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# The evaluation of bottled water quality compliance association formal and informal retailers in Gauteng municipality. South Africa

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ABSTRACT

The quality of bottled water (BW) can vary based on factors such as handling, processing, transportation, hygiene practices, and the retail shop from which it is purchased. This study aimed to compare the microbiological quality of BW (Heterotrophic plate count (HPC), *E.coli,* and total coliforms (TC)) purchased from both formal and informal retail shops. The study used a convenience sampling approach and categorized the shops into formal and informal. A total of 117 samples were obtained, with 16 from informal shops and 101 from formal shops. The data was analysed using SPSS version 29, and the water quality compliance was assessed based on SANS 241, 1657, and World Health Organization standards for drinking water. The findings indicated a significant link between compliance with bottled water (BW) standards and the specific shop from which the BW was purchased (p 0.001). These results highlight shop compliance's crucial role in influencing BW's microbiological quality, especially in relation to total coliforms (TC) and *E.coli* presence. Bottled water obtained from informal shops did not meet the standards, whereas BW from formal shops adhered to the standards for TC and *E.coli*.

## 1. Introduction

Bottled water (BW) is defined as any potable water that is bottled or packaged and distributed or offered for sale and is specifically intended for human consumption as posited by Amenu (2014). The BW is widely available in both formal and informal retail outlets, and it can be packaged in either glass or food-grade plastic containers (Amenu, 2014). The perceived quality of the water is often associated with the location of its sale. Interestingly, in many countries, it is used as a substitute for drinkable tap water (Shapsugova, 2021; Ajala et al., 2020; Pacheco-Vega, 2019; Odeyemi, 2015), even in regions where tap water is of high quality (Cohen & Kay, 2018). Additionally, it is commonly utilized during both formal and informal gatherings (Maselela et al., 2024), and in emergency situations such as natural disasters (Pacheco-Vega, 2019). It is also considered a food item in some areas (Shapsugova, 2021; SANBWA, 2021; Cohen & Kay, 2018). The lack of access to safe and clean drinking water exacerbates the use of BW as a primary source of drinking water (Juba & Tanyanyiwa, 2018; Stoler, 2012). Some of the BW is not treated for chemical (Banda et al., 2021; Chidya et al., 2019), microbiological contamination (Maselela et al., 2024; Keleb et al., 2022), and may contain faecal pollutants (Love, 2013) and heavy metals (Olowoyo, 2022; Ajala et al., 2020). These contaminants can lead to infectious diseases (Gautam,2021), and are costly to treat (Keleb et al., 2022; Love, 2013). Other studies suggest that improper storage, transportation as well as poorly protected BW plants are also causes for concern (Gautam, 2021; Addo et al., 2009; Ehlers et al., 2004). Bottled water has previously been implicated as the source of Cholera and Typhoid fever outbreaks in certain areas (Keleb et al., 2022; Osei et al., 2013; Ehlers et al., 2004). Subsequently, these could be linked to the area where it is sourced, purchased and stored. However, studies have shown that these outbreaks are less frequent compared to those associated with tap water (William et al., 2015; Gangil et al., 2013). This has resulted in most consumers using BW (Pacheco-Vega, 2019; Brei, 2018) without considering its source, sale, and technology.

A study from Nigeria suggested that the lack of advanced water treatment technologies and the necessary skills to produce high-quality BW are contributing factors to the contamination of BW (Odeyemi, 2015). Furthermore, other contributing factors include unscrupulous businesses producing low-quality BW (Maselela et al., 2024), as well as inadequate regulation and water monitoring systems (Maselela et al., 2024; Manjaya, 2019; Vapnek & Williams, 2016). The absence of effective water monitoring systems and regulations may be fuelling the rapid expansion of the BW industry and retailers, many of which operate informally due to minimal oversight, as suggested by Maselela et al.

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In South Africa, the Department of Health (DoH) is responsible for ensuring the quality of bottled drinking water in accordance with the South African National Standards (SANS) 241 and 1657, as well as guidelines from the World Health Organization (WHO). These standards specify the acceptable levels of total coliforms (TC), *E. coli*, and heterotrophic plate counts (HPC) in drinking water. However, Maselela et al. (2024) and Barnes and Cao (2013) have suggested that inadequate enforcement of these regulations has led to the sale of counterfeit bottled drinking water from reputable brands in the informal market. Studies have indicated that the government lacks the capacity to monitor bottled drinking water, especially in informal retail settings, compared to formal retailers (Manjaya et al., 2019; Barnes & Cao, 2013), potentially exposing consumers to contaminated water. Furthermore, a recent study by Olowoyo et al. (2022) revealed that 25 % of bottled drinking water purchased from formal and informal outlets was found to be unfit for human consumption.

