



## BACTERIOLOGICAL CONTAMINATION OF TRADITIONAL CASKS (ZEERS) AND ELECTRICAL COOLERS IN POST-WAR KHARTOUM STATE, SUDAN

Abdulahleim Yahia Mohamed Salih <sup>1,\*</sup>, Muntaha Mohammed Saeed Mohammed <sup>2</sup> and Mujahid Hashim Hassan Ali <sup>3</sup>

<sup>1</sup> Faculty of Medicine, Imperial University College, Khartoum, Sudan.

<sup>2</sup> Faculty of Medicine, Ankara University, Ankara, Turkey.

<sup>3</sup> Fakeeh Care Group, Riyadh, Saudi Arabia.

\* Corresponding Author

International Journal of Science and Research Archive, 2026, 20(03), 462–468

Publication history: Received on 24 July 2026; revised on 13 September 2026; accepted on 15 September 2026

Article DOI: <https://doi.org/10.30574/ijrsra.2026.20.3.1766>

Copyright © 2026 Author(s) retain the copyright of this article. This article is published under the terms of the Creative Commons Attribution License 4.0

### ABSTRACT

Acute microbial diarrheal diseases are a major public health problem in developing countries. This study was a descriptive cross-sectional study conducted at Khartoum State, Sudan to isolate and identify bacteria that are present in traditional casks (Zeers) and electrical coolers in Khartoum State. Two hundred samples of water were taken from casks (zeer) and electrical coolers for drinking water. Total number of 200 samples from different sources were investigated during the study. A total of 105 samples (52.5%) revealed no growth; while 95 samples (47.5%) revealed positive growth under aerobic condition. Among the 95 positive samples monomicrobial isolates have been detected in 76 samples (80%) whereas 19 samples (20 %) showed two organisms per sample. Microbiological culture isolated (119) bacterial isolates with an average of 1.25 organisms per positive culture.

In this study, it has been indicated that public water stands (zeer) are the most vulnerable drinking water source to bacterial contamination in the study area when compared to electrical drinking water coolers.

**Keywords:** Drinking water; Bacterial contamination; Traditional casks (zeers); Electrical coolers; Khartoum State.

### 1 INTRODUCTION

People can survive days, weeks or months without food, but only about four days without water. Although Sudan is a large country and lies mostly in the arid region, it is considered to be rich in water resources. However, ignorance of the potential risks may result in unnecessary waterborne disease outbreaks [1,2].

Even with well-operated drinking-water treatment systems, there is growing concern that aging drinking water distribution systems (DWDSS) are vulnerable to higher rates of mains breaks/repairs and related pressure losses that may lead to pathogen intrusion scenarios [3]. There are over 500 waterborne pathogens of potential concern in drinking waters such as that have been identified by the US Environmental Protection Agency (EPA).

In general terms, the greatest microbial risks are associated with ingestion of water that is contaminated with human or animal feces, wastewater discharges in fresh waters and coastal seawaters are the major source of fecal microorganisms [4].

Acute microbial diarrheal diseases are a major public health problem in developing countries. People affected by diarrheal diseases are those with the lowest financial resources and poorest hygienic facilities. Children under five, primarily in Asian and African countries, are the most affected by microbial diseases transmitted through water [5]. Microbial waterborne diseases also affect developed countries as they are fighting for a sustainable microbiological control of drinking water. In the USA, it has been estimated that each year 560,000 people suffer from severe waterborne diseases, and 7.1 million suffer from a mild to moderate infections, resulting in estimated 12,000 deaths a year [6].

The most important bacterial diseases transmitted through water are *Vibrio cholerae*, sero-varieties O1 and O139, Typhoid fever and other serious salmonellosis, *Salmonella enterica* subsp. *enterica* serovar Paratyphi, *Salmonella enterica* subsp. *enterica* serovar Typhi, *Salmonella enterica* subsp. *enterica* serovar Typhimurium and Bacillary dysentery or shigellosis. Acute diarrheas and gastroenteritis are also common by *Escherichia coli*, particularly serotypes such as O148, O157 and O124 [7].

Several research have been found to be concerned with this matter internationally as well as in Sudan, Ell-Amin and colleagues [8] in their study stated that almost 50% of Wadmedani surface water samples show the presence of coliform and fecal coliform. Other international findings do vary according to demographics as well as study designs adopted [9-13]. Hence, this study was aimed to isolate and identify bacteria that are present in traditional casks (Zeers) and electrical coolers in Khartoum State.

## 2 MATERIAL AND METHODS

This study was a descriptive cross-sectional study conducted at Khartoum State, Sudan in the period from January to March 2026.

### 2.1 Study area

Study was conducted in Khartoum, Khartoum North cities representing Khartoum State.

### 2.2 Study samples

Water samples of casks (zeer) and electrical coolers.

### 2.3 Sample size

Two hundred samples of water were taken from casks (zeer) and electrical coolers for drinking water. Two samples were taken from each source of drinking water (casks and electrical coolers) in the study; one sample was taken using the drinking cup attached to each source of water while the other sample was taken using sterile cup directly from the water.

### 2.4 Sample collection

Samples for bacteriological analysis were collected in sterile 50 ml medical laboratory bottles. The samples used for bacteriological analysis were taken from different drinking water sources in random places in the study area (markets, mosques, schools, streets); direct water source either casks (zeer) or electrical coolers as well as from the attached cup. The sterile bottle was carefully opened close to the water and filled with about 10 ml of the water sample and then immediately closed while it was close to the water source in order to avoid contamination by bacteria other than that already existing in the source of the intended sample. For the samples taken from cups; the samples bottle was immersed, before opening, into the drinking cup that was filled with the water from the pot, then opened inside the utensil and entirely filled and immediately closed while it was inside the utensil in order to prevent any contamination by bacteria from air or any other source of bacteria other than the intended source. The collected water samples were then immediately sent to the laboratory and stored in the refrigerator at 4°C pending analysis.

### 2.5 Laboratory Procedures

Glassware was washed with deionized water, dried, and sterilized in a hot oven at 160°C for at least 3 hours. Loops, needles, forceps, and spoons were sterilized by flaming after dipping in spirit [17].

Labelled specimens were inoculated onto Blood agar and MacConkey agar (HiMedia Laboratories Ltd., Mumbai, India) and incubated aerobically at 37°C for 24 hours. Blood agar was prepared according to the manufacturer's instructions, sterilized by autoclaving at 121°C for 15 minutes, cooled to 50°C, supplemented aseptically with sterile blood, and

dispensed into sterile Petri plates. Mannitol salt agar (Oxoid, UK) was used for subculturing pure colonies, followed by incubation at 37°C for 24 hours; yellow coloration indicated mannitol fermentation.

Bacterial isolates were evaluated according to colony morphology, including colour, diameter, transparency, shape, hemolysis, and lactose fermentation. Gram staining was performed on smears prepared from overnight cultures and examined microscopically under oil immersion. Biochemical identification was performed using Kligler iron agar, tryptophan peptone water, semisolid medium, Simmons citrate agar, and Christensen's urea agar (HiMedia, India), followed by incubation at 37°C overnight. Catalase, coagulase, and DNase tests were performed for Gram-positive cocci. Catalase activity was determined by observing immediate bubbling after exposure of colonies to 3 mL hydrogen peroxide [18]. Coagulase testing was performed by mixing 0.2 mL plasma with 0.8 mL of the test organism and incubating at 37°C for 4 hours; clot formation was considered positive [18]. DNase activity was assessed on DNase test agar according to the manufacturer's instructions, with strong clearing comparable to *S. aureus* ATCC 29213 considered positive. Sugar fermentation was assessed in phenol-red broth containing glucose, maltose, sucrose, mannose, arabinose, trehalose, lactose, xylose, and raffinose after overnight incubation at 37°C; yellow coloration indicated acid production, whereas pink indicated a negative result [19].

