Full Length Research Paper

Compliance to Bacteriological Standards for Bottled Drinking Water Sold in Lusaka District, Zambia

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Abstract

Many people in Zambia and the world over perceive bottled water as safe for consumption. However, studies indicate that not all bottled water is up to standards. This study aimed at assessing the bacteriological quality of bottled drinking water sold in Lusaka and level of compliance to standards by water bottling companies of Lusaka district. Fourteen brands of bottled water were sampled from companies and on the market (supermarkets, grocery shops and distribution centres). A total of 56 bottled water samples were collected and tested for total and faecal coliform using membrane filtration technique. The study revealed 8.9% of samples positive for both faecal and total coliforms. Contamination levels ranged from two coliform forming units (cfu) to too numerous to count (TNTC) and nine cfu to TNTC for faecal and total coliforms respectively. The majority of the samples that tested positive were from the market representing 7.1%. The study revealed that not all water sold in Lusaka district was of good quality. This is an indication of the risk related to consumption of bottled water and calls for attention.

Keywords: Compliance, Bottled drinking water, Bacteriological, Standards, Lusaka.

INTRODUCTION

It is reported that over one billion people in the world lack safe drinking water (UNICEF, 2006). According to World Health Organization (WHO) guidelines for drinking water (2011), safe drinking water is defined as water that does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages (WHO, 2011 p.1). One of the primary goals of the WHO is to provide access to an adequate supply of safe drinking water to half of the world population by 2015. This goal was attained five years before the target year in most countries. However, this goal is still far from being achieved in most developing countries especially in the rural and peri-urban areas (UNICEF and World Health Organization, 2012).

According to UNICEF (2008) over three million people die annually of water-related diseases. Almost two million people due to diarrhoeal diseases such as cholera, typhoid and polio caused by drinking of contaminated water, poor hygiene and sanitation (UNICEF, 2008 p.4).

The lack of safe drinking water, status symbol, taste and potential health benefits has resulted to people spending over 100 billions of dollars per year to buy bottled drinking water (The water project, 2014; United States Environmental Protection Agency, 2005). In addition, the prevalence of cholera, dysentery and other waterborne diseases, coupled with the perceived poor quality of municipal tap water has greatly increased the consumption of bottled drinking water (Safe Drinking Water Foundation, 2005). However, according to literature there is no guarantee that processed and bottled water is absolutely safe for human consumption (Lusaka City Council, 2012; Times of Zambia, 2012; Nyundu et al., 2012; Kassenga, 2007; Okagbue, 2002).

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In Zambia, there are various institutions that are responsible for ensuring that bottled drinking water is always up to set standards. The Zambia Bureau of Standards (ZABS) and Lusaka City Council (LCC) are among these regulatory institutions. It is their responsibility to ensure that bottled drinking water sold to the population is up to the recommended standards (LCC, 2012; ZABS, 2000). These authorities are mandated by law to carry out inspections and collect water samples to ensure that water sold is up to set standards (LCC, 2012; ZABS, 2000). In addition, water bottling companies are also required to ensure that standards are followed. This can be achieved by making sure that they adhere to hygiene standards in the handling and use of appropriate methods when processing the products. The Food and Drugs Act Chapter 303 of the laws of Zambia, Zambia Bureau of Standards Acts Cap 416 of 1994 and World Health Organization Standards are the main laws and regulations concerned with the quality of bottled drinking water in Zambia. These laws and regulations indicate that the faecal and total coliforms have to be zero in every 100mls of water tested. However, the Zambia Food and Drugs Act recommends total coliform less than 10 coliform forming unit in every 100mls of water tested (ZABS, 2000; Government of the Republic of Zambia, 1995; WHO, 1996; WHO, 1988).