The microbiological quality of water is of paramount importance for public health. Contaminated water can pose various health risks, such as diarrhoea, cholera, and typhoid fever. Therefore, ensuring compliance and enforcement of water quality standards is crucial to guarantee the safety and good quality of water for consumers. This study aims to determine if microbial parameters for BW vary based on the point of purchase.

## 2. Material and methods

### 2.1. Sample strategy

The study employed a convenience sampling approach, meaning that the sample was gathered from readily available sources. In this case, 500 ml (BW) was chosen from various retail shops in the municipality. The sample size of 384 was determined using the Check Market calculator (Check Market. 2024). However, for this study, the sample size was reduced from 384 to 117 due to financial constraints and the limited availability of BW from different brands at informal retailers.

### 2.2. Sample collection

About 117 samples of BW were purchased from informal and formal retailers. A total of 16 samples of BW of different brands from informal retailers and 101 samples from formal retailers were purchased. Each batch was purchased from each shop (16) and (101). About 8 brands were similar to the BW brands purchased from formal and informal retailers.

The samples (BW) were collected for a period of three months. The collected samples were marked for identification and stored in a cooler box with ice, at a temperature of <4 °C transported to Tshwane University of Technology (TUT), and were analysed for HPC, TC and *E.coli*

### 2.3. Analysis for E.coli and TC

Total coliform and *E. coli* were detected simultaneously using the Colilert method following manual instruction (IDDEX, 2019) and analysed within six hours of collection. Wells that were positive showed a yellow colour, which indicated the presence of TC. When placed under fluoresces ultraviolet (UV) light, if the wells showed a milky colour, it indicated the presence of *E. coli*. Therefore, positive wells were then counted and presented as CFU/100ml.

### 2.4. Analysis for HPC

The heterotrophic plate count was then analysed using Colilert for HPC following manual instruction (IDDEX, 2019) and within six hours of collection. The wells that showed a blue colour under fluorescent light indicate the presence of HPC. Therefore, positive wells were also counted and presented as CFU/100 ml following manual instruction.

### 2.5. Data analysis

Data was recorded and entered into an Excel spreadsheet and exported into the SPSS version 29 for analysis. Inferential statistics was used for statistical analysis at a 95 % confidence level, and trends were noted.

A Fisher's exact test was used to determine whether there was an association between the shops (informal/formal) where BW was purchased and its microbiological quality. The test was performed at a 5 % level of significance for microbiological quality in TC, *E. coli,* and HPC by type of (informal and formal) shops where BW was purchased.

The hypothesis tested was:

*Ho: There is no association between the shop where bottled water was bought and its microbiological quality.*

*H1: There is an association between the shop where bottled water was bought and microbiological quality*.

The confidence interval for TC, *E. coli,* and HPC was determined using the non-parametric binomial test using Fisher's Exact test. Hypothesis testing was used to determine whether BW is contaminated with (TC, HPC and *E. coli*), based on the shop where it was purchased. The hypothesis value was <1 %. BW was then tested at the 5 % level of significance to determine whether the microbiological quality was $H_0 : \pi \geq 0.99$ against $H_1 : \pi < 0.99$ or if hypothesis or microbiological quality was $H_0 : \pi \leq 0.01$ against $H_1 : \pi > 0.01$ as compared to (Table 1). The magnitude of the test was measured using Cramer's V to assess the extent of the association using guidelines as posited by Akoglu (2018), where >0.25 indicates a strong association and >0 indicates a weak association.

## 3. Results

In this study, the association between the formal and informal shops and various microbiological quality indicators in BW was determined (Table 2). Fisher's exact test was used to determine the association between compliance to shop and the presence of TC, *E-coli*, and HPC levels. The null hypothesis (Ho) stated no association between the shop where water was purchased and its microbiological quality, while the alternative hypothesis (H1) proposed an association between them. The results revealed compelling evidence in Table 3 supporting the alternative hypothesis for TC levels ($p < 0.001$) and moderately supporting it for *E-coli* presence ($p = 0.008$). Specifically, compliance to shop demonstrated a very strong association with TC levels (Cramer's $V = 0\ 0.855$) and a moderate association with *E.coli* presence (Cramer's $V = 0\ 0.336$). However, no statistically significant association ($p = 0.383$), was found between compliance to shop and HPC levels, indicating insufficient evidence to reject the null hypothesis in this regard. These findings underscore the importance of compliance to shop in determining the microbiological quality of BW, particularly in terms of TC and *E.coli* presence.

The results of the non-parametric binomial test using Fisher's Exact test on informal shops in Table 4, showed a probability of compliance of 0.125 for TC in BW. The compliance level was estimated between 1.6 % and 38.2 %, based on the 95 % confidence interval. This is below the stipulated compliance rate of 99 % and it is not contained in the interval. The hypothesis test resulted in a p-value < 0 0.001, therefore leading rejecting the null hypothesis ($H_0$: $\pi > 0.99$), at a 5 % level of significance.

