ISSN 2286-4822
www.euacademic.org

EUROPEAN ACADEMIC RESEARCH
Vol. XIII, Issue 11/ February 2026

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

Microbial Quality of Drinking and Utility Water in Food Establishments in El Madinah El Munawwara: Assessment of Filtration Effectiveness and Contamination Sources

SHAFAG H. M. KIRKUSAWO
BUSHRA AL-BELAIHSHI QASSEM
ANHAR AL-MOWAFI MOHAMMED
MOROUJ FUAD SHAKER
ABRAR ALJOHANI MARZOUQ
ADNAN ZAKARIA ABDULLAH
REEM SALEH ALKADI
Food and Environment Laboratories, El Madinah El Munawwarah Municipality
Kingdom of Saudi Arabia KSA
ANAS M. ELNAZEER
International University of Africa, Faculty of Pure and Applied Sciences
Department of Microbiology, Khartoum, Sudan

Abstract

The microbial quality of drinking and utility water is very important for public health and environmental safety. Contaminated water can contain harmful microorganisms that may cause different diseases. For this reason governments set standards for drinking water quality and require regular testing to ensure safety.

This study assessed the microbial quality of drinking and utility water in fourteen food facilities in Al Madinah Al Munawwara from 16 June 2025 to 20 July 2025. A total of twenty-eight water samples were collected from fourteen facilities located in five municipalities. Samples were taken before and after water filtration. The presence of Enterococcus faecalis, Escherichia coli, coliform bacteria, and Pseudomonas aeruginosa was tested using the membrane filtration method. Reference materials for each bacterium were used to confirm the accuracy of the results.

The findings showed that contamination was present in both pre-filter and post-filter samples at a rate of 16.7%. Enterococcus faecalis was detected in 8.3% of both pre-filter and post-filter samples. Coliform bacteria were found in 6.3% of pre-filter samples and 14.6% of post-filter samples. Escherichia coli was detected in 6.3% of pre-filter samples and 4.2% of post-filter samples. Pseudomonas aeruginosa was detected in 10.4% of pre-filter samples and 8.3% of post-filter sample.

The study concludes that filtration alone is not sufficient to fully control microbial contamination. Poorly maintained filters may also contribute to secondary contamination. Therefore, the study recommends using high-efficiency filters with dual filtration systems, along with regular cleaning and sterilization of pipelines before and after filtration, to ensure safe water use in food facilities.

Keywords: microbial quality, drinking and utility water, food establishments, El Madinah El Munawwara, filtration effectiveness, contamination sources

INTRODUCTION

Water is fundamental to all forms of life and is indispensable for biological processes, food production, and public health protection. Despite its essential role, global water resources face increasing pressure due to population growth, urbanization, aging infrastructure, and environmental pollution. These pressures compromise water quality and necessitate effective management strategies to ensure sustainable access to safe water. In recognition of its critical importance, the United Nations General Assembly formally acknowledged access to safe drinking water and sanitation as a fundamental human right, emphasizing that water must be sufficient, safe, acceptable, physically accessible, and affordable for personal and domestic use (WHO, 2008).

Microbiological contamination of drinking and utility water remains a major public health concern worldwide. It is estimated that more than 900,000 deaths occur annually as a result of foodborne and waterborne diseases, with approximately 80% of infectious diseases in developing and transitional regions linked to the consumption of unsafe water (Nasseri et al., 2018; Teja and Koh, 2009; Ellis and Schoenberger, 2017). Water contaminated with pathogenic microorganisms can serve as a transmission route for a wide range of illnesses, particularly affecting vulnerable populations such as infants, children, the elderly, and immunocompromised individuals.

Indicator microorganisms are widely used to assess the microbiological safety of drinking water. Among these, coliform bacteria are considered primary indicators of fecal contamination, as they originate mainly from the intestinal tract of warm-blooded animals, although some species may also be found in soil and vegetation. The World Health Organization stipulates that the detection of coliforms, fecal coliforms, Escherichia coli, Enterococci, or Pseudomonas aeruginosa in drinking water constitutes a significant public health risk and renders the water unsuitable for consumption (Khatoon and Pirzada, 2010). Escherichia coli, in particular, is regarded as a definitive indicator of recent fecal contamination, as it is rarely detected in water in the absence of a fecal source (Curutiu et al., 2019).

Enterococcus faecalis is another critical indicator organism used to assess water quality. Its presence is associated with chronic or long-term fecal contamination, as this organism is capable of surviving for extended periods in aquatic environments compared to E. coli and many other enteric pathogens. Consequently, Enterococci are considered sensitive indicators of persistent fecal pollution and system integrity failures (WHO, 2006; Scientific Committee of the Irish Food Safety Authority, 2009).

Pseudomonas aeruginosa is a Gram-negative, opportunistic pathogen commonly found in natural and engineered water systems. Although it does not typically proliferate in treated drinking water, it readily colonizes plumbing systems and filtration units through biofilm formation. This organism poses a particular risk in healthcare and food-related environments due to its intrinsic resistance to multiple antibiotics and its capacity to acquire and disseminate resistance genes (Zamberlan da Silva et al., 2008). In addition to bacterial contaminants, fungal growth within water distribution systems has emerged as an increasing concern. Fungi can adversely affect the organoleptic properties of water, contribute to operational challenges, and present health risks including allergic reactions and mycotoxin exposure (Izaguirre and Taylor, 2004; Grabińska-Łoniewska et al., 2007).

Although bottled water is often perceived as a safer alternative to tap water, numerous studies have demonstrated that bottled water may also be subject to microbiological or chemical contamination, thereby posing unanticipated risks to public health (Khaniki et al., 2010). Moreover, chronic microbial contamination of water distribution systems has been documented across diverse geographic regions, including parts of Asia and Europe, underscoring the global nature of this issue (Jáchymová et al., 2002; Lanciotti et al., 2003).

Given the critical role of water quality in food safety and public health, particularly in food establishments where water is extensively used for processing, cleaning, and direct consumption, continuous monitoring and evaluation of microbial water quality are essential. This study aims to assess the microbiological quality of drinking and utility water in selected food establishments in Al Madinah Al Munawwara, with a specific focus on identifying potential sources of contamination and evaluating the effectiveness of filtration systems in controlling microbial hazards.

MATERIAL AND METHOD

For this study, drinking and utility water samples were collected from 14 different food facilities which were selected from different municipalities of Madinah Al Munawwara. Two food facilities were located in Al-Mintaqah Al-Markaziyah Municipality, 3 in Uhud Municipality, 4 in Al-Awali Municipality, 3 in Quba Municipality, and the remaining 2 in Al-Aqiq Municipality. The water samples were collected aseptically with the necessary precautions during the period from 16 June 2025 to 20 July 2025.

Sample Collection

Sterile 500 mL bottles include sodium thiosulfate were used for water sampling, and the containers were completely filled without air pockets. All water samples were taken and transported carefully, protected from sunlight and avoided any contact to prevent contamination. A total of 28 samples were collected from the various facilities, with each facility providing one sample before and one sample after passing through the filtration system. Samples were delivered to the laboratory within 1 hour after collection and stored at 4±2°C. All microbiological analyses were conducted at the Food and Environmental Laboratories of the Al Madinah Al Munawwara Municipality, Al Madinah Al Munawwara, Saudi Arabia.

Membrane Filtration Analysis

In order to determine the quality of drinking and utility water, all analyses were done according to APHA Standards methods (2023). Analysis was conducted by using a membrane filtration system (Merck Millipore, Spain). The samples were passed through a membrane filter with a pore size of 0.45 µm (PALL, USA). The membrane filter was subsequently placed onto Compact Dry EC, ETC, and PA plates (Shimadzu, Italy) for the detection of coliforms, *Enterococcus faecalis*, and *Pseudomonas aeruginosa*, respectively. The filter, along with the compact dry plates, is incubated at 36±1°C for 24±2H. After the incubation period, colonies with a color change (red/pink/purple colonies are indicative of coliform bacteria, blue or blue-purple colonies indicate the presence of *E. coli*, red colonies with green/yellow pigment are marked as *Pseudomonas aeruginosa* and Light blue or blue colonies of 1~2 in diameter is indicative of *E. faecalis*) were counted as positive.