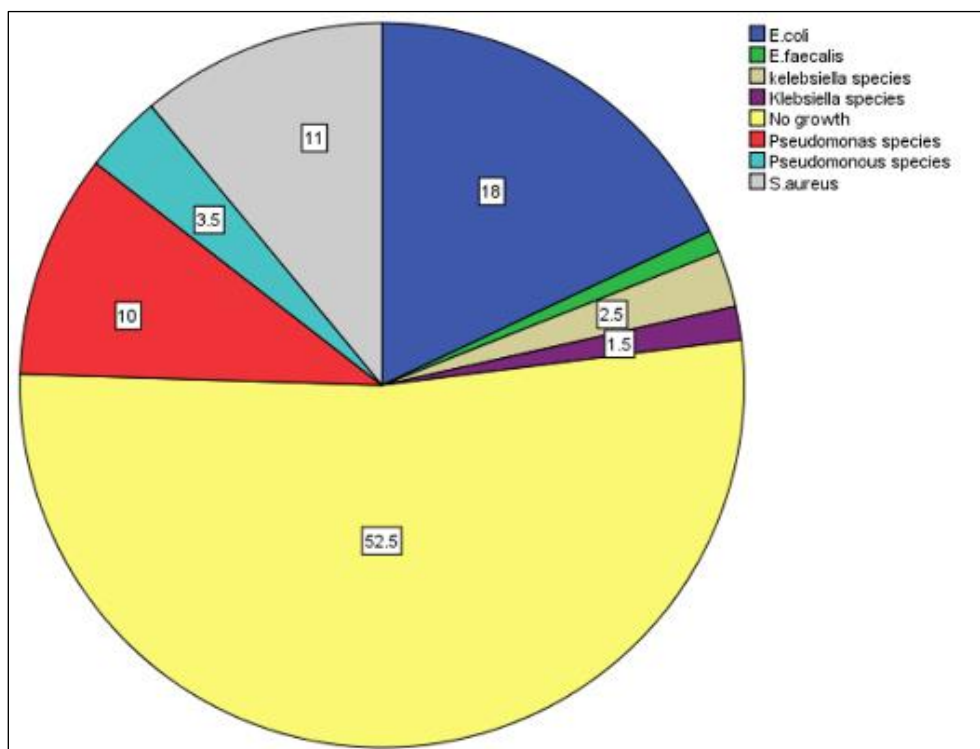
## 2.6 Statistical Analysis

Results obtained from the study were analysed using Scientific Package of Social Sciences (SPSS v. 22) software to estimate proportions and percentages.

## 3 RESULTS

Total number of 200 samples from different sources were investigated during the study. A total of 105 samples (52.5%) revealed no growth; while 95 samples (47.5%) revealed positive growth under aerobic condition. Among the 95 positive samples; monomicrobial isolates have been detected in 76 samples (80%) whereas 19 samples (20 %) showed two organisms per sample. Microbiological culture isolated (119) bacterial isolates with an average of 1.25 organisms per positive culture.

Gram negative bacilli predominated as 75 (63.02%) isolates while Gram positive cocci as 44(36.97%) isolates only. The commonest organism isolated was *E. coli* as 38 isolates (18%) from all samples and (32%) from all isolated bacteria. Prevalence of different isolates in all collected water samples is summarized in (Fig 1).



**Figure 1: Prevalence of different types of bacteria isolated from Zeers and electrical coolers in the current study.**

Regarding area of collection (i.e. Khartoum or Khartoum North) and source of collection (i.e. cup or directly from water); no significant differences were observed in the current study. The results are summarized in (Tables 1&2).

**Table 1: Bacteria isolated from Zeers and electrical coolers from different cities in the current study**

| Result                     | City           |                |               |                | Total |
|----------------------------|----------------|----------------|---------------|----------------|-------|
|                            | Khartoum North |                | Khartoum      |                |       |
|                            | No of samples  | % <sup>1</sup> | No of samples | % <sup>2</sup> |       |
| No growth                  | 49             | 49.0           | 56            | 56.0           | 105   |
| <i>E. coli</i>             | 20             | 20.0           | 16            | 16.0           | 36    |
| <i>E. faecalis</i>         | 2              | 2.0            | 0             | 0.0            | 2     |
| <i>Klebsiella</i> species  | 4              | 4.0            | 4             | 4.0            | 8     |
| <i>Pseudomonas</i> species | 13             | 13.0           | 14            | 14.0           | 27    |
| <i>S. aureus</i>           | 12             | 12.0           | 10            | 10.0           | 22    |
| Total                      | 100            | 100            | 100           | 100            | 200   |

<sup>1,2</sup> Percentage out of the sample size of the corresponding City in the current study.

