

## The health-related microbiological quality of bottled drinking water sold in Dar es Salaam, Tanzania

Gabriel R. Kassenga

### ABSTRACT

The consumption of bottled and plastic-bagged drinking water in Tanzania has increased largely because of the deteriorating quality of tap water. It is uncertain whether these water products are safe for drinking. In this study, the microbiological quality of bottled and plastic-bagged drinking water sold in Dar es Salaam, Tanzania, was investigated. One hundred and thirty samples representing 13 brands of bottled water collected from shops, supermarkets and street vendors were analysed for total coliform and faecal coliform organisms as well as heterotrophic bacteria. These were compared with 61 samples of tap water. Heterotrophic bacteria were detected in 92% of the bottled water samples analysed. Total and faecal coliform bacteria were present in 4.6% and 3.6%, respectively, of samples analysed with a tendency for higher contamination rates in plastic-bagged drinking water. Microbiological quality of tap water was found to be worse compared with bottled water, with 49.2% and 26.2% of sampling points showing the presence of total coliform and faecal coliform organisms, respectively. The results suggest caution and vigilance to avert outbreaks of waterborne diseases from these types of drinking water.

**Key words** | bottled water, faecal coliforms, heterotrophic organisms, Tanzania, tap water, total coliforms

### Gabriel R. Kassenga

Department of Environmental Engineering,  
University College of Lands and Architectural  
Studies (UCLAS),  
PO Box 35176, Dar es Salaam,  
Tanzania  
Tel.: (255) 22 2775004  
Fax: (255) 22 2775479  
E-mail: [kassengagr@yahoo.com](mailto:kassengagr@yahoo.com);  
[kassenga@uclas.ac.tz](mailto:kassenga@uclas.ac.tz)

### INTRODUCTION

Bottled water is generally perceived as pure, clean, of good quality and 'protected'. Although waterborne diseases associated with consumption of commercial bottled water are not common, some such cases have been reported. Bottled drinking water has been occasionally related to diarrhoea conditions known as traveller's disease (Warburton *et al.* 1992). In Portugal, during the cholera epidemic of 1974, bottled mineral water was identified as one of the vehicles of transmission of *Vibrio cholerae* (Blake *et al.* 1977). A survey of bottled water conducted in the United Arab Emirates, where about 90% of the population drink bottled mineral water, showed that out of 20–1.5 litre bottles, 40% were bacteriologically contaminated (Nsaze & Babarinde 1999). A study conducted in Canada by Warburton *et al.* (1986) indicated that 46% of the domestic purified

waters exceeded the Canadian bottled-water standard of 100 colony forming units per millilitre (CFU ml<sup>-1</sup>) for plate counts. In Wales, UK, *Staphylococcus epidermidis* and *Staphylococcus hominids* were found in 6 out of 52 bottles of water examined, and their occurrence was attributed to poor hygiene during processing (Hunter & Burge 1987).

Although the microbial quantity levels in processed water are often initially low, they can evolve rapidly to high levels during storage (Stickler 1992). This rapid growth of bacteria after the water is bottled may be due to oxygenation of the water during processing, the increase in surface area provided by the bottle, the increase in temperature, and the amount of nutrients arising from the bottle (Warburton *et al.* 1992; Warburton 2000). Gonzalez *et al.* (1987) observed multiplication of bacteria 1 to 3 weeks after bottling with

bacterial counts ranging from 103 to 140 CFU ml<sup>-1</sup> at 37°C in the absence of chlorine or ozone treatment. Growth of microorganisms may also occur via carriers such as introduced flakes of human skin, particularly in non-ozonated and non-carbonated water (Hunter & Burge 1987).

Tap water in Dar es Salaam is generally not considered safe for drinking because of inadequate treatment and post-treatment contamination in distribution systems. This situation, linked with the prevalence of waterborne diseases in the city (Chaggu 2004), has caused the business of bottled water to flourish, as many people believe that bottled water is safe. There are about 38 brands of bottled drinking water registered by the Tanzania Bureau of Standards (TBS), of which 13 brands are currently available in the Dar es Salaam consumer market.