Verification

Colonies suspected as coliforms were verified according to ISO 7251:2005/Amd 1:2023, where samples showing turbidity, cloudiness, or gas production in Lauryl Sulphate Tryptose Broth (LSTB), followed by gas production in EC broth and a positive indole reaction in peptone water at 44 °C, were considered presumptive coliforms. The colonies marked as *E. coli* were verified by using indole test. The colonies were picked and inoculated into a broth containing tryptophan. The inoculated broth was incubated at 37°C for up to 48 days, to allow bacteria to produce indole. After incubation, 0.5 ml Kovac's reagent was added to the broth. If indole is present, the reagent reacts with it to produce a red or pink color which floats on top of the broth. A positive indole test was indicated by this red or pink color change, i.e. verifying *E. coli*. A negative indole test resulted in no color change or a yellowish color, indicating that the bacterium did not produce indole. In addition, quality control was ensured using reference samples, including a positive control (*Escherichia coli* ATCC 25922) and a negative control (*Staphylococcus aureus* ATCC 25923).

Colonies suspected as *E. faecalis* were verified by using Slanetz and Bartley Medium as described in ISO 7899-2, using a membrane filtration technique. Enterococci reduce tetrazolium chloride to the insoluble red dye formazan, producing colonies which are dark red or maroon on the surface of the membrane or agar. In addition, quality control was ensured using reference-strain *E. coli* (ATCC 25922), *E. faecalis* (obtained from positive samples during a proficiency testing program SFDA -2025), *P. aeruginosa* (obtained from positive samples during the SFDA 2025 and the BIPEA proficiency testing programs) and a negative control *S. aureus* (ATCC 25923). Certified reference materials were obtained from the American Type Culture Collection (ATCC) and were stored as glycerol stocks at −80 °C.

RESULT AND DISCUSSION

The study results are summarized in Table 1. Out of a total of 14 facilities, water from 9 facilities was found to be contaminated, whereas only 5 facilities had water that met microbiological safety standards and was free from contamination. These findings are consistent with those reported in a previous study on microbial water quality, which also demonstrated that the majority of drinking water samples did not meet acceptable safety levels (Nural and Seyhun, 2024).

Water samples collected from facilities A, H, J, L, and N, both pre and post filter, showed no detection of *E. faecalis, Coliforms, E. coli* and *P. aeruginosa*, all below the legal limit of 0/100 ml (GSO, 2015), indicating effective filtration and compliance with national water. These results demonstrate the effectiveness of the filtration systems in maintaining microbiological water quality and compliance with safety standards. These findings differ from those reported in a previous study, which revealed the presence of microbial contaminants, including *E. faecalis*, *E. coli*, and *P. aeruginosa*, in water samples (Khanna and Bhushan, 2025).

The results indicated that water samples collected pre filter system in Facility B were contaminated with *P. aeruginosa*. Post-filter water samples showed contamination with *E. faecalis*, *Coliforms*, as well as the persistent presence of *P. aeruginosa*, all above the legal limit of 0/100 ml (GSO, 2015). These results indicate that the filtration system used in Facility B is ineffective in eliminating *P. aeruginosa* and the system is contaminated with *E. faecalis* and *Coliforms*, as confirmed by the findings. This finding contrasts with the study by Trautmann *et al.*, 2008, which indicated that *P. aeruginosa* should be absent following water filtration.

Water samples collected pre filter system in Facility C were contaminated with *P. aeruginosa*. Post-filter samples showed persistent *P. aeruginosa* together with *E. coli*, *Coliforms*, and *E. faecalis*., indicating the inefficiency of the system. No *Coliforms*, *E. coli, E. faecalis* and *P. aeruginosa* are allowed in drinking and utility water (GSO, 2015). The detection of additional bacteria post filter may be explained by inadequate filter pore size, biofilm formation within the unit, insufficient maintenance, or recontamination during water passage. These findings indicate that contamination with *P. aeruginosa* may occur prior to the filtration system, likely originating from polluted storage tanks or biofilm-contaminated pipes and connections. Biofilms provide a favorable environment for bacterial growth, allowing the bacteria to persist in water systems and resist cleaning and disinfection processes (Mulcahy *et al.*, 2014).

