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Assessment of Bacteriological Quality of Drinking Water Taiz and Ibb Governorates, Yemen

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Abstract: Objectives: the aim of this study was the assessment and monitoring of the safety and quality of the existing water supplies in Ibb and Taiz governorates from the microbial side and testing the quality of drinking water in the Ibb and Taiz governments and comparing it with the World Health Organization. **Methods:** the water samples (99 samples) taken from some water sources, distribution reservoirs, and different regions were studied for bacteriological analysis, in which they were inoculated into culture media using two methods: the presumptive test for the most probable number and the confirmatory test for bacterial identification. **Results:** the results indicated the non-existence of indicator bacteria that were used to indicate the possible presence of fecal bacteria among 24 (24.24%) water samples taken from Taiz governorate, while the presence of an unacceptable number of *Escherichia coli* in house tanks (30%) was indicated among 75 (74.25%) water samples taken from Ibb governorate. **Conclusions:** the results of the study in Taiz governorate show that the water is fit for human consumption, as well as the samples taken from water sources and distribution networks in Ibb governorate, but the results of the samples taken from house tanks showed that the water is not fit for human consumption and needs to be treated.

Keywords: *Escherichia coli*; coliform; total bacterial count; presumptive test; Taiz; Ibb; Yemen

Introduction

Water is a natural resource that is critical to human survival (Adimall and Qian, 2022; Ugwu *et al*., 2017). It sustains all forms of life and generates jobs and wealth in the water, tourism, and recreation industries. Te global slogan "Water is Life" implies that water is one of the most basic human needs. Life as we know it on our planet would be impossible without water (Adimalla *et al*., 2022; Bekele *et al*., 2018).

Water is an essential natural resource for humans to live (Adimall, and Qian, 2022; Ugwu *et al*., 2017). Water nourishes all forms of life and contributes to the economic growth of several industries such as water, tourism, and recreation. The worldwide expression "Water is Life" demonstrates the idea that water is an essential and fundamental requirement for the continued existence of people. Water is essential for supporting life on our planet (Adimalla *et al*., 2022; Bekele *et al*., 2018).

The high clay content of the soil, which results in a slow rate of water percolation and a significant distance to the groundwater, will lead to a greater likelihood of bacterial survival compared to the well-aerated sand. Nevertheless, the extended duration of the flow permits ample time for the water to undergo filtration prior to its entry into the groundwater (Adetunde and Glover, 2010). A multitude of significant challenges that jeopardize the existence of humanity on Earth arise from the scarcity of potable water in numerous areas, along with the degradation of environmental aesthetics (Adimalla 2020; Bote and Desta, 2022).

Microorganisms have a significant impact on the quality of water, particularly in relation to waterborne diseases. The specific bacteria that are associated with these diseases include *Salmonella*

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spp., *Shigella* spp., *Escherichia coli*, and *Vibrio cholera*. These factors contribute to the occurrence of typhoid fever, diarrhea, dysentery, gastroenteritis, and cholera (Adetunde and Glover, 2010). Consequently, water is analyzed microbiologically in order to assess its hygienic condition and its appropriateness for common purposes (Ohanu *et al*., 2012). Yemen is classified as a developing country that does not have effective policies or programs in place to manage or prevent the spread of disease-causing microbes among its people (Al-Hadheq *et al*., 2023; Mengstie *et al*., 2020). The World Health Organization (WHO) reports that over 30% of the global population lacks access to potable water. Every year, 829,000 individuals suffer to diarrhea caused by a drink of contaminated drinking water, inadequate sanitation, and poor hand hygiene (WHO, 2019).

In order to provide a safe source of drinking water, it is essential to perform observation for the existence of pathogens. Nevertheless, doing a comprehensive examination of the water supply for each individual bacterium would be costly and time-consuming. Instead, an indicator organism is employed to signal the potential existence of harmful bacteria, which are capable of causing diseases (Charles *et al*., 2005). In this current research, we have performed microbiological analysis of drinking water samples from Taiz and Ibb governorates to assessment of the quality drinking water from bacterial side.

Materials and Methods

Study Area and Period

This cross-sectional study was carried out in different areas of water supply in the Taiz and Ibb governorates, Yemen, during the period from January to February 2023. In total, 99 water samples from different sources, distribution networks, and house tanks in Taiz and Ibb governorates were collected for bacterial analysis.

Sample Collection

Drinking water samples were aseptically collected in a sterilized 300-mL capacity and placed in an insulated cold box for transport to a water testing laboratory. Water samples are examined as soon as possible on arrival and always within 6 hours of collection (Lansing *et al*., 2005).

Microbiological Analysis

For the total bacterial count, about one mL of each water sample was separately inoculated onto a plate containing 25 mL of nutrient agar with 1 mL of water sample and incubated at 37°C for 72 hours. The total bacterial visible colonies were counted after the incubation period according to the following formula: CFU/mL = (Number of colonies × dilution factor) / volume of culture plate.

Furthermore, the detection of *Enterococcus faecalis* was performed by inculcating one mL of a water sample into 10 mL of Azide dextrose broth and incubating at 37°C for 24 hours. Investigation of *Escherichia coli*: One mL from the water sample was inculcated into 10 mL of MacConkey broth and incubated at 37°C as a presumptive test for 48 hr. In addition, the Eosin Methylene blue was inoculated by loop and incubated at 37°C for 24 h to check the positive presumptive test. The isolation of coliform was done by using MacConkey agar that differentiates between lactose and non-lactose fermenter organisms, where coliforms are lactose fermenters and produce pink colonies on this medium after the incubation period. The quality control of each process was done by incubating two control plates for checking the sterility of the samples.

Statistical Analysis

The data collected from the results of microbiology tests, were analyzed by using SPSS Version 16. P-values of less than 0.05 (P<0.05) were considered statistically significant.

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Results

Results of Studied Samples from Taiz Government

The fecal bacteria were not present in all studied water sources, but the high total bacterial counts were in Al-Hoban, followed by Kalaba, and the low number was in Al-Dabab, as shown in Table 1. Our finding showed that the relationship between the free chlorine ratio and the total bacterial count was variable in some regions, where the high ratio of free chlorine was in the distribution reservoir and the low ratio was in Bab Mosa, whereas in Al-Shamasi, Al-Markazi, and Kalaba, the ratio was variable. However, the total bacterial count was high in Bab Mosa, while in Kalaba, Al-Shmasi, and the distribution reserve, it was the same. It also shows no growth of the fecal bacteria in all studied regions.

Table 1. The bacterial count of samples taken from some water sources in Taiz government.

Water Sources	TBC ×10² per 100 mL				Fecal Bacteria/100 mL	
	Number of Samples			Mean	Coliform/ *E. coli*	*E. Fecalis*
	1st	2nd	3rd			
Kalaba	16	10	11	12	0	0
Al Dapab	5	13	6	8	0	0
Hoban	15	18	20	18	0	0

TBC = Total Bacterial Count.

The total bacterial count before and after sterilization and the effectiveness of sterilization showed that the effectiveness of sterilization was high in Al-Markazi, low in Bab Mosa, and variable in other regions, as shown in Table 2.

Table 2. The total bacterial count before and after sterilization and the effectiveness of sterilization.

Regions	TBC ×10² per 100 mL		Effectiveness of Sterilization
	Before sterilization	After sterilization	
Distribution Reservoir	**12**	**2**	**83.3%**
Bab Mosa	**12**	**4**	**66.7%**
Al-Shamasi	**12**	**2**	**83.3%**
Al-markazi	**12**	**1**	**91.7%**
Kalaba	**12**	**2**	**83.3%**

TBC = Total Bacterial Count.

Results of Studied Samples from Ibb Government

The number of bacteria in samples collected from different sources of water in the Ibb government was higher in Al-Sign Al-Markazi well and lower in Al-Salaba; however, there was no growth of fecal bacteria in all studied water samples, as shown in Table 3.

Table 3. The number of bacteria of samples taken from some water sources in Ibb governorate.

Wells	Total Bacteria ×10² per 100 mL				Fecal Bacteria/100 mL	
	Number of Samples			Mean	Coliform/ *E. coli*	*E. Fecalis*
	1st	2nd	3rd			
Al-Salaba	0	2	1	1	0	0
Al-Mala'ab	4	11	16	10	0	0
Al-Segn Al-Markazi	11	15	9	11	0	0
Seven	10	6	6	7	0	0
Eight	7	5	10	7	0	0

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Our finding showed that the number of bacteria in samples taken from the distribution network of five regions supplied by Al-Salaba and Al-Mala'ab wells was higher in the Mophleh line, followed by Al-Madariah, Alodain Street, and Al-Wazeiah regions, but the lower number was in the Al-Mohafadah region. However, the fecal bacteria were not present in all regions, as shown in Table 4.

Table 4. The bacterial count in samples taken from distribution network of different regions that supplies by Al-Salaba and Al-Mala'ab.

Region	Total Bacteria ×10^2 per 100 mL				Fecal Bacteria/100 mL	
	Number of Samples			Mean	Coliform/ *E. coli*	*E. Fecalis*
	1st	2nd	3rd			
Alodain street	31	19	25	25	0	0
Al-Madriah	45	42	37	41	0	0
Almohafadah	16	13	21	16	0	0
Mophleh line	56	61	63	60	0	0
Al-Wazeiah	12	17	38	22	0	0

Our results showed that there where the higher number of total bacteria and *E. coli* were present in Al-Mohafadah region and the lower number were in Al-Wazeiah region, however, the *Enterococcus fecalis* was not present, as showing as in Figure 1.

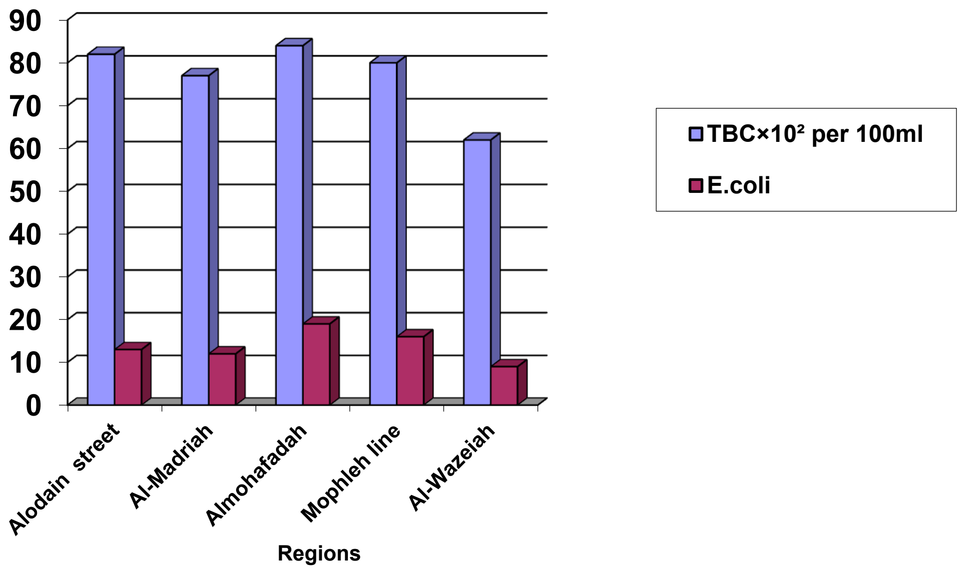

Figure 1. The total bacterial count and *E. coli* of samples taken from different regions that supplies by Al-Salaba and Al-Mala'ab wells.

The number of bacteria in samples taken from the distribution network of the two regions was supplied by Al-Signs Al-Markazi well, where a higher number was present in the Wadi Al-Dahab region and a lower number in the Al-Signs Al-Markazi region, and *Enterococcus faecalis* was not present, as shown in Table 5. Our findings showed that the number of bacteria in samples taken from the distribution network of two regions supplied by Al-Signs Al-Markazi well, where a higher number was present in the Wadi Al-Dahab region and a lower number in the Al-Signs Al-Markazi region and *Enterococcus faecalis* was not present.

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Table 5. The bacterial count of samples taken from distribution network of different regions that supplies by Al-Segn Al-Markazi wells.

Region	Total Bacteria ×10² per 100 mL				Fecal Bacteria/100 mL	
	Number of Samples			Mean	Coliform/ *E. coli*	*E. Fecalis*
	1st	2nd	3rd			
Al-Segn Al-Markazi	51	56	72	59	0	0
Wadi Al-Dahab	82	75	87	81	0	0

These results showed that the higher number was present in the Akamat Easa region, followed by the Haratha region, while the lower number was in the Dar Al-Sharaf region. However, the fecal bacteria were not present in all studied regions, as shown in Table 6.

Table 6. The bacterial count of samples taken from distribution network of different regions that supplies.