**Table 2: Bacteria isolated from casks (Zeers) and electrical coolers according to site of collection in the current study**

| Result                     | Site of collection |                |                |               |                |                |
|----------------------------|--------------------|----------------|----------------|---------------|----------------|----------------|
|                            | Cup                |                |                | Source        |                |                |
|                            | No of samples      | % <sup>1</sup> | % <sup>2</sup> | No of samples | % <sup>1</sup> | % <sup>2</sup> |
| No growth                  | 48                 | 45.7           | 48.0           | 57            | 54.3           | 57.0           |
| <i>E. coli</i>             | 18                 | 50.0           | 18.0           | 18            | 50.0           | 18.0           |
| <i>E. faecalis</i>         | 1                  | 50.0           | 1.0            | 1             | 50.0           | 1.0            |
| <i>Klebsiella species</i>  | 4                  | 50.0           | 4.0            | 4             | 50.0           | 4.0            |
| <i>Pseudomonas species</i> | 16                 | 59.3           | 16.0           | 11            | 40.7           | 11.0           |
| <i>S. aureus</i>           | 13                 | 59.1           | 13.0           | 9             | 40.9           | 9.0            |

<sup>1</sup> Percentage among the corresponding result. i.e. the percentage of the result in the particular site of collection when compared to other sites of infection. <sup>2</sup> Percentage among the corresponding site. i.e. the percentage of the result in the particular site of collection when compared to other results in the same site.

**Table 3: Bacteria isolated according to type of water source in the current study**

| Result                     | Type              |                |                |               |                |                |
|----------------------------|-------------------|----------------|----------------|---------------|----------------|----------------|
|                            | Electrical cooler |                |                | Cask          |                |                |
|                            | No of samples     | % <sup>1</sup> | % <sup>2</sup> | No of samples | % <sup>1</sup> | % <sup>2</sup> |
| No growth                  | 87                | 82.9           | 87.0           | 18            | 17.1           | 18.0           |
| <i>E. coli</i>             | 2                 | 5.6            | 2.0            | 34            | 94.4           | 34.0           |
| <i>E. faecalis</i>         | 0                 | 0.0            | 0.0            | 2             | 100.0          | 2.0            |
| <i>Klebsiella species</i>  | 0                 | 0.0            | 0.0            | 8             | 100.0          | 8.0            |
| <i>Pseudomonas species</i> | 7                 | 25.9           | 7.0            | 20            | 74.1           | 20.0           |
| <i>S. aureus</i>           | 4                 | 18.2           | 4.0            | 18            | 81.8           | 18.0           |

<sup>1</sup> Percentage among the corresponding result. i.e. the percentage of the result in the type of source when compared to other sources. <sup>2</sup> Percentage among the corresponding type of water source. i.e. the percentage of the result in the particular type of source when compared to other results in the same source.

However, a statistically significant relationship between casks (zeer) and bacterial contamination is demonstrated at confidence level of 99% ( $p=.00$ ). 87% of all samples collected from electrical coolers revealed no growth, while only 18% of samples collected from casks revealed no growth. Nevertheless, no significant associations were found between any specific bacteria and casks (zeer) or electrical coolers contamination. The result is depicted in (Table 3).

#### 4 DISCUSSION

In this study, the contaminated water samples were positive for *E. coli*, coliforms, and the HPC bacteria. This indicated a possible health risk to consumers, due to the potential co-occurrence of pathogens such as *Salmonella*, *Yersinia* and *Shigella* [20]. The presence of coliforms indicates an unsanitary condition of this water at the specific sampling occasion [21]. Furthermore, it indicated fecal contamination of the water at the distribution point, either from the source water, the incoming distribution pipes or as a result of poor household hygiene. Such contamination could have also occurred as a result of operational and maintenance problems.

The significance of any positive bacteriological test result is always related on the potential health risk this may cause to consumers [22]. Drinking water that contain some levels of pathogens may not necessarily cause illness to healthy individuals and the probability of an adverse health effect depends on the interaction of the organisms with the immune system of the host [23]. For instance, some bacteria which are not normally pathogenic, such as *Pseudomonas aeruginosa*, are capable of causing infectious diseases in immunosuppressed individuals. Therefore, a thorough assessment of both the level of microorganisms presents in the water as well as the virulence of the microbe identified and the immune condition of the consumer is needed to evaluate the likelihood of a disease occurring as a result of consuming contaminated drinking water [23].