The results demonstrated that water samples collected both pre and post the filter system in Facility D contained *E. faecalis.* and *Coliforms*. These findings clearly deviate from the GSO (2015) requirements, which mandate the absence (0/100 ml) of *E. faecalis* and *Coliforms* in drinking and utility water. The detection of these organisms above the permissible limit highlights non-compliance with microbiological safety standards and indicates insufficient performance of the filtration system. Notably, *E. faecalis* is capable of surviving under harsh environmental conditions, colonizing medical devices, and evading both immune responses and antimicrobial therapies, mainly through biofilm formation (Sadanandan and Yogendraiah, 2025). This outcome suggests that replacing filters alone is not sufficient; proper disinfection of the pipelines is also required, particularly to eliminate *E. faecalis*, which can survive under harsh environmental conditions and form biofilms that enhance its persistence as reported by Sadanandan and Yogendraiah, 2025.

The results showed that water samples collected pre filter system in Facility F were contaminated with *E. faecalis.* and *P. aeruginosa*. In contrast, post-filter samples contained *Coliforms* in addition to *P. aeruginosa*, while it was noted that pre-filtration water was free from *Coliforms*. This shift in the microbial profile suggests that the filtration system not only failed to eliminate *P. aeruginosa* but may also have contributed to the introduction or redistribution of *Coliforms*. The presence of *Coliforms*, in water system, is an indication that the water sources are of poor microbiological quality (Oyewale *et al.*, 2024). The detection of *Coliforms* in this study after filtration is likely due to their persistence within the filter medium or secondary contamination from downstream pipelines. Furthermore, the detection of *E. faecalis*, *Coliforms*, and *P. aeruginosa* in the water samples constitutes a clear violation of the GSO (2015) standards. As reported by Kamdar *et al.*, 2025 all isolates obtained demonstrated the ability to form biofilms, primarily associated with *Coliforms*. A study revealed that, biofilms in stored water systems and pipes pose a substantial challenge to drinking water safety (Kamdar *et al.*, 2025).

The results showed that water samples collected from Facility G, both pre- and post-filtration, were contaminated with *P. aeruginosa*. Usually, *P. aeruginosa* does not grow in drinking water, mostly it is found in pipes, thanks to its ability to form biofilms in plumbing systems (e.g. taps, showers, etc.) (Lombardi *et al.*, 2025). This finding indicates that the filtration system in use is ineffective in eliminating this opportunistic pathogen. The persistence of *P. aeruginosa* across both sampling points highlights either the resistance of the organism to the applied treatment process or potential biofilm development within the system. Such contamination exceeds the legal limit of 0/100 ml, as stipulated by GSO (2015), and represents a significant public health concern.

Pre-filter water samples from Facility I showed no detection of *E. faecalis*, Coliforms, *E. coli*, or *P. aeruginosa*. However, post-filter samples were contaminated with *Coliforms*, exceeding the legal limit of 0/100 ml for drinking water (GSO, 2015). The presence of *Coliforms* in water samples indicates the existence of opportunistic pathogenic bacteria like *Klebsiella* and *Enterobacter* that can multiply in water environments, as well as pathogenic bacteria like *Salmonella* spp., *Shigella* spp., and *E. coli* (Oyewale *et al.*, 2024).

The analysis showed that water samples from facility K, collected both pre and post filter were contaminated with *E. faecalis*, *Coliforms*, and *E. coli*, all exceeding the legal limit of 0/100 ml for drinking water (GSO, 2015). These findings demonstrate that the filtration system was ineffective in removing these microorganisms, suggesting either insufficient filter performance or persistent contamination within the downstream distribution network.

The results showed that water samples from facility M, collected pre filter, were free of *E. faecalis*, *Coliforms*, *E. coli*, and *P. aeruginosa*, exceeding the legal limit of 0/100 ml for drinking water (GSO, 2015). In contrast, post-filter samples were contaminated with *Coliforms*, suggesting potential contamination from the filter itself or from the downstream distribution system.

The results showed that water samples from facility O, collected pre filter, were contaminated with *E. faecalis*, *Coliforms*, *E. coli*, and *P. aeruginosa*, all below the legal limit of 0/100 ml for drinking water (GSO, 2015). In contrast, post-filter samples were free of these microorganisms, indicating that the filtration system effectively removed both indicator and opportunistic bacteria.