Region	TBC ×10² per 100 mL				Fecal Bacteria/100 mL	
	Number of Samples			Mean	Coliform/ *E. coli*	*E. Fecalis*
	1st	2nd	3rd			
Haratha	55	58	64	59	0	0
Dar Al-Sharaf	42	38	54	44	0	0
Akamt Easah	63	54	71	62	0	0

Finally, the number of bacteria in samples taken from houses in tanks of three regions was supplied by seven and eight wells, where the higher number of total bacteria was present in the Haratha region and the lower number was present in Akamat Easa; however, the number of *Escherichia coli* was high in Haratha, Akamat Easa, and Dar Al-Sharaf, as shown in Table 7.

Table 7. The bacterial count in samples of houses tanks from different regions that supplies by Seven and Eight wells.

Region	Number of samples						Mean		
	1st		2nd		3rd				
	TBC ×10²	*E.coli*	TBC ×10²	*E.coli*	TBC ×10²	*E.coli*	TBC ×10²	Coliform/ *E. coli*	*E. fecalis*
Haratha	85	16	82	18	73	11	80	15	0
Dar Al-Sharaf	65	23	81	29	69	10	71	21	0
Akamt Easah	59	12	67	14	70	20	65	15	0

TBC = Total Bacterial Coun.

Discussion

The occurrence of waterborne diseases in developed countries is generally low due to a generally good system of water treatment, distribution, and monitoring. Waterborne diseases are among the leading causes of morbidity and mortality in low- and middle-income countries, frequently called developing countries.

Developed countries typically have good systems for treating, distributing, and monitoring water, which helps to reduce the incidence of waterborne illnesses. Low- and middle-income nations, often known as developing countries, have one of the highest rates of morbidity and mortality from waterborne diseases.

In wealthy countries, the incidence of waterborne infections is often low due to an effective system of water treatment, distribution, and monitoring. Waterborne infections are a significant source of illness and death in poor and middle-income nations, sometimes referred to as developing countries (Adimall, and Qian, 2022). Yemen, such a developing country, suffers from a lot of water-related health problems. Contaminated or polluted water is water that contains poisonous chemicals,

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pathogenic organisms, industrial waste, or sewage. The majority of diseases in underdeveloped nations can be attributed to the absence of potable water, such as typhoid, cholera, and hepatitis (Ohanu *et al*., 2012; Penna *et al*., 2002).

In Taiz governorate, the results of the study showed no growth of indicator bacteria in all studied water samples. This means that these waters are free from pathogenic bacteria. Thus, these waters are drinkable and fit for human consumption from a bacteriological perspective. In addition, the total bacterial count was high in Bab Mosa, while in Kalaba, Al-Shmasi, and the distribution reserve, it was the same. It also shows no growth of the fecal bacteria in all studied regions. Similar findings were reported in Thailand (Mengstie *et al*., 2020) and Iran (Shahryari *et al*., 2020). Other studies have also reported the high bacteria count in water in Iran (Kouchesfahani *et al*., 2015; Moazeni *et al*., 2012).

In addition, the present study found that there was no growth of indicator bacteria in all samples taken from the Ibb Governorate wells and distribution network, but the samples taken from house tanks (10%) showed growth of *E. coli*, which indicates that the water is unacceptable for human consumption according to WHO (WHO, 2015). This could be attributed to the presence of gelatinous layers accumulating on the walls of the tank, resulting in turbidity (Lewandowski and Beyenal, 2007). Similar findings were reported in Iraq (Aldhamin, 2023) and Pakistan (Shafique *et al*., 2020). In addition, other reports revealed that most bacteria contaminating drinking water in Aden and Hadhramout governorates were *E. coli* (Hassan *et al*., 2008; Bin Hamed and Bubakr, 2019). A high rate of *E. coli* was reported in drinking water in Thailand (Yongyod *et al*., 2023) and Indonesia (Alfian *et al*., 2023).

Author Contributions: Al-Hadheq and Al-Abood Conceived and designed the experiments. Al-Hadheq performed the experiments: Al-Hadheq, Al-Aboud, and Al-Arabi analyzed the data and wrote the first draft of the manuscript. Al-Maktari contributed to the writing of the manuscript. Al-Hadheq, Al-Asbahi, and Edress agree with the manuscript results and conclusions. All authors have read, revised, and approved the final manuscript.

Data Availability: The original data source could be shared upon the request of the principal investigator.

Consent for Publication: Not applicable.

Competing Interests: The authors declare that they have no competing interests.

Ethics Approval and Consent to Participate: The study protocol was approved by the medical microbiology department, faculty of sciences, Ibb University.

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