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Assessment of Bottled Drinking Water Quality, Safety and Community Perceptions in Dodoma City, Tanzania

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Abstract

The popularity of bottled drinking water stems from its convenience and purity, driving its rapid growth, but concerns about safety and quality persist. Physicochemical and microbiological parameters of bottled drinking in Dodoma City were evaluated from September to December 2023. Additionally, key informant interviews and questionnaire surveys were conducted with government regulators, producers, and consumers on regulatory frameworks, production processes, and consumer perceptions. Overall, all brands tested were suitable for drinking and met World Health Organization and Tanzania Bureau of Standards guidelines. The total dissolved solids ($F = 0.86$, $p < 0.05$), calcium ($F = 5.26$, $p < 0.05$) and chloride ($F = 0.32$, $p < 0.05$) were significantly different, while other parameters were not ($p > 0.05$) between measured and labelled values. The total viable and coliform counts in two brands (10%) of water were higher than the suggested levels of 100 cfu/ml and 0 cfu/ml, respectively. Bottling companies reported observance of quality control measures (93%), adherence to regulations (91%), transparency in production processes (86%), and consumer awareness of labels, expiration dates, and trust in the bottled water industry (95%). Public awareness, inspection, and testing of bottled water, as well as strengthening the existing framework, are recommended.

Keywords: Physicochemical parameters; Microbiological characteristics; Coliform counts; Regulatory frameworks; Purity.

Introduction

Access to clean and safe water is a human right (World Health Organization / United Nations Children's Fund 2022), essential for maintaining health (Allaire et al. 2019) and ensuring the well-being of communities around the world (Hall 2009, Hamad et al. 2022). Waterborne diseases, particularly diarrhoea, cholera, typhoid fever, hepatitis A, E, and giardiasis, pose a global public health concern, especially in developing countries, causing severe illness and death, particularly in children under five (Igbeneghu and Lamikanra 2014, MoH 2022). Bottled water bacterial and viral contamination poses health risks, especially for vulnerable populations (Georgieva and Dimitrova 2016). Bottled drinking water consumption has surged globally due to safety and quality concerns (Kassinga and Mbuligwe 2009, Pant et al. 2016, Qian et al. 2018, Howell et al. 2019, Hamad et al. 2022), a choice for individuals and households driven by purity and ease of use (Pu and Fukushi 2016, Qian et al. 2018).

Tanzania faces health risks from contaminated drinking water due to widespread waterborne diseases, inadequate treatment, limited sanitation access, rapid urban expansion, and a lack of knowledge about safe drinking practices. The growing bottled water sector in Dodoma City, covering 2,607 km² with a population of 765,179 (Tanzania National Bureau of Statistics 2022), raises security and quality concerns, despite its perceived safety, as existing regulations are questioned (Energy and Water Utilities Regulatory Authority 2020). Studies have highlighted variations in regulatory frameworks across different countries and regions regarding bottled water (Chidya et al. 2019, Maddah and Alzhrani 2017; REAL - water 2022). The effectiveness of these regulations, however, remains a subject of scrutiny and debate (Güler 2007; Valavanidis 2020). While regulations provide a level of assurance, consumers must exercise discretion and awareness in their bottled water choices (March et al. 2020).

Studies have found instances of misleading labelling, such as exaggerated claims about water sources or purity (Kassinga and Mbuligwe 2009). The Tanzanian government enforces regulations to ensure the quality of bottled water due to urbanisation and increasing demand. The Tanzania Food, Drug, and Cosmetic Act No. 1 of 2003 govern this, while the Tanzania Bureau of Standards (TBS 2005, 2016) enforces national standards based on WHO guidelines (TFDA 2003). Bottled water must meet strict packaging (IBWA 2022a) and labelling requirements, and companies must obtain permits and licenses to ensure compliance (Energy and Water Utilities Regulatory Authority 2020). Environmental regulations and consumer complaints are also in place to minimize environmental impacts. The main elemental compositions include chloride (Cl^-), fluoride (F^-), sulfate (SO_4^{2-}), nitrate (NO_3^-), sodium (Na^+), potassium (K^+), iron (Fe^{2+}), zinc (Zn^{2+}), copper (Cu^{2+}), calcium (Ca^{2+}), and magnesium (Mg^{2+}) (Aris et al. 2013). These ions are essential for body processes like nerve and immune functions, muscle contractions, dietary intake, wound healing, red blood cell formation, bone health, tooth decay prevention, and many more (Francisco 2014, Pant et al. 2016, Chidya et al. 2019, WHO 2022, Kaur et al. 2024). Bottled water should not be used with infants due to its salty or sulfate-rich content of less than 200 mg sodium and less than 250 mg sulfate per litre of water (Rudnicka and Hozyasz 2018). Some water is suitable for baby food but must be boiled before use (Song et al. 2021). Kidney disease sufferers should monitor product labels for mineral content and seek medical advice before using them (Rodgers 1997). Kaur et al. (2024) highlights the importance of potassium, phosphorus, sodium, and calcium, which are of significant concern due to their potential impact on kidney function. The recommended daily intake for these minerals varies based on age, health status, and medical conditions: potassium (3,510 mg), phosphorus (700 mg), sodium (2,000 mg), and calcium (1,000 mg).