Table 1. *E. faecalis, Coliform, E. coli and P. aeruginosa* detection for drinking and utility water samples taken from 14 different food facilities

Facility	Sampling Point	*E. faecalis*	*Coliform*	*E. coli*	*P. aeruginosa*
A	pre-filter	ND	ND	ND	**ND**
	post-filter	ND	ND	ND	**ND**
B	pre-filter	ND	ND	ND	**D**
	post-filter	D	D	ND	**D**
C	pre-filter	ND	ND	ND	**D**
	post-filter	D	D	D	**D**
D	pre-filter	D	D	ND	**ND**
	post-filter	D	D	ND	**ND**
F	pre-filter	D	ND	ND	**D**
	post-filter	ND	D	ND	**D**
G	pre-filter	ND	ND	ND	**D**
	post-filter	ND	ND	ND	**D**
H	pre-filter	ND	ND	ND	**ND**
	post-filter	ND	ND	ND	**ND**
I	pre-filter	ND	ND	ND	**ND**
	post-filter	ND	D	ND	**ND**
J	pre-filter	ND	ND	ND	**ND**
	post-filter	ND	ND	ND	**ND**
K	pre-filter	D	D	D	**ND**
	post-filter	D	D	D	**ND**
L	pre-filter	ND	ND	ND	**ND**
	post-filter	ND	ND	ND	**ND**
M	pre-filter	ND	ND	ND	**ND**

	post-filter	ND	D	ND	**ND**
N	pre-filter	ND	ND	D	**ND**
	post-filter	ND	ND	ND	**ND**
O	pre-filter	D	D	D	**D**
	post-filter	ND	ND	ND	**ND**

ND: **Not detected** **D:** **Detected**

Plate 1.

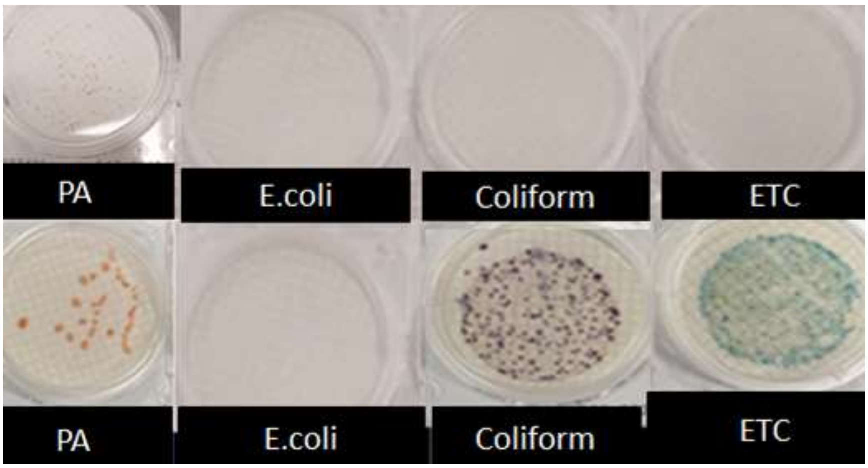


Plate 2.

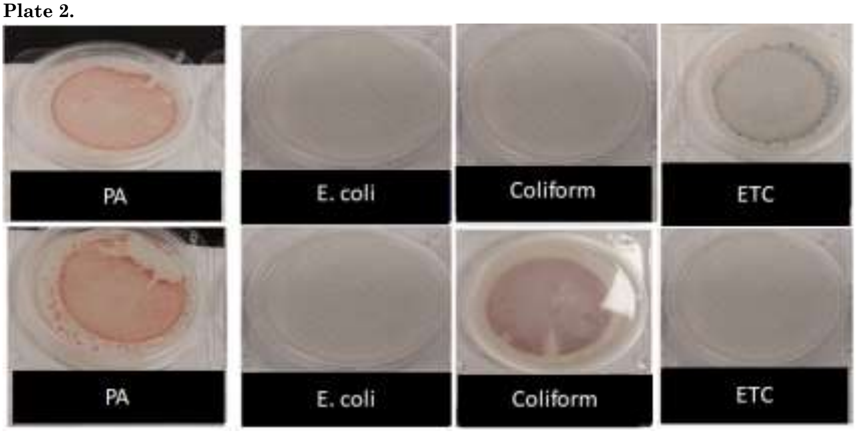


Plate 3.