Generally, the relatively high-contaminated samples were those taken from casks (zeer), locally known as “sabeel”; charity cask stands that supply water to passing-by persons in streets and market places. Sabeel stands are situated in various locations throughout the study area in Khartoum and Khartoum North. *E. coli* test was positive for 34 samples (34%) out of the 100 tested samples, 8 (8%) *Klebsiella* species, 20 (20%) *Pseudomonas* species, 18 (18%) *S. aureus* and (2%) *Enterococcus faecalis*. These rates are much higher than the rates reported in the study of Abdelmonem and colleagues in Al-Butana region, where *E. coli* was positive in 6 samples (26%) out of the 23 tested samples and none of the examined water samples have shown any positive results for *Enterococcus faecalis*. Nevertheless, one may point to the variety of ethnicity that are present in the study population of the current study when compared to the study population of Abdelmonem and colleagues as well as the difference in sample size [24].

Significant relationship between cask (zeer) water and bacterial contamination has been found in the current study. The reason might be as public water stands are the most vulnerable drinking water source to bacterial contamination in the communities of the study area. Generally, bacterial contamination in public water stands may be attributed to a variety of factors; among these factors, the microbial contaminated hands of some of the users, in particular children, is the most plausible. Handle-less cups when used for drinking further exacerbate bacterial transmission by the contaminated hands that are immersed to various depths into the bulk of the drinking water inside the pot. Moreover, coverless cask (zeer) facilitates the bacterial accession into drinking water; especially widely open cask (zeer). Dust storms, unattended domestic animals and insects increase the potential for bacterial contamination as well [25]. The absence of the daily cleaning practice, prior to filling the cask (zeer), further allows growth of bacteria, algae and other microorganisms, especially, in overlooked locations. Furthermore, the hoses that are usually used for filling the pots are another potential source of bacterial contamination [26].

Lastly, the post-war context of this study is important when interpreting the observed bacteriological contamination of drinking-water containers. The disruption of water-supply systems, sanitation services, routine cleaning practices, and public-health infrastructure following armed conflict may increase the vulnerability of household and public drinking-water facilities to bacterial contamination. Displacement of populations and the increased reliance on traditional water storage and distribution practices may further contribute to this risk. Therefore, the relatively high contamination observed particularly in traditional zeers may have important implications for waterborne disease transmission in the post-war setting. These findings highlight the need to strengthen water-quality monitoring, sanitation, hygiene practices, and safe water-storage measures as part of post-war public-health recovery in Khartoum State.

#### 5 CONCLUSION

In this study, it has been indicated that public water stands (zeer) are the most vulnerable drinking water source to bacterial contamination in the study area when compared to electrical drinking water coolers. Moreover, no significant differences in contamination of water were observed between Khartoum and Khartoum North cities.

## STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

### *Disclosure of conflict of interest*

All authors declare that there is no any conflict of interests; financial or another.