In Tanzania, 22% of households treat drinking water, while 66% do not (Tanzania Demographic and Health Survey reports 2022). Improving water quality at the source doesn't eliminate disease risk, as contamination occurs during collection and storage (March et al. 2020). Home water containers have higher contamination levels than taps (Song et al. 2021, Umoafia 2023). Bottled water safety depends on the source, treatment processes, the duration and conditions of storage, sanitary conditions, cleaning, and packaging materials (Kassenga 2007, Georgieva and Dimitrova 2016, IBWA 2022b). Diduch et al. (2013) emphasised the need for sanitary conditions in bottling plants, proper cleaning of bottles, and the use of suitable materials for packaging to prevent contamination. The bottled water quality is poorly evaluated across brands and production sites, and the long-term health effects of contaminated water are not well documented (Song et al. 2021). Existing regulations' impact on quality improvement is unclear, and contamination sources are not well-established. This study assesses the chemical, physical, and microbial contamination of bottled water and its compliance with national and international standards for safety and suitability for consumption in Dodoma City, Tanzania.

Materials and methods

Study area description

Dodoma City, the capital of Tanzania lies at 6° 10' 43" South and 35° 45' 2" East (Fig. 1).

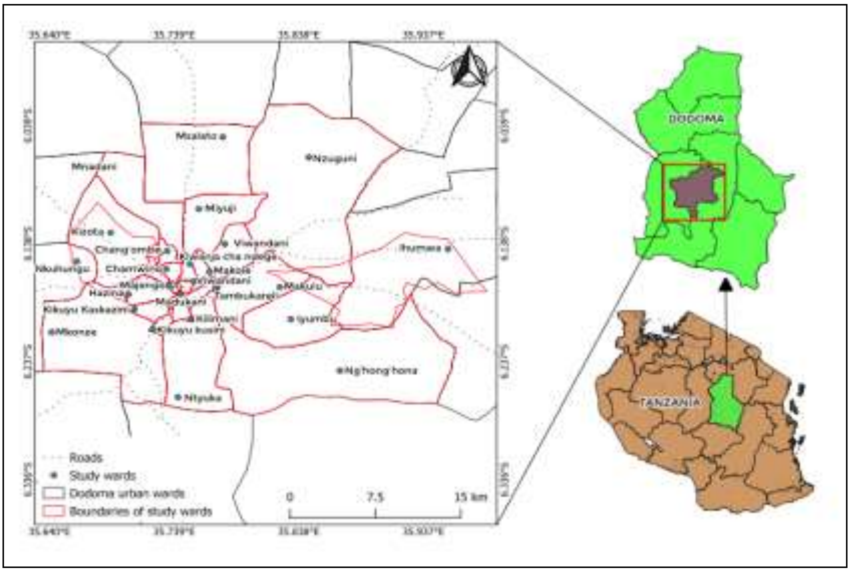

Figure 1: A map showing sampling wards in Dodoma City, Tanzania.