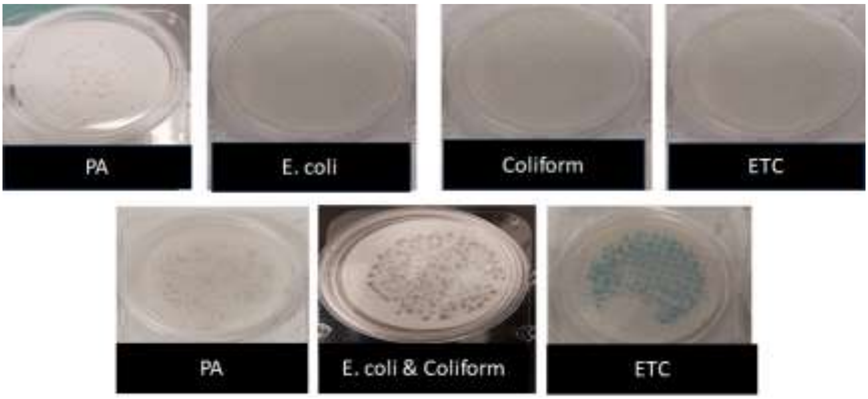


Plate 4.

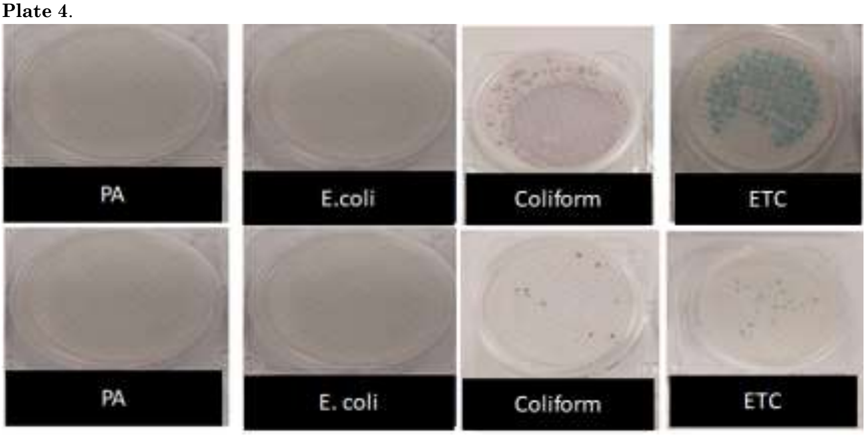


Plate 5.

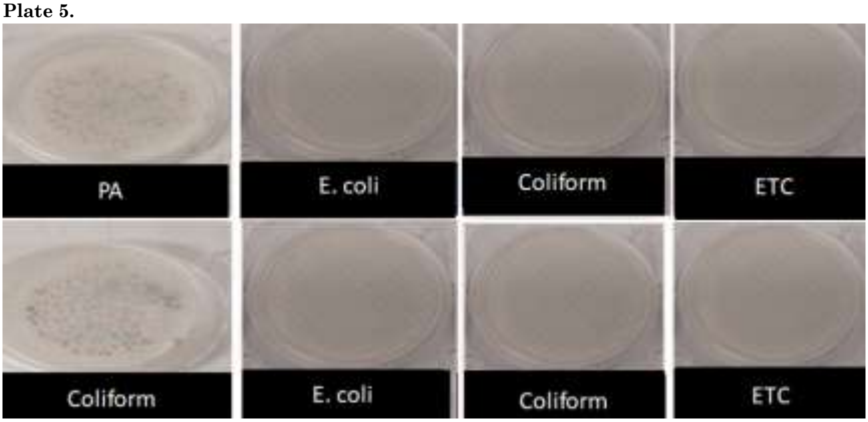


Plate 6.