## REFERENCES

- [1] Kendall P. Newsletter in drinking water quality and health. Colorado State University; 1992.
- [2] Ibrahim. Microbiological quality of water in some food factories storage cisterns in Khartoum North industrial area [PhD thesis]. Khartoum: University of Khartoum; 2005. p. 20-32,54-60.
- [3] Ebacher G, Besner MC, Clément B, Prévost M. Sensitivity analysis of some critical factors affecting simulated intrusion volumes during a low pressure transient event in a full-scale water distribution system. *Water Res.* 2012;46(13):4017-30.
- [4] World Health Organization. Guidelines for drinking-water quality: incorporating 1st and 2nd addenda. Vol 1, Recommendations. 3rd ed. Geneva: WHO; 2008.
- [5] Seas C, Alarcon M, Aragon JC, Beneit S, Quiñonez M, Guerra H, Gotuzzo E. Surveillance of bacterial pathogens associated with acute diarrhea in Lima, Peru. *Int J Infect Dis.* 2000;4:96-99.
- [6] Medema GJ, Payment P, Dufour A, Robertson W, Waite M, Hunter P, Kirby R, Anderson Y. Assessing microbial safety of drinking water: improving approaches and methods. In: *Safe drinking water: an ongoing challenge.* London: IWA Publishing; 2003. p. 11-45.
- [7] Cabral JPS. Water microbiology. Bacterial pathogens and water. *Int J Environ Res Public Health.* 2010;7(10):3657-3703.
- [8] Ell-Amin AM, Sulieman AE, El-Khalifa EA. Quality characteristics of drinking water in Khartoum State and Wad-Medani district, Sudan. In: *Fourteenth International Water Technology Conference (IWTC 14);* Cairo, Egypt; 2010. p. 863-76.
- [9] Exner M, Kramer A, Lajoie L, Gebel J, Engelhart S, Hartemann P. Prevention and control of health care-associated water-borne infections in health care facilities. *Am J Infect Control.* 2005;33(5 Suppl 1):S26-40.
- [10] Craun GF, Brunkard JM, Yoder JS, Roberts VA, Carpenter J, Wade T. Causes of outbreaks associated with drinking water in the United States from 1971 to 2006. *Clin Microbiol Rev.* 2010;23(3):507-28.
- [11] El Emam IA, El Jalii IM. Bacterial contamination of drinking water in selected dairy farms in Sudan. *Sci J King Faisal Univ Basic Appl Sci.* 2010;11(1):153-60.
- [12] Homaida MA, Goja AM. Microbiological quality assessment of drinking water at Ed-Dueim Town, Sudan. *N Y Sci J.* 2013;6(5):10-16.
- [13] Musa AM, Abdelgadir AE. Bacteriological evaluation of the drinking water quality in dairy farms in Khartoum State, Sudan. *J Vet Med Anim Health.* 2014;6(3):95-100.
- [14] Fong TT, Mansfield LS, Wilson DL, Schwab DJ, Molloy SL, Rose JB. Massive microbiological groundwater contamination associated with a waterborne outbreak in Lake Erie, South Bass Island, Ohio. *Environ Health Perspect.* 2007;115(6):856-64.
- [15] Carter JT, Rice EW, Buchberger SG, Lee Y. Relationships between levels of heterotrophic bacteria and water quality parameters in a drinking water distribution system. *Water Res.* 2000;34(5):1495-1502. doi:10.1016/S0043-1354(99)00310-3.
- [16] Green RM, Kane K. The effective enforcement of HACCP based food safety management system in the UK. *Food Control.* 2014;37:257-62.
- [17] Harrigan WF, McCance ME. *Laboratory methods in food and dairy microbiology.* London: Academic Press; 1976.
- [18] Cheesbrough M. *District laboratory practice in tropical countries.* 2nd ed. Cambridge: Cambridge University Press; 2006.
- [19] Collee JG, editor. *Mackie and McCartney practical medical microbiology.* 14th ed. New York: Churchill Livingstone; 1996.
- [20] Odonkor ST, Ampofo JK. *Escherichia coli* as an indicator of bacteriological quality of water: an overview. *Microbiol Res.* 2013;4(1):e2. doi:10.4081/mr.2013.e2.

- [21] An YJ, Breindenbach GP. Monitoring E. coli and total coliforms in natural spring water as related to recreational mountain areas. *Environ Monit Assess.* 2005;102(1-3):131-7.
- [22] Edberg SC, Allen MJ. Virulence and risk from drinking water of heterotrophic plate count bacteria in human population groups. *Int J Food Microbiol.* 2004;92(3):255-63. doi:10.1016/j.ijfoodmicro.2003.08.012.
- [23] Allen MJ, Edberg SC, Reasoner DJ. Heterotrophic plate count bacteria—what is their significance in drinking water? *Int J Food Microbiol.* 2004;92(3):265-74. doi:10.1016/j.ijfoodmicro.2003.08.017.
- [24] Abdelmonem M Abdellah, Abdel-Magid HM, Yahia NA. Assessment of drinking water microbial contamination in Al-Butana region of Sudan. *J Appl Sci.* 2012;12:856-62.
- [25] Hamad ZH, Dirar HA. Microbiological examination of Sabeel water. *Appl Environ Microbiol.* 1982;43:1238-43.
- [26] Abdel Magid HM. Assessment of drinking water quality in the Al-Gassim region of Saudi Arabia. *Environ Int.* 1997;23(2):247-51. doi:10.1016/S0160-4120(97)81162-2.