There are no reported studies on the bacteriological quality of the various bottled waters consumed in Tanzania and the methods for minimizing contaminants. The main objective of this study was therefore to examine the bacteriological quality of bottled water available in Dar es Salaam using total coliform, faecal coliform and heterotrophic bacteria as indicators of the possible presence of microbial pathogens. The bacteriological quality of bottled water was also compared with that of tap water to verify whether the consumption of expensive bottled water is really warranted. Field observations and a consumer survey were also conducted to supplement data on bacteriological quality.

## MATERIALS AND METHODS

Dar es Salaam was selected as the study area because the city is the largest business centre in Tanzania and also constitutes about 30% of the urban population. Dar es Salaam probably has the highest number of bottled water consumers of any other urban centre in Tanzania since about 57% of all bottled water companies are located in the city.

### Sampling of bottled water

Thirteen different bottled water brands (marked Brands A-M) were selected since these were the ones available to

the consumer. The bottled water was purchased from grocery shops, supermarkets, street vendors and distribution centres, clearly marked for identification, and brought into the Environmental Engineering Laboratory at UCLAS for immediate analysis. The study used the sampling procedure for bottled water as specified by the Tanzania Standard for Drinking Water TZS 574, 1999 Clause 8 (TBS 1999). Ten bottles for each of the identified brands were sampled and analysed for total and faecal coliform organisms over a period of two months. Fifty of the samples were from plastic-bagged water, and the rest (80) from water in plastic bottles. Four samples of each brand were analysed for heterotrophic organisms for a total of 52 samples.

The cap of each water bottle was carefully removed avoiding touching the opening with bare hands. The bottle contents were then poured into a sterile container. For plastic-bagged water, an edge of the packet was cut with sterile scissors and the contents emptied into a sterile container.

### Sampling of consumer tap water

This was done according to the WHO *Guidelines for Drinking Water Quality Standards* (WHO 2004). Samples were taken randomly at locations throughout the distribution system, including points near its extremities and taps connected directly to the mains in houses and large multi-occupancy buildings, where there is a greater risk of contamination through cross-connections and back-siphonage. The 61 sampling points were also those used for water quality monitoring by Dar es Salaam Water Supply and Sanitation Authority (DAWASA). Residual chlorine levels in the distribution system were used as a surrogate assessment method to assess the potential threat of post-treatment contamination of water.

### Analytical procedures

Total coliform and faecal coliform organism numbers were determined using Standard Method 9222B Standard Total Coliform Membrane Filter Procedure and Standard Method 9221E Faecal Coliform Membrane Filter Procedure, respectively, as detailed in *Standard Methods* (1998).

Heterotrophic bacteria were enumerated using Standard Method 9215C Spread Plate Method. The number of colony forming organisms was counted manually. Counting stopped at a ceiling of 1,000 CFU.

Residual chlorine was measured using Standard Method 4500-CL-B Iodometric Method I. The detection limit applied for this method was  $40 \mu\text{g l}^{-1}$  according to *Standard Methods* (1998).

### Consumer survey and physical observations

A questionnaire form was used to interview 200 bottled-water consumers at various places in the city during sampling operations. The interviews mainly focused on determining consumption rates of bottled water, understanding reasons for preferring bottled water to tap water and establishing the level of awareness on the information provided on the labels of bottled water brands.

Physical observations were conducted to assess field conditions. This included visits to bottled-water processing, packaging and sealing plants to assess the hygienic conditions. Observations were also made on the storage facilities at the factories, wholesale and retail points. The key issues assessed were hygienic conditions during handling, transportation and storage. The purpose of socio-economic survey was to estimate bottled water consumption rates and pattern.

## RESULTS AND DISCUSSION

### Bottled water

Table 1 shows sources of water, treatment methods used and package volumes for the bottled water brands investigated. According to TBS (1999), the quality and types of packaging material used for bottled water must be the same as those for packaging food products. The TBS specifications stipulate that bottled drinking water shall be packaged in hermetically sealed sterilized retail containers suitable for preventing possible contamination (TBS 1999). Plastic is the most commonly used type of packaging material for bottled drinking water in Tanzania. The types of plastic material used include polyester-terephthalate (PET) and high-density