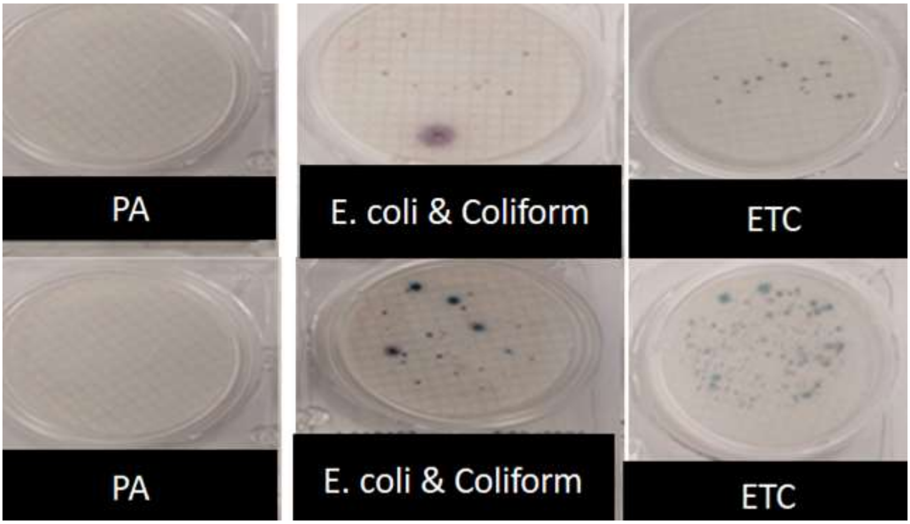
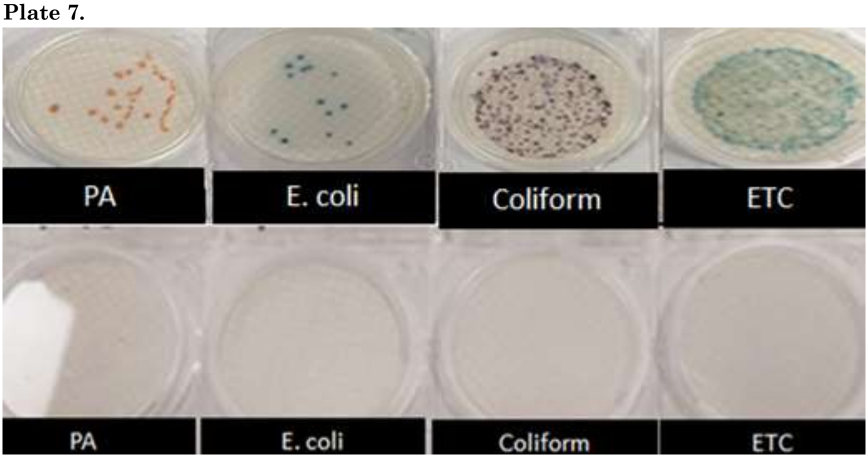


Plate 7.



CONCLUSION

This study demonstrated that filtration alone is insufficient to ensure complete microbial removal from drinking and utility water in food facilities. The presence of E. faecalis, E. coli, coliforms, and P. aeruginosa in post-filter samples suggests possible biofilm formation or recontamination within filtration systems. These results highlight persistent microbiological risks and underscore the critical importance of monitoring water quality to protect public health.

RECOMMENDATIONS

- Implement regular inspection, cleaning, and sterilization of filtration units and distribution networks to prevent microbial buildup and ensure system efficiency.
- Conduct periodic performance assessments using microbiological indicators to verify the effectiveness of filtration and maintain compliance with regulatory standards.
- Adopt advanced filtration technologies, such as dual-stage or ultrafiltration systems, and supplementary treatment methods to enhance pathogen removal.
- Apply targeted strategies to control biofilm formation within pipelines and storage tanks, minimizing the risk of secondary contamination.
- Establish continuous microbial monitoring to detect contamination early and enable prompt corrective actions.