**Table 1**
SANS −241 (2015) and WHO standards.

| Parameter | Unit | Standard limit |
|---|---|---|
| total coliforms | cfu/100ml | 0/100ml |
| *E.coli* | cfu/100ml | 0/100ml |
| heterotrophic plate count | cfu/100ml | 100/1ml |

**Table 2**
Bacteriological count for bottled water purchased from formal and informal retail shops.

| Bacteria type | Type of shop | Non-compliant | Compliant | Number of samples collected | Average detection Non-compliant/ CFU/100ml | Average detection compliant CFU/100ml |
|---|---|---|---|---|---|---|
| Heterotrophic plate count (HPC) | Formal | 81 | 20 | 101 | 81.2 % | 18.8 % |
| | Informal | 14 | 2 | 16 | | |
| Total | | 95 | 22 | 117 | | |
| Total coliform(TC) | Formal | 2 | 99 | 101 | 13.7 % | 86.3 % |
| | Informal | 14 | 2 | 16 | | |
| Total | | 16 | 101 | 117 | | |
| *E.coli* | Formal | 1 | 100 | 101 | 3.4 % | 96.6 % |
| | Informal | 3 | 13 | 16 | | |
| Total | | 4 | 113 | 117 | | |

**Table 3**
Fisher's exact test to determine association between the shops where bottled water was bought and its microbiological quality.

| Type of bacteria | Fisher's exact test (p-value) | Cramer's V |
|---|---|---|
| TC in bottled water | <0.001 | 0.855 |
| *E.coli* in bottled water | 0.008 | 0.336 |
| HPC in bottled water | 0.383 | 0.064 |

**Table 4**
Inferential statistics of compliance levels for Total coliform, *E.coli* and HPC in bottled water from informal shops.

| Confidence Interval Type | Parameter | Estimate | 95.0 % Confidence Interval | |
|---|---|---|---|---|
| | | | Lower | Upper |
| One-Sample Binomial Success Rate (Clopper-Pearson) | Total coliforms =Compliance. | 0.125 | 0.016 | 0.383 |
| | *E.Coli*=Compliance. | 0.813 | 0.544 | 0.960 |
| | HPC =Compliance. | 0.125 | 0.016 | 0.383 |

It can be concluded that the one binomial test for TC in BW showed that the TC was not compliant with the SANS 241 standards. Similarly, the probability for compliance for *E.coli* was 0 0.813, and the absence of *E. coli* in BW was between 54.4 % and 96 %. The hypothesis test showed a p-value $< 0.05$, resulting in the rejection of the null hypothesis ($H_0$: $\pi > 0.99$) at a 5 % level of significance, concluding that the *E. coli* in BW did not comply with the SANS 241 Table 1.

The HPC < 2419CFU/100 ml in BW probability for compliance with Colilert most probability number (MPN) chart was 0.125 and the absence of HPC < 2419CFU in BW was between 1.6 % and 38.3 %. The hypothesis test resulted in a p-value $< 0.001$, resulting in the rejection of the null hypothesis ($H_0$: $\pi > 0.99$) at a 5 % level of significance. The one binomial test for HPC <2419CFU/100 ml of BW was not compliant with the Colilert MPN chart.

The results of the non-parametric binomial test using the Clopper-Pearson Exact test in formal shops (Table 5) showed that the probability of compliance is 0.980 for TC in bottled water. The compliance level was estimated between 93 % and 99.8 %, based on the 95 % confidence interval. This is within the range of the stipulated compliance rate of 99 % and it is contained in the interval. The hypothesis test resulted in a p-value =0.312, which is greater than 0.05, therefore leading to retaining the null hypothesis ($H_0$: $\pi > 0.99$) at a 5 % level of significance. It can be concluded that the one binomial test for TC in BW Showed that the TC was compliant with the SANS 241 standards.

Similarly, the probability for compliance in *E-coli* was 0.990 and the absence of *E. coli* in BW was between 94.6 % and 100 %. The hypothesis test showed a p-value of 0.500, resulting in the retaining of the null hypothesis ($H_0$: $\pi > 0.99$) at a 5 % level of significance, concluding that the *E. coli* in BW complied with the SANS 241. The HPC < 2419CFU/100 ml in BW probability for compliance and the absence of HPC < 2419CFU in BW was between 12.5 % and 28.9 %. The hypothesis test resulted in a p-value $< 0.001$, resulting in the rejection of the null hypothesis ($H_0$: $\pi > 0.99$) at a 5 % level of significance. The one binomial test for HPC <2419CFU/100 ml of BW was not compliant with the Colilert MPN chart.