It has a semi-arid climate with 550-600 mm annual rainfall. The city has moderate-drain soils and Savannah vegetation type characterized by Acacia and Baobab tree woodlands. The temperatures range from 20°C in July to 30 °C in November. The area has a number of seasonal rivers, dams, and shallow wells with (Myeya 2021). A total of 25 wards representing 61% of the sampling sites were chosen. The wards were Chamwino, Chang'ombe, Dodoma Makulu, Hazina, Ihumwa, Ipagala, Iyumbu, Kilimani, Kikuyu kusini, Kikuyu kaskazini, Kiwanja cha Ndege, Madukani, Kizota, Makole, Majengo, Miyuji, Mkonze, Mnadani, Msalato, Ng'ong'ona, Nkuhungu, Nzuguni, Ntyuka, Tambukareli, and Viwandani. The consumption of bottled water was notably high in these locations, where information regarding usage patterns, quality perceptions, and regulatory compliance of bottled water was available. The study was limited to evaluating brands of bottled mineral water available in Dodoma City. Brands were assigned an alphabetical code from AA to AT in order to protect the anonymity of the brand identities; this convention is used throughout the text.

Data collection methods

Questionnaire survey, review of regulations and interview with stakeholders

A sample size of 400 people was used to compare perceptions between age, gender, income levels, education levels, and geographic areas. A structured questionnaire was developed to gather data on community perceptions regarding the quality and safety of bottled products. The questionnaire underwent pre-testing for validity and reliability to enhance its effectiveness. Respondents were selected using stratified random sampling to ensure diverse representation across various areas of the city. The Tanzanian regulations and standards for bottled drinking water, including the National Environment Management Act of 2004, the Public Health Act of 2010, the Water Resources Management Act of 2009, quality control logs, certification documents, and test results, the 2018 National Drinking

Water Quality Monitoring and Reporting guidelines, as well as TBS and WHO standards, were reviewed to see if they aligned with these standards. The documentation provided by manufacturers and distributors was used to ascertain if bottled drinking water met the criteria for water quality and safety. Conversations guided by a checklist between producers, officials, regulatory officials, industry representatives, and consumers encompassed the quality and safety of bottled water to gather qualitative and quantitative data on the effectiveness of the regulations. The questions probed the understanding of environmental laws, institutional mandates, and duties; whether the production and distribution of bottled water were supported by law; and whether any action had been taken to guarantee adherence to TBS and WHO standards. Face-to-face interviews surveys were conducted by trained field staff. The safety of bottled water and compliance evaluation of labelled information were examined according to the procedure outlined by Oyeku et al. (2001). A thorough analysis of bottled water labels, including checking for accurate source identification, manufacturing date, expiration date, and manufacturer contact information, was conducted to verify adherence to TBS and WHO standards.

Sample collection and analysis of physical, chemical, and microbiological characteristics

A survey identified 20 renowned bottled water brands in Tanzania from local markets, shops, and stores, including at least one brand from each ward that was available at the time of sampling. A total of 100 samples, five samples from each brand, were collected over two months, three times per week. Samples analysis for physicochemical and microbiological parameters was conducted at the University of Dodoma Department of Chemistry and Microbiology Laboratories, ensuring no market exclusions and the inclusion of representative and well-known brand names in Tanzania.

A calibrated digital pH meter measured the pH of each water sample. A Hach Turbidimeter Model 2100 was used to measure turbidity. Chloride (Cl^-), nitrate (NO_3^-), and fluoride (F^-) were determined using Standard Methods for the Examination of Water and Wastewater (APHA 2005). Sodium (Na), potassium (K), and magnesium (Mg) were analysed using an atomic absorption spectrophotometer, while iron (Fe^{2+}), zinc (Zn^{2+}), copper (Cu^{2+}), and calcium (Ca^{2+}) were analysed using a spectrophotometer [S: 15121: 2002, ISO 6869: 2000]. For microbiological analysis, chemical reagents were employed as per manufacturers' guidelines to prepare the necessary growth media. The plate count standard method was used for the analysis, and sequential two-fold dilutions of the water samples were performed. Microbial analysis of the water samples employed two indices: the total viable count and the total coliform count. The total viable count was determined through the pour-plate method. A ten-fold dilution of water was prepared, dispensed onto nutrient agar plates, incubated for 24 hours at 37°C, and examined for bacterial growth. Presumptive positive samples were cultured on MacConkey agar plates and incubated at 35°C for 48 hours as per procedure described by Rompré (2002) and Atlas (2010).

Statistical Analysis

Descriptive statistics were used to summarize results for concentration ranges, means, and standard deviations of different water parameters. Analysis of variance (ANOVA) was used to compare the means of parameters in different brands to see if there were significant differences between labelled and measured values, if $p < 0.05$. The differences between the means were determined using the Duncan Multiple Range Test (DMRT). Other statistical analyses were carried out using the statistical package IBM SPSS Statistics 23.0.