REFERENCES

1. **Kamdar, D., Shah, M., and Patil, S**. (2025). Antimicrobial Resistant and Biofilm forming Coliforms in Drinking Water Systems of Mumbai's Harbour Line Railway Stations. Journal of Scientific Research, 17(2), 637-645.
2. **Khanna, R., and Bhushan, K.** (2025). Microbial safety and quality assessment of drinking water from various water sources in Punjab, India. International Journal of Environmental Health Research, 1-15.
3. **Lombardi, A., Cornacchia, A., Borriello, T., Maccauro, M. L., Nardo, A., Bosica, S., ... and Pennino, F**. (2025). Pseudomonas Aeruginosa Investigation in Water Samples of Campania Region, Southern Italy. Southern Italy.
4. **Mulcahy, L. R., Isabella, V. M., and Lewis, K.** (2014). Pseudomonas aeruginosa biofilms in disease. Microbial ecology, 68(1), 1-12.
5. **Nural, R. E., and Seyhun, N**. (2024). Microbial Quality of Drinking and Utility Water in Tourism Facilities in Antalya. Türk Doğa ve Fen Dergisi, 13(3), 184-188.
6. Oyewale, A. T., Odetoyin, B. W., Oluduro, A. O., and Adeniyi, I. F. (2024). Occurrence of coliforms and biofilm-forming bacteria in raw, treated, and distributed water from two waterwork systems in Osun State, Southwestern Nigeria. Journal of Water and Health, 22(4), 673-688.
7. **Sadanandan, B., and Yogendraiah, K. M.** (2025, August). Enterococcus faecalis biofilm: a clinical and environmental hazard. In Medical Sciences Forum (Vol. 35, No. 1, p. 5). MDPI.
8. **Trautmann, M., Halder, S., Hoegel, J., Royer, H., and Haller, M.** (2008). Point-of-use water filtration reduces endemic Pseudomonas aeruginosa infections on a surgical intensive care unit. American journal of infection control, 36(6), 421-429.
9. **World Health Organization (WHO),** 2008. Guidelines for Drinking-water quality, incorporating 1st and 2nd Addenda, Volume 1, Recommendations, third ed. WHO, Geneva, Switzerland.
10. **Nasseri, B., Soleimani, N., Rabiee, N., Kalbasi, A., Karimi, M., and Hamblin, M. R.** (2018). Point-of-care microfluidic devices for pathogen detection. Biosensors and Bioelectronics, 117, 112-128.
11. **Teja, A. S., and Koh, P. Y.** (2009). Synthesis, properties, and applications of magnetic iron oxide nanoparticles. Progress in crystal growth and characterization of materials, 55(1-2), 22-45.
12. **Ellis, H., and Schoenberger, E.** (2017). On the identification of associations between five world health organization water, sanitation and hygiene phenotypes and six predictors in low and middle-income countries. PloS one, 12(1), e0170451.

13. **Khatoon, A., and Pirzada, Z. A**. (2010). Bacteriological quality of bottled water brands in Karachi, Pakistan. Biologia (Pakistan), 56(1-2), 137-143.
14. **Curutiu, C., Iordache, F., Gurban, P., Lazar, V., and Chifiriuc, M. C.** (2019). Main Microbiological Pollutants of Bottled Waters and Beverages. Bottled and Packaged Water, 403–422.
15. **WHO** (World Health Organization) Guidelines for Drinking Water Quality. First Addendum to Third Edition, Volume 1: .2006. http://www.who.int/water_sanit ation_health/dwq/gdwq3rev/en/
16. **Report of the Scientific Committee of the Food Safety Authority of Ireland Food Safety Authority of Ireland; Dublin**: 2009. The consumption of bottled water containing certain bacteria or groups of bacteria and the implications for public health.
17. **da Silva, M. E. Z., Santana, R. G., Guilhermetti, M., Camargo Filho, I., Endo, E. H., Ueda-Nakamura, T., ... and Dias Filho, B. P**. (2008). Comparison of the bacteriological quality of tap water and bottled mineral water. International journal of hygiene and environmental health, 211(5-6), 504-509.
18. **Izaguirre, G., and Taylor, W. D.** (2004). A guide to geosmin-and MIB-producing cyanobacteria in the United States. Water science and technology, 49(9), 19-24.
19. **Grabińska-Łoniewska, A., Koniłłowicz-Kowalska, T., Wardzyńska, G., and Boryn, K.** (2007). Occurrence of fungi in water distribution system. growth, 11, 12.
20. **Khaniki, G. J., Zarei, A., Kamkar, A., Fazlzadehdavil, M., Ghaderpoori, M., and Zarei, A**. (2010). Bacteriological evaluation of bottled water from domestic brands in Tehran markets, Iran.
21. **Jáchymová, J., Votruba, J., Viden, I., and Řezanka, T.** (2002). Identification of Streptomyces odor spectrum. Folia microbiologica, 47, 37-41.
22. **Lanciotti, E., Santini, C., Lupi, E., and Burrini, D.** (2003). Actinomycetes, cyanobacteria and algae causing tastes and odours in water of the River Arno used for the water supply of Florence. Journal of Water Supply: Research and Technology—AQUA, 52(7), 489-500.