator of human fecal contamination in water quality assessment. Coliform bacteria are harmless and cause no diseases, but their presence in water is an indication of recent fecal contamination [9]. If none are found, the water is free from fecal contamination and can be assumed to be free from pathogenic organisms, hence fit for human consumption. The drinking water recommended standards set by the TBS, IBWA, FDA, USEPA, WHO and the EC are shown in Table 5.

Table 5. Guidelines on bottled water limits of microbial contamination

S/N	Authority	Fecal coliform/*E. coli*
1.	TBS	0/100 ml
2.	IBWA	0/100 ml
3.	FDA	<2.2/100 ml
4.	USEPA	0/100 ml
5.	WHO	0/100 ml
6.	EC	0/100 ml

TBS = Tanzania Bureau of Standards; IBWA = International Bottled Water Association; FDA = Food and Drug Administration; USEPA = United States Environmental protection agency; WHO = World Health Organization; EC = European Community

With the exception of tap water from DAWASCO, all of the studied bottled water samples complied with microbial safety requirement as per TBS, IBWA, FDA, USEPA, WHO and the EC for drinking water quality.

Thirteen brands of bottled water collected from shops, supermarkets and street vendors in Dar es Salaam were investigated for their microbiological qualities and 4.6% of them were found to be contaminated with total and faecal coliform bacteria [10].

In another study, it was revealed that 95.4% of bottled water was free from total and fecal coliform bacteria. Similar findings have been reported in a recent study whereby physico-chemical quality parameters of nine bottled water in Dar es Salaam, Tanzania were found to be good [11]. Furthermore, the findings from the previous study on microbiological quality of bottled water and this current observation in this study, indicates significant improvement in water treatment by the manufacturers as evidenced by the total absence of fecal coliform bacteria in bottled water.

Similar findings have recently been reported whereby in all the bottled drinking water brands available in retail shops in Mwanza city in Tanzania were found to have conformed to TBS and WHO guidelines for drinking water. The study concluded that the bottled water brands were safe for human consumption [12].

With regard to the quality of tap water from DAWASCO, similarly in the previous study it was also found to be worse with higher total and fecal coliform bacterial counts, hence is still unfit for human consumption unless properly disinfected [10]. Principally, bottled water is supposed to be the reliable healthy drinking water in any parts of the world including Tanzania as it is regulated and have to undergo through series of treatments to ensure safety.

5. CONCLUSION

Our findings provides an insight on the physicochemical and microbiological quality of ten bottled water brands currently sold in retail shops in Dar es Salaam city in Tanzania. The results obtained revealed that the pH, TDS and turbidity were within the required levels set by TBS and WHO. This indicates that, the manufacturers of sampled bottled water brands and DAWASCO in Tanzania are conforming to the TBS and WHO standards on physicochemical requirements for drinking water. Results also showed the absence of thermotolerant fecal coliforms bacteria in the bottled water brands hence indicative of safety for public consumption. With the exception of DAWASCO tap water, all of the studied bottled water samples complied with microbial safety requirement as per TBS, IBWA, FDA, USEPA, WHO and the EC for drinking water quality. Tap water from DAWASCO is unfit

for human consumption and it needs to be treated to render it safe for human consumption. The measured physicochemical and microbiological quality parameters in the brands are within standards limits set by TBS, IBWA, FDA, USEPA, WHO and the EC for drinking water quality. Our findings revealed that the brands of bottled water analyzed are safe for human consumption. However, concerned authority should prioritize on the regular monitoring of drinking water physicochemical and microbial quality conformation of bottled water brands and tap water in Tanzania to continue providing safe drinking water to the population.

CONSENT

Not applicable.

ETHICAL APPROVAL

The research protocol was approved by the Faculty of Science, Technology and Environmental Studies of the Open University of Tanzania, P.O. Box 23409, Dar es Salaam, Tanzania.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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