Results and discussions

Socio-demographic characteristics

In Table 1, the majority of respondents (63.6%) were male, with females being higher in Mnadani ward (54.4%). The majority (66.6%) had secondary or higher education, suggesting high literacy levels in addressing bottled water quality and safety issues.

Table 1: Socio-demographic characteristics of the respondents and perceptions (%) on bottled drinking water quality and safety from consumers in Dodoma city, Tanzania (n=400)

Demographic characteristics	Proportion (%)	Perception of Water Quality (%)	p-value
Gender			
Males	63.6		
Females	36.4, Mnadani ward (54.4)		
Education Level			
Secondary or Higher	66.6	High literacy	
Age Groups			
18-29	25	70	$p < 0.01$
30-44	35	60	$p < 0.05$
45-59	25	50	$p < 0.05$
60 and above	15	40	$p < 0.05$
Occupations			
Students	20	75%	$p < 0.01$

Significant differences in perceptions of bottled drinking water quality and safety across different age groups and occupations were observed. Students and younger respondents tended to view the quality of bottled water more favourably (60%), while older respondents and those who were retired or unemployed had more concerns about safety. The high percentage indicates a positive perception of bottled water quality, which was statistically significant ($p < 0.05$). 60% of respondents rated bottled water quality as high, with 30% describing it as moderate, and 10% as low, indicating a generally positive perception of bottled water safety. The high percentage indicates a general positive perception of bottled water quality, which was statistically significant ($p < 0.05$). 40% of respondents expressed safety concerns about bottled water, while 60% were not concerned. Reasons for choosing bottled water included taste, health benefits, and convenience, with taste being the most significant preference. The preference for taste was statistically significant ($p < 0.01$), indicating a strong preference based on this attribute.

Compliance with existing regulations

Bottled water brands at the time of sampling were Afya, Cool Blue, Dasani, Dew Drop, Eco Water, Hill, Hydrop, Ice Drop, Jibu, Kai, Kilimanjaro, Kisima, Lilaqua, Maji Tanzania, Marangu, Mkwawa, Royal, Sequa, Udzungwa, and Uhai. Importing bottled water from outside Dodoma city is unregulated, with Dar es Salaam accounting for 40% of the total. Proportions from other regions were: Kilimanjaro (15%), Mwanza (10%), Morogoro (5%), Iringa (5%), Rukwa (5%), and Dodoma city itself (20%). The city bottled water industry lacks laws to prevent transportation from other locations, allowing a variety of brands from different regions. Despite TBS and TFDA commitment to safety and quality improvement, existing regulations haven't been reviewed or updated for 15 years. Bottling companies in the city have 93% quality control measures, 91% adherence to regulations, and 86% transparency (Table 2). Bottled water production has designated testing and certification processes, but additives and treatments are not addressed. Consumers are 80.8% aware of labels and expiration dates, and 95.6% trust the industry. This high level of trust indicated a positive perception of the industry's practices and products among consumers (Howell et al. 2019, Francisco 2014). However, local governments in the city have not adequately promoted public awareness about safe and quality bottled water, leading to consumers being unaware of health risks, struggling to distinguish reliable brands, and compromising consumer safety.

Table 2: Awareness and perceptions of regulatory body (n=2), bottling company (n=4), and consumers (n = 400) on bottled water quality and regulatory compliance in Dodoma City, Tanzania

Stakeholder	Key points assessed	Responses	
		Yes %	No %
Regulatory Body	- Committed to enforcing regulations	100.0	-
	- Recognizes the need for ongoing improvements	100.0	-
Bottling Company	- Invests in advanced quality control measures	93.0	7.0
	- Ensures adherence to regulations	91.0	9.0
	- Highlights transparency in production	86.0	14.0
Consumers	- Importance of labels and expiration dates	80.8	19.2
	- Expresses trust in bottled water industry	95. 6	4.4

Table 3 shows differences in labelling of constituents in bottled water brands. While some constituents, like pH and chloride ions, are always listed, others, like iron and nitrate ions, are only rarely mentioned, raising questions about transparency and consumer trust. The information is valuable for making informed choices and gaining consumer trust and confidence in product labelling (Francisco 2014, Allaire 2019). In all brands assessed, there were no special considerations or rules that were labelled for specific vulnerable populations, such as infants, pregnant women, and those with kidney dysfunction. According to Rodgers (1997), Rudnicka and Hozyasz (2018), and Song et al. (2021), special groups like infants, pregnant women, and those with kidney dysfunction require special consideration when consuming bottled water. Failure to provide labelling or special considerations poses significant health risks (Kassinga and Mbuligwe 2009, Mihayo and Mkoma 2012). Regulatory authorities and manufacturers must prioritise vulnerable populations' needs in regulation and marketing to ensure safe drinking water, including mandatory labelling and quality control standards.