**Table 5**
Inferential statistics of compliance levels for total coliform, *E.coli* and HPC for formal shop.

| Confidence Interval Type | Parameter | Estimate | 95.0 % Confidence Interval | |
|---|---|---|---|---|
| | | | Lower | Upper |
| One-Sample Binomial Success Rate (Clopper-Pearson) | Probability (TC==Compliance). | 0.980 | 0.930 | 0.998 |
| | Probability (*E. Coli*=Compliance). | 0.990 | 0.946 | 1.000 |
| | Probability (HPC =Compliance). | 0.198 | 0.125 | 0.289 |

## 4. Discussions

Bottled water must adhere to the highest quality standards and be safe for public consumption, as it frequently serves as an alternative to tap water, as highlighted by Venkatesan et al. (2014). A recent study unequivocally demonstrated that bottled water sold in informal shops consistently exhibited lower quality compared to water purchased from formal shops. The study conclusively identified a higher prevalence of microorganisms such as *E. coli*, HPC, and TC in bottled water from informal shops. This underscores the critical imperative of ensuring the safety and quality of bottled water to protect public health. Heterotrophic plate count was detected in 81 % of BW purchased from formal and informal shops. The presence of HPC indicates that the water quality is compromised, and HPC of a higher concentration is associated with pathogens in water (Gautam, 2021). This might be due to the improperly handling of BW during manufacturing stages, including processing, and transportation, as well as poor hygiene practices as a contributing factor, as posited in research by Gautam (2021); Addo et al. (2009) and Ehler et al. (2004)

Research suggests that informal shops are often less regulated compared to formal shops (Maselela et al., 2024; Barnes & Cao, 2013). This lack of oversight may impact the trade of bottled water of poor quality. A recent study revealed that a majority of bottled water purchased from informal shops was contaminated with indicator organisms. Furthermore, some of the bottled water from these informal shops lacked physical addresses of the packaging location, making traceability difficult in the event of outbreaks. The quality of bottled water sold in formal shops was generally better. This contradicts the findings of a study conducted by Lindani et al. (2014) at a Bulawayo supermarket, where majority of bottled water purchased from formal retailers was found to be contaminated with indicator organisms.

A study conducted in Nigeria by Odeyemi (2015) suggests that a significant challenge regarding the safety of bottled water may be that some of the BW companies are not adhering to drinking water standards. This aligns with the findings of Vapnek and Williams (2016), who identified informal shops as contributing to poor-quality bottled water. This could be attributed to the lack of advanced water purification technology and the necessary skills to produce quality bottled water (Odeyemi, 2015). Moreover, unscrupulous businesses produce bottled water with minimal quality standards, driven by the pursuit of immediate financial benefits, as emphasized in the research conducted by Maselela et al. (2024).

A significant portion of this substandard bottled water is distributed to the informal market at a reduced price, targeting unaware consumers. Another factor might be the lack of water monitoring systems and regulations, a finding similar to Maselela et al. (2024), Ajaya et al. (2020) and Vapnek and William 's (2016)research studies. The absence of water monitoring systems and regulations can contribute to the proliferation of informal bottled water manufacturers, as there are minimal regulations and controls in place (Maselela et al., 2024). Therefore, it is crucial for government authorities responsible for public health to intensify their efforts in regulating and monitoring these facilities.

## 5. Conclusion and recommendations

The study findings indicate that the source and the store from which bottled water (BW) is obtained are important factors to consider. It was observed that the microbiological quality of BW in the municipality varies depending on the purchasing location. Notably, the quality of BW from informal shops did not meet the SANS 241 standards, particularly in relation to total coliforms (TC) and E. coli, whereas BW from formal shops complied with these standards. The study suggests that government authorities should more effectively regulate and monitor the BW industry, particularly the informal sector, to ensure compliance with quality standards and improve public awareness of the risks associated with consuming contaminated water. Additionally, the study recommends increasing public awareness about the risks of consuming contaminated water and the importance of maintaining proper hygiene practices during the manufacturing and distribution of BW in the informal sector. Hence, it is important to enforce laws for non-compliance to hold manufacturers accountable for producing low-quality bottled water. Additionally, the researchers suggest that further investigation be conducted on the factors affecting the microbiological quality of bottled water sold by informal vendors, in order to inform regulatory actions aimed at ensuring consumer safety.

## CRediT authorship contribution statement

**J.L. Maselela:** Writing – original draft, Methodology, Investigation, Conceptualization, Formal analysis. **M.I. Mokgobu:** Writing – review & editing, Writing – original draft, Supervision. **L.S. Mudau:** Writing – review & editing, Supervision, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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*Ethical statement*

The authors declare that no human or animal was used for the purpose of this study.

## Data availability

Data will be made available on request.

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