**Table 1** | Source of water, treatment method used and package volume for the surveyed brands

Brand	Source of water	Treatment method	Package volume (l)
A	Borehole	Not mentioned	0.5–1.5
B	Borehole	Not mentioned	0.25
C	Borehole	Not mentioned	0.25
D	Borehole	Ozonation	0.5–1.5
E	Spring water	Not mentioned	0.5–2.0
F	Borehole	Not mentioned	0.25
G	Borehole	Ozonation	0.25
H	Spring water	Not mentioned	0.5–3.0
I	Natural spring	Not mentioned	0.5–1.5
J	Natural spring	Filtration and sterilization	0.25–3.0
K	Borehole	Reverse osmosis	0.5–5.0
L	Borehole	Ozonation	0.5–1.5
M	Groundwater	German reverse osmosis and ozonation	1.5

polyethylene (HDPE) for bottles and low-density polyethylene (LDPE) for plastic bags. Most of the caps used are made from HDPE. According to the Tanzania Drinking Water Specifications TZS 574 Part 1 Section 7.2 bottled drinking water should be packaged in various units up to 2-l containers and should be stored away from direct sunlight. It was observed that for some brands water was packaged in bottles that exceed the maximum TBS package volume of 2l (Table 1).

The heterotrophic bacteria counts from the bottled water samples showed that most of the bottled-water brands were excessively contaminated (Table 2). All 40 samples of brands A, B, C, D, E, F, G, H, I, J and L tested positive for the presence of heterotrophic bacteria (Table 2). For brands E and K, 75% and 50%, respectively, of samples examined indicated the presence of heterotrophic organisms. There was no bacterial growth in brand M for all samples

**Table 2** | Heterotrophic bacterial count in bottled water

Bottled water brand	Range of bacterial counts (CFU ml <sup>-1</sup> )
A	500 to 850
B	750 to > 1,000
C	310 to > 1,000
D	250 to > 1,000
E	0 to 450
F	200 to > 1,000
G	26 to 200
H	130 to > 1,000
I	300 to > 1,000
J	600 to > 1,000
K	0 to 216
L	16 to 53
M	ND

Number of samples per brand,  $n = 4$ ; ND = not detected.

examined. On the whole, 92.3% of all sampled brands available in Dar es Salaam indicated the presence of heterotrophic organisms. Sixty-two per cent of all bottled water products investigated had more than 500 CFU ml<sup>-1</sup> of heterotrophic bacteria. WHO drinking water quality specifications allow HPCs of as high as 500 CFU ml<sup>-1</sup> (WHO 2004); therefore, 62% of the samples analysed were non-compliant with the WHO Water Quality Guidelines.

There is no evidence that HPC values alone directly relate to health risk either from epidemiological studies or from correlation with occurrence of waterborne pathogens (Bartram *et al.* 2003). However, specific strains of microbial species that may be a part of HPC microbiota can cause infection in certain vulnerable people especially the immuno-compromised (Nsaze & Babarinde 1999).

In general, the presence of coliform organisms indicates the possible presence of microbial pathogenic agents. For example, an outbreak of non-O1-*Vibrio cholerae* in the United States was associated with bottled water, which

tested positive for coliforms although the source of contamination was not determined (Nsaze & Babarinde 1999).

Some of the samples contained coliform bacteria (Table 3). Numbers of CFU of faecal coliform and total coliform organisms ranged from 1 to 15 and from 1 to 20 per 100 ml, respectively.

It was found that 20% and 8% of the plastic-bagged water samples ( $n = 50$ ) indicated the presence of total coliforms and faecal coliforms, respectively, whereas 2.5% of the plastic-bottled water samples ( $n = 80$ ) contained total coliforms and 1.3% had faecal coliforms. In general, out of 130 analysed samples, 9.2% and 3.1% contained total coliform organisms and faecal contamination indicator organisms, respectively.

These findings on the microbiological quality of plastic-bagged water compared favourably with the findings of a recent study conducted in Metropolitan Kumasi, Ghana, which showed that 42.5% of hand-filled hand-tied

**Table 3** | Extent of bacterial contamination of bottled drinking water

Bottled water brand	Type of plastic package	Number of bottles showing growth of total coliform	Number of bottles showing growth of faecal coliform
A	Bottle	Nil	Nil
B	Bag	2	1
C	Bag	1	1
D	Bottle	Nil	Nil
E	Bottle	1	Nil
F	Bag	3	1
G	Bag	2	Nil
H	Bottle	Nil	Nil
I	Bottle	Nil	Nil
J	Bag	1	1
K	Bottle	Nil	Nil
L	Bottle	2	Nil
M	Bottle	Nil	Nil

Number of samples per brand,  $n = 10$ .

polythene bagged drinking waters ( $n = 40$ ) contained total coliforms, 22.5% contained faecal coliforms and 5% enterococci (Obiri-Danso *et al.* 2003). No microbial indicators of faecal contamination were found in bottled water in the study conducted by Obiri-Danso *et al.* (2003) in contrast with the observations made in this study.

From the physical survey, poor hygiene during processing, storage and distribution and leaking of packages appear to be the main cause for contamination of bottled water products in Dar es Salaam. Street vendors in particular sell bagged and bottled water under unacceptable sanitary conditions. Fifty-four per cent of the surveyed brands did not indicate on the labels the water treatment methods used. Lack of treatment for prevention of bacterial regrowth in some of the surveyed brands sold in Dar es Salaam may also partly explain the observed higher rate of contamination in accordance with the findings of other studies conducted elsewhere (Hunter & Burge 1987; Warburton *et al.* 1986). During the socio-economic survey, manufacturers of bottled water reported that pre-used (and therefore branded) factory plastic-bagged sachets are hand-filled with water of suspect quality under unhygienic conditions and sold at a cheaper price thus affecting their businesses. This is a possible reason for the higher contamination rate of plastic-bagged water compared with bottled water because it is much easier to reseal a plastic bag than to mend the broken seal of a water bottle for producing counterfeits. In addition, plastic bags are more susceptible to puncturing and leaking than plastic bottles, consequently plastic-bagged water is more likely to be contaminated through leaks than bottled water. Leaking of caps due to defective seals was observed for some brands; this could be one of the possible reasons for contamination of bottled water. The bouncing movement of bottles in delivery trucks and during handling are other possible causes of leakage.

It is not uncommon to find bottled water products stored under direct sunlight in unhygienic conditions. In view of this, the possibility of growth of microorganisms is greatly increased considering that temperatures in Dar es Salaam may be as high as 30°C. A study conducted by Nsaze & Babarinde (1999) in the United Arab Emirates demonstrated that the organisms multiply more easily between 25 and 37°C. The normal room temperature (from 28 to 32°C) in most of the bottled water storage facilities and grocery

shops in Dar es Salaam may also favour the growth of microbial pathogens.

Figure 1 can help to shed light on the possible influence of bottled water distribution routes on the final quality of water. It is evident that the distribution routes of bottled water products before they reach the consumers are longer compared with those in most developed countries where bottled water is mostly obtained directly from authorised sellers, which are usually regulated. In view of this, the possibility of post-packaging contamination is greatly increased especially where street vendors, who normally operate in unsanitary conditions, are involved.

### Tap water

Heterotrophic organisms were found in 68% of the tap water samples ( $n = 30$ ), with HPCs ranging from 125 to >1,000 CFU ml<sup>-1</sup>. Tap water was more contaminated with coliform organisms than was bottled water, suggesting that the preference of bottled water over tap water for health reasons by many consumers is indeed justified. About 49.2% of tap water sampling points were found to contain total coliform organisms with CFU counts ranging from 1 to 280 per 100 ml. Faecal coliform organisms were detected in 26.2% of the sampling points with CFU counts ranging from 1 to 196 per 100 ml. Residual chlorine was detected in 14 sampling points only, representing 23% of all sampling points. Residual chlorine concentrations at the sampling points ranged from 0.1 to 0.5 mg l<sup>-1</sup>, with 93% of the points having less than 0.3 mg l<sup>-1</sup>, which is the optimum chlorine residual for prevention of bacterial regrowth (WHO 2004). Only one sampling point containing residual chlorine (0.1 mg l<sup>-1</sup>) was observed to be contaminated with coliform organisms. It can generally be inferred from these findings that there was a good correlation between the absence of

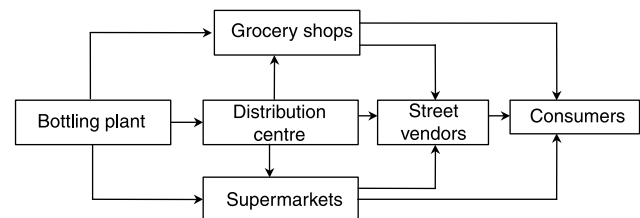


Figure 1 | Bottled drinking water distribution routes in Dar es Salaam.



coliform organisms and the presence of residual chlorine in the distribution system.