Table 3: Number of ingredients labelled and not labelled on the bottles for twenty bottled water brands collected in Dodoma City, Tanzania (n=100). Samples per brand, n = 5.

Ingredients	pH	TDS	Cl^-	Na^+	Ca^{2+}	Mag^{2+}	SO_4^{2-}	F^-	K^+	NO_3^-	Fe^{2+}
Brands labelled	19	12	20	10	12	12	10	10	13	6	2
Brands unlabelled	1	8	0	10	8	8	10	10	7	14	18

The study reveals that while most bottled water brands comply with labelling requirements, some exhibit better adherence. However, only a few brands, such as AD, AE, AI, AO and AP, have an approval mark from the Tanzania Bureau of Standards, except for AD, AE and AP. All brands provide accurate information about the product name, source (except AB, AC, AF, AG, AH, AL, AM, AN and AO), and contact information except AE, which is essential for consumer inquiries and feedback (Mihayo and Mkoma 2012). The treatment process was stated by AA, AP, AQ, AR, AS, and AT; the rest did not. This lack of transparency can be a concern for consumers who want to know how water was treated (March et al. 2020; Valavanidis 2020). All brands indicated bottle sizes, storage conditions, production dates, and expiry dates for consumers to ensure quality control, freshness assessment, and safe water consumption, except for AB, AD, AE, AG, AM, AO, AP, and AS (Energy and Water Utilities Regulatory Authority 2020, March et al. 2020). Consistently adhering to labelling requirements indicates better quality adherence and regulatory control (Rodgers 1997). Accurate labelling provides consumers with essential information (Rudnicka and Hozyasz 2018; Song et al. 2021), promoting transparency (Chidya et al. 2019), and informed decision-making (Kassenga and Mbuligwe 2009). Most bottled drinking water brands meet quality and safety standards, with all 20 brands exhibiting colourless, odourless, and tasteless characteristics. All brands meet chemical standards and have 99.1% of no detectable bacteria. Most brands are packaged in PET (polyethylene terephthalate) bottles and stored at normal room temperature. Most brands were stored at normal room temperature, with variations in exposure to sunlight and dust contamination.

The review of existing regulations and standards revealed several important considerations. Firstly, it is important for regulatory authorities to periodically update and refine regulations to align them with evolving scientific knowledge and international best practices (Energy and Water Utilities Regulatory Authority 2020). Secondly, the study identified discrepancies between the existing and observed amounts of ingredients (Güler 2007). Some brands (AG and AI), constituting 10%, have raised concerns by indicating non-compliance with microbial standards. The presence of microbes in samples suggests that there may be potential health risks in certain brands (Georgieva and Dimitrova 2016; Mahmoud et al. 2019), hence the need for continuous monitoring (Maddah and Alzhrani 2017), quality control improvements, and regulatory enforcement (Chidya et al. 2019) to ensure the safety of all bottled water products on the market. The safety and quality testing procedures were conducted regularly and with adequate frequency for bottled water.

Table 4: Comparison of number of ingredients (NI), concentration of physical, chemical, and microbiological parameters for labelled (L) and measured (M) to allowable limits for drinking water quality of the Tanzania Bureau of Standards (TBS) and World Health Organization (WHO) of various bottled water brands (AA, AB, AC, AD,…and AT) collected in Dodoma City, Tanzania (n=100). Samples per brand, n = 5, for each parameter.

		pH		**Turbidity**		**TDS (mg/l)**		**Chloride (mg/l)**		**Sodium (mg/l)**		**Calcium (mg/l)**		**Magnesium (mg/l)**	
Brand	NI	L	M	L	M	L	M	L	M	L	M	L	M	L	M
AA	9	7.3	7.3	-	0.0	40.0	30.5	9.4	6.1	14.5	3.9	4.0	6.0	1.5	28.0
AB	6	7.0	7.3	-	0.0	40.0	79.6	16.0	12.2	-	7.8	-	6.0	1.8	4.0
AC	6	7.0	7.5	-	0.0	-	26.9	2.5	6.1	4.0	3.9	1.0	4.0	-	3.5
AD	7	7.0	8.0	-	0.0	40.0	79.6	9.4	10.0	-	0.9	4.0	8.0	12.0	12.0
AE	5	7.0	8.0	-	0.0	-	26.9	8.2	12.2	12.0	78.0	-	8.0	-	2.0
AF	6	7.0	7.4	-	0.0	-	9.7	9.1	18.3	26.2	11.7	-	20.0	-	0.9
AG	8	7.1	7.5	-	1.5	78.0	111	18.7	9.4	-	11.0	6.2	14.2	-	1.0
AH	5	-	7.9	-	0.0	-	33.7	6.0	6.1	5.0	3.9	-	2.0	2.0	8.0
AI	8	7.0	7.7	-	1.0	40.0	33.6	9.2	6.1	8.2	3.9	3.2	12.0	1.7	10.0
AJ	6	7.3	8.0	-	0.0	-	49.8	10.6	5.9	-	2.9	4.0	13.2	6.4	1.5
AK	7	7.0	7.3	-	0.5	39.0	35.6	9.1	6.1	-	39.0	8.0	8.0	1.6	2.0
AL	8	7.2	8.2	-	0.0	-	77.9	14.2	18.2	7.4	11.7	-	4.0	3.6	2.0
AM	8	7.1	7.5	-	1.5	78.0	67	2.2	12.0	-	12.1	6.2	11.2	-	1.0
AN	7	7.1	8.0	-	0.0	38.0	92	14.2	13.0	14.1	18.0	-	7.8	0.1	8.0
AO	8	7.0	7.5	-	0.0	-	48.1	5.8	12.2	16.0	12.0	2.4	6.0	2.6	2.0
AP	7	7.0	8.9	-	0.5	90.0	35.6	28.0	6.1	30.0	30.9	8.0	4.0	3.0	4.0
AQ	4	7.0	8.3	-	0.0	-	4.6	8.5	0.9	-	0.8	1.8	4.0	2.4	26.0
AR	4	7.0	7.0	-	0.0	40.0	53.4	8.9	12.2	-	7.8	2.0	6.0	-	2.0
AS	3	7.2	8.0	-	0.0	41.0	49.1	11.2	19.0	-	11.9	-	5.5	-	9.7

AT	4	7.0	7.8	-	0.5	39.0	41.5	13.0	17.6	-	29.0	-	9.0	-	8.0
Mean		7.1	7.7	-	0.3	50.2	49.3	10.7	10.5	13.7	15.1	4.2	7.9	3.8	6.8
SEM		0.0	0.1	-	0.1	5.6	6.2	1.3	1.1	2.7	4.0	0.7	1.0	1.3	1.7
SD		0.1	0.4	-	0.5	19.4	27.6	5.8	5.1	8.6	18.1	2.4	4.3	3.7	7.7
TBS		6.2 - 9.2		5-25		< 1000.0		200.0		200-800.0		50-100.0		75-300.0	
WHO		6.5 - 8.5		5		1000.0		250.0		250.0		200.0		200.0	

	Sulphate (mg/l)		Fluoride (mg/l)		Potassium (mg/l)		Nitrate (mg/l)		Iron (mg/l)		Total Plate Count (Cfu/100ml)	Total Coliform (Cfu/100ml)
Brand	L	M	L	M	L	M	L	M	L	M		
AA	23.0	5.0	0.2	1.0	2.6	3.5	-	3.8	-	0.2	100	00
AB	-	5.0	-	0.5	0.1	0.7	0.4	0.7	-	0.1	20	00
AC	-	4.5	0.2	1.3	0.5	0.8	-	1.9	-	0.2	100	00
AD	9.0	4.0	-	1.0	2.6	2.6	-	2.0	-	0.1	40	00
AE	-	3.0	0.1	0.7	-	11.0	-	3.4	0.1	0.2	10	00
AF	-	4.0	0.5	0.5	8.0	8.9	6.9	11.1	-	0.1	100	00
AG	6.0	3.7	0.1	0.2	3.3	3.0	10.0	13	-	0.1	130	13
AH	10.0	1.5	-	0.1	3.0	3.1	-	3.5	-	0.1	60	00
AI	-	3.0	0.1	0.2	0.6	0.8	-	2.4	-	0.2	100	38
AJ	5.2	2.9	-	0.1	-	1.1	-	3.1	0.2	0.2	20	00
AK	-	6.0	-	0.1	0.2	0.5	0.5	2.0	-	0.2	20	00
AL	1.6	4.0	0.2	0.1	0.4	0.5	1.7	1.5	-	0.1	60	00
AM	6.0	7.1	0.3	0.1	3.3	3.5	1.0	1.9	-	0.1	100	00
AN	-	6.0	0.1	0.2	2.5	2.8	-	1.7	-	0.1	50	00
AO	7.0	2.0	0.7	0.6	1.6	1.7	-	3.2	-	0.2	20	00
AP	5.4	5.0	-	0.1	-	2.0	-	2.3	-	0.1	10	00
AQ	-	3.0	-	0.2	-	11.2	-	2.2	-	0.1	10	00
AR	-	7.0	-	1.0	-	9.8	-	2.6	-	0.1	20	00
AS	-	4.5	-	0.2	-	7.7	-	1.9	-	0.2	60	00
AT	6.5	3.1	-	0.1	-	13.9	-	2.4	-	0.2	100	00
Mean	8.0	4.2	0.2	0.4	2.2	4.4	3.4	3.3	00	0.1	56.5	9.6
SEM	1.8	0.3	0.1	0.2	0.6	0.9	1.6	0.7	00	00	8.9	6.7
SD	5.7	1.5	0.2	0.4	2.1	4.3	4.0	3.1	0.1	00	39.9	29.9
TBS	10-100.0		1.5-4.0		-		<10		0.3-1.0		00	00
WHO	150.0		1.5		-		50.0		0.3		100 cfu/ml	00

NB: (-) - Not mentioned, Standard Errors of the Mean (SEM), Standard Deviation (SD), and Total Dissolved Solids (TDS).

Physical, chemical and microbiological characteristics

Table 4 presents the composition of the minerals (in mg/l) of different water brands, the number of ingredients (NI), and whether they are labelled (L) or measured (M), excluding pH for each brand (AA to AT). Findings indicated that none of the sampled water exceeded the allowable limits for labelled (L) and measured values (M), suggesting that the regulations in place effectively control chemical quality. The physical, chemical, and microbiological characteristics of the bottled water samples showed variations within the WHO and TBS acceptable range, suggesting that the water products were in compliance with regulatory standards. The TDS, chloride, and calcium were significantly different ($p < 0.05$), while others had no significant variations in physical and chemical parameters among different brands of bottled water from labels and measured samples ($p > 0.05$). For several brands, there were differences in the amount of constituents between the labelled and tested water samples, as reported by Kassenga and Mbuligwe (2009), which compared the physico-chemical quality of tap and bottled water in Dar es Salaam. The existence of coliform bacteria and Escherichia coli in some bottled water brands (AG and AI) raises health risks. While most brands meet microbiological safety criteria, 10% have coliform bacteria, indicating contamination in production, bottling, and distribution processes. Regular inspections and regulatory compliance are crucial (Diduch et al. 2013; Wright et al. 2016). Ineffective treatment processes fail to eliminate microbial contaminants.

Insufficient equipment cleaning and unhygienic conditions within bottling facilities (Ministry of water and irrigation 2018; WHO, 2022), improper handling of bottles and caps (Georgieva and Dimitrova 2016), and exposure to sunlight, heat, or prolonged storage periods create favourable environments for microbial growth (Igbeneghu and Lamikanra 2014).

Conclusions

Assessments of bottled drinking water quality, safety, and community perceptions revealed that most brands met WHO and TBS standards. Microbiological analysis indicated that 10% of brands exceeded safe limits for total viable and coliform counts. Bottling companies demonstrated high compliance with quality control and regulatory standards, and consumers exhibited strong trust and awareness, though potential biases may exist due to limited geographic scope and reliance on self-reported data. Increased public awareness, regular inspections, and enhanced regulatory measures are recommended.

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Conflict of Interest

We have no personal relationships with individuals or organizations that could bias our interpretation of the results or conclusions drawn in this study.

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