Total and faecal coliforms are the most common microorganisms checked for water safety. Total coliform count is primarily used as a practical indicator of the general hygienic quality of water and mainly used in routine monitoring of drinking water supplies. Faecal coliform bacteria count is used as a practical indicator of faecal pollution and it is more specific for faecal pollution than total coliforms (WHO, 2011)

Despite existing laws and regulations that guide water quality, some companies in Zambia do not meet the standards for bottled drinking water qualities (LCC, 2012). For example, an assessment of water quality in Lusaka by Lusaka City Council revealed that most companies (60%) dealing in bottled water did not meet the bacteriological standards (Times of Zambia, 2012). In addition, a study conducted by Nyundu et al. (2012) in various sites of Zambia revealed similar findings. Most studies conducted outside Zambia also revealed similar findings for example, a study in Tanzania revealed that out of 130 samples representing 13 brands of water tested, 4.6% and 3.6% were contaminated with total and faecal coliform respectively (Kassenga, 2007). A study in Zimbabwe which involved 60 samples from 3 companies revealed 11.7% of water tested exceeding the total coliform count (Okagbue, 2002). On the other hand, a study conducted in Ghana in 2009 revealed that all sampled water complied with WHO standards (Addo et al., 2009).

It is therefore undeniable that if bottled water being sold is not up to standards, consumers are at risk of diseases and water poisoning. Cholera outbreak related to consumption of bottled water were reported in Portugal in the 1970s and another outbreak in the United States territory Mariana Island in 1994 (Safe Drinking Water Foundation, 2005; Blake et al., 1977). This could be one of the main contributing factors to high incidence of diarrhea and other water related diseases in Zambia. The fact that consumers are at risk calls for further investigation.

While most of the assessments and studies concluded that most water sold in Zambia is not safe, no known documented and published study considered determining the bacteriological quality standards of bottled drinking water and level of compliance to standards by water bottling companies in Lusaka district. In addition, other studies included water bottling companies outside Lusaka as well as outside Zambia. This study aimed to fill the gap that existed. A cross-section study was done to sample bottled water of different brands and to test for total and fecal coliform as indicators of compliance with standards.

The study adds to the existing body of knowledge on standards of bottled water and helps the water bottling companies, policy makers and other stakeholders concerned with standards of bottled water to make relevant decisions on bottled water in Zambia, thereby improving the health of the public.

MATERIALS AND METHODS

Study design and setting

A quantitative cross-sectional study was conducted in Lusaka district, Zambia. The study involved sampling of bottled drinking water to determine compliance to set bacteriological quality standards.

Target population and sampling of companies

The target population consisted of 26 water bottling companies registered with ZABS and LCC in Lusaka (ZABS, 2013). Thus out of these, only 14 companies (54%) who gave consent to the study were included in the study. However, this sample size is large enough as a representative sample to make meaningful conclusion from the findings.

The companies were sampled by firstly categorizing them into sizes: small, medium and large according to Zambia Bureau of Standards (2013). The number of companies to be picked in each category was determined using probability sampling proportional to size.

This was done as follows:

Number of companies to be sampled in each category = Total number of companies in each category/Total number of companies x Total sample size required.

From the calculation, five, six and three companies were picked from small, medium and large categories respectively. The companies included in the study were picked using simple random lottery sampling for each category.

Data collection and water sampling

Data were collected by the principal investigator with the help of three research assistants from December 2013 to January 2014. A total of 56 samples of bottled water were collected, four for each brand of which two were from the company and another two were from the market. One sample at two different times for each brand and point was drawn at about 10-to-14 day intervals. Water from the companies was sampled at the packaging stage from the batches of water ready for distribution. In terms of the market, water was purchased from the grocery shops, supermarkets and distribution centres. These centres were selected using systematic random sampling from the lists of all water distributors identified by each company. At each company and distribution centre lot sampling technique for quality control in industrial production was used to sample the water. Lot sampling technique involve taking a small random sample from a set of items check for compliance and generalize it to the whole set of items from which the samples were picked (Rao, 2011). The sampled water was clearly marked for identification. The collected water was stored in a cooler with ice packs maintaining the temperature to avoid reactions that could result when the sampled water is exposed to sunlight and high temperatures. The sampled water was delivered to the laboratory within 24 hours of collection for analysis.

Water analysis

Analysis of water samples was done at the University of Zambia Environmental Engineering laboratory. A total of 112 tests were carried out: 56 tests for presence of total coliform and another 56 for faecal coliform using membrane filtration method. For each sample, 100 ml of water was filtered through a membrane made of cellulose compound of pores 0.45 microns. After filtration the membrane was incubated on a suitable selective medium called endo medium for Total Coliform and MFC agar medium for Faecal Coliform. The coliform bacteria were then left to reproduce and form colonies for 24 hours on the medium. The number of colonies produced at 35 degrees Celsius gave the total coliform count. For faecal coliform the membranes were incubated at 44.5 degrees Celsius on the medium; the colonies formed on the medium after 24 hours represented the faecal coliforms in the sample. The number of colonies on the media was counted using a low-power microscope. When the total number of colonies were more than 200

or could not be counted through the microscope, the results were reported as "Too Numerous to Count" (TNTC). Water samples that had more than 0 total cfu per 100mls or indicated the presence of faecal coliforms were graded as non-complying with recommended standards in accordance with the WHO and Zambian standards.

Table 1 shows the recommended bacteriological standards of bottled water that was used in grading for compliance in this study and this is in accordance with the Food and Drugs Act, Zambia Bureau of Standards Zambia and World Health Organization.

Ethical considerations

Before commencement of data collection, permission was obtained from Lusaka City Council and each company which accepted to take part in the study. Study approval was also obtained from Excellence in Research Ethics and Science Coverage Research Ethics Committee. The names of the companies that participated in the study including their water brands were kept confidential during data analysis and compilation of the final report.

Data analysis

The laboratory results were analysed using Microsoft excel obtaining frequencies and proportions.

RESULTS

Distribution of companies and analyzed sampled water

The study included 14 water bottling companies in Lusaka district representing 14 brands of bottled water. The Distribution of the companies was as follows: five (35.7%) small, six (42.9%) medium and three (21.4%) large. In terms of water samples, a total of 56 bottles of water were sampled by drawing four (4) from each of the selected companies, and out of these 28 were from the company premises while the remaining 28 samples were from the market. Thus out of the 56 water bottles that were sampled a total of 112 laboratory water tests were conducted of which 56 were for total coliform and the remaining 56 for faecal coliform.

Bacteriological quality standards of bottled drinking water and compliance to standards

The study revealed that out of the 56 bottles sampled, five tests were positive for both faecal and total coliforms. Meaning (8.9%) of the analysed samples did

Table 1. Recommended bacteriological standards of bottled drinking water

Laws/ Regulations	Total coliform cfu per 100ml	Faecal coliform cfu per 100ml
WHO	0	0
ZABS	0	0
FDA	10	0

Source: (ZABS, 2000; Government of the Republic of Zambia, 1995: WHO, 1996; WHO, 1988)

not comply with standards. The level of contamination of faecal coliform ranged from two cfu to TNTC. In terms of total coliform the level of contamination ranged from nine cfu to TNTC. The majority of the positive tests were from the water that was collected from the market, which were eight tests representing (7.1%) of the water samples tested. In terms of collection time, the first samples from the company collected recorded two positive tests while none of the samples of the second samples from the company were contaminated. At the market the first group of samples reported two contaminated samples. The second and last samples from the market contained six contaminated samples. Information on the laboratory results is presented in Table 2.

DISCUSSION

The study revealed that not all bottled drinking water sold in Lusaka district was safe. The study revealed that 8.9% of water tested were not complying with World Health Organization and Zambia's (Food and Drugs Act and Zambia Bureau of Standards) standards of bottled drinking water of zero total and faecal coliform in every 100mls of samples tested. The sample water were found to be contaminated with both faecal and total coliform. These results are in line with the study and assessment conducted in Zambia by Nyundu et al. 2012 that revealed water sold in Lusaka was not safe. However, the level of compliance with standards was higher compared to the ones from other studies in Zambia (Times of Zambia 2012; Nyundu et al., 2012). The difference in contamination among the studies might be attributed to the number of water samples tested; more samples were tested in the study and assessments in Zambia by Nyundu et al. 2012 and Lusaka City Council, 2012. For example, 233 samples representing 39 brands were collected in the study by Nyundu and others compared to the 112 samples representing 14 brands that were included in the current study. In addition, the assessment and study in Lusaka extended their sample to water companies outside Lusaka and Zambia. Furthers more, the companies within Lusaka that were part of the prior assessments were more likely to comply with standards if improvements were made after the results of the assessments by Nyundu et al. 2012 and the Lusaka City Council in 2012 were communicated

and recommendations addressed.

The results of the current study are also in line with studies conducted outside Zambia. For example, the current study findings are in line with results from a study conducted in Zimbabwe that investigated the microbiological quality of water processed and bottled in Zimbabwe (Okagbue, 2002) and a study in Tanzania 2007 on the microbiological quality of bottled drinking water sold in Dar es Salaam by Kassenga. On a contrary, a study conducted in Ghana in 2009 was not in agreement with the results of the current study, as all the water tested for fecal and total coliform and E. coli were in accordance with the WHO standards (Addo et al., 2009). In general, the majority of the studies and assessments conducted in Zambia and outside Zambia showed similar results, an indication that the problem of the quality of bottled drinking water is not only a problem in Zambia but in other countries as well.

The current study also established that most of the water that was contaminated was from the market, indicating that contamination might have been attributed to factors occurring after the treatment and bottling processes such as transportation and storage - most likely if the bottles were leaking. Contamination might also have been the result of counterfeit products at the market. Some samples had high levels of contamination levels too numerous to count, an indication of high contamination.

These results indicate a serious threat to the health of consumers as this can lead to serious outbreak like was the case in Portugal and the United States of America (Safe Drinking Water Foundation, 2005; Blake, 1977). In addition, it is important to note that the level of contamination revealed in this study may possibly cause adverse health effects to the consumers. This is because any level of contamination may result into adverse health effects considering that bottled water is consumed by different people. The water sample containing faecal coliform was an indication of faecal contamination that may result into diseases (Kassenga, 2007).

The following were the limitations of the study; only companies that were registered with Lusaka City Council and Zambia Bureau of Standards were included in the study. This might have affected the results in determining proper company representation in Lusaka.

The other limitation of the study was that only two

Table 2. Laboratory test results for total and faecal coliform in bottled drinking water

Company Number	1st Test Company		2nd Test Company		1st Test Market		2nd Test Market	
	TC# per 100ml	FC # per 100ml	TC per # 100ml	FC # per 100ml	TC per # 100ml	FC # per 100ml	TC per # 100ml	FC # per 100ml
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	12	10
8	0	0	0	0	0	0	9	2
9	0	0	0	0	0	0	TNTC	TNTC
10	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0
13	14	8	0	0	0	0	0	0
14	0	0	0	0	TNTC	TNTC	0	0

NOTE: TNTC: Too Numerous to Count, FC: Faecal Coliform, TC: Total Coliform.

bacteriological parameters were considered in assessing compliance among other bacteriological parameters. In addition, only one laboratory was used for all tests carried out and no confirmatory tests were carried out. These limitations might have affected the reliability and validity of the results. However, all possible precautions were put in place to make sure that samples were representative of the target population by random sampling of companies, distribution points and water samples. In addition all research assistants were trained on proper water sampling method.

Despite the limitations of the study discussed above, it has possibly contributed to the body of knowledge on water quality in terms of revealing that not all bottled drinking water sold in Lusaka district is up to bacteriological standards.

CONCLUSION

The study revealed that not all the bottled drinking water sold in Lusaka district was of good quality, as 8.9% of water tested was not complying with zero cfu per 100mls of both faecal and total coliforms as recommended by World Health Organization and the Zambian standards. This is an indication of the risk related to consumption of bottled drinking water.

In view of these study findings, the following recommendations are made for consideration by relevant stakeholders and policy makers: Regulatory authorities involved in bottled water in Zambia such as; the Lusaka City Council and Zambia Bureau of Standards must ensure that water sold to the public comply with standards. This can be achieved by conducting regular inspection of bottling water

companies and quality monitoring of water on the market and companies: Water Bottling Companies must ensure quality control of water being sold to the public. Similarly, water distributors in markets must also ensure that they buy water from reputable sources. In addition, more research is needed to cover areas not addressed in this study such as; compliance to chemical and physical parameters of bottled drinking water, treatment methods, handling and storage of bottled drinking water in Zambia.

ACKNOWLEDGEMENTS

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