Leaking of distribution pipes (estimated to range from 30 to 50%) due to old age and inadequate maintenance is considered to be the main cause of contamination of tap water (Mato 2002). Presumably in recognition of the fact that tap water is prone to contamination, public health authorities and even utility companies themselves advocate boiling of tap water before drinking as a precaution against contracting waterborne diseases.

### Consumer survey

Results based on the survey of 200 consumers of bottled water products showed that they preferred bottled water to tap water mostly because of safety (62%) followed by taste (33%) and smell and colour (5%). Consumption rates of bottled drinking water ranged between 0.25 and 2.5 l per person per day (Figure 2) with most of the consumers (93.5%) consuming between 0.25 and 1.5 l per day.

The consumption rates of bottled water (Figure 2) were significantly higher than an average value of about 0.23 l per capita per day for European countries as reported by Ferrier (2001). This is not surprising considering that Dar es Salaam has high temperatures (28 to 32°C) and humidity (67 to 97%) for more than 70% of the year (Mato 2002). Availability of cheaper bottled/bagged water brands (costing as little as US\$0.2 per litre) almost everywhere including in the streets makes bottled/bagged water a readily available and more attractive option than tap water, which is also (normally) considered unsafe.

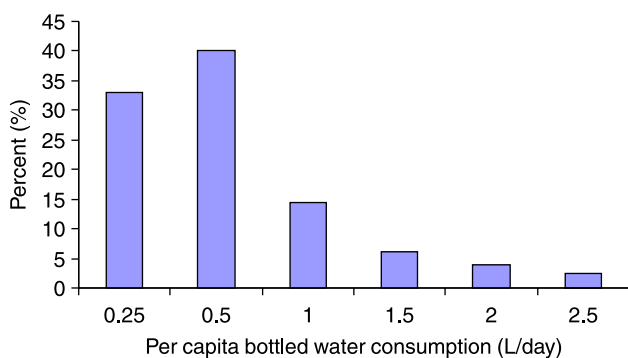


Figure 2 | Consumption rates of bottled water in Dar es Salaam.

### Public health risk

The significance for public health of the presence in bottled water of heterotrophic and coliform organisms is difficult to analyse by means of risk assessment because of the lack of direct linkage between these organisms and a specific pathogen and/or disease. Notwithstanding this limitation to risk assessment, the observed high consumption rates of bottled water (0.25 to 2.5 l per person per day) with compromised microbial quality (faecal coliform count 1 to 15 CFU 100 ml<sup>-1</sup>) put the general public at a risk of acquiring waterborne diseases. The presence of coliform organisms generally indicates that the water is not safe since faecal material, which may contain disease agents, can gain access to the water.

### CONCLUSION

Although the sources of contamination were not determined, it was suspected that storage of bottled water products in unhygienic and high temperature conditions, defective packaging and lack of protective measures against bacterial regrowth were probably the main contributing factors affecting the bacteriological quality of bottled water. There is a possibility that water was contaminated before bottling as other previous studies also observed. The degree and rate of contamination suggest a need to be cautious and vigilant to avert the possibility of an outbreak of waterborne diseases from these types of drinking water. Regulations geared towards the prevention of exogenous sources of contamination of bottled water products should also be enforced.

There is no doubt that bacteriological quality of bottled water sampled for this study was superior to that of tap water. Considering that in Dar es Salaam the price of bottled water (US-cents 20–40 per litre) is between 87 and 174 times that of tap water (US-cents 0.23 per litre), boiling and filtering of tap water at the household level may be a more cost effective approach (especially for low-income families) for obtaining safe drinking water than purchasing expensive bottled water of suspicious quality.

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