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Factors Affecting the Microbiological Quality of Refilled Drinking Water at Refilled Drinking Water Depots: Literature Review

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Abstract

Access to safe drinking water remains a public health challenge, particularly in developing countries. Refilled drinking water depots (DAMIU) are vulnerable to microbiological contamination by pathogens such as Escherichia coli and coliform bacteria, which may increase the risk of waterborne diseases. This study aimed to identify factors affecting the microbiological quality of refilled drinking water. A literature review was conducted using articles obtained from Google Scholar and Scopus. Articles published between 2020 and 2026 in English or Indonesian and available in full text were included. Eleven studies met the inclusion criteria. The findings showed that poor depot sanitation, inadequate operator hygiene, and improper equipment maintenance were significantly associated with microbiological contamination. Unsanitary locations and poor cleaning practices increased the risk of Escherichia coli and coliform contamination. Equipment conditions, including sterilization systems and microfilters, also influenced water quality. Reverse Osmosis (RO) was more effective in reducing microbial contamination than ultraviolet (UV) and ozone methods. Depot sanitation, operator hygiene, equipment conditions, and disinfection methods influence the microbiological quality of refilled drinking water. Proper management of these factors is essential to ensure safe drinking water.

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Introduction

Access to safe drinking water remains a global public health issue, particularly in developing countries, as water contaminated with pathogenic microorganisms can cause waterborne diseases such as diarrhea, cholera, and typhoid (Ramay et al., 2025). Therefore, the availability and

consumption of safe drinking water are crucial factors in disease prevention and overall public health improvement.

Access to safe drinking water in Indonesia still faces various challenges, particularly disparities between urban and rural areas, water quality issues, and environmental and socioeconomic factors. Several studies have shown that access to piped drinking water in Indonesia remains limited and unequal, particularly in rural areas, which still rely on alternative water sources of varying safety (Sutomo et al., 2021). In urban areas, although water service coverage is relatively better, water quality remains a problem due to river pollution and high urbanization pressures (Basuki et al., 2024). Furthermore, climate change affects water availability through increased incidence of droughts and floods, as well as declines in the quality of raw water sources, which undermine the sustainability of drinking water supplies (Kurniawan et al., 2024). Socioeconomic factors also play a significant role, with households with higher levels of education and income tending to have safer access to drinking water than lower-income groups, who still rely on unprotected water sources (Ari et al., 2024). This situation demonstrates that although Indonesia has seen increased access to drinking water, challenges related to equitable service distribution, water quality, and the sustainability of water sources remain critical issues in efforts to provide safe drinking water to the community.

Drinking water is defined as water that is safe for human consumption and complies with established physical, chemical, and microbiological quality standards to protect public health (Mitchell & Frisbie, 2023; Rahim et al., 2024). Among these quality parameters, microbiological safety is particularly critical because contamination by pathogenic microorganisms can directly cause waterborne diseases, underscoring the importance of continuous monitoring and quality assurance throughout drinking water production and distribution, including refill drinking water depots (Costopoulos et al., 2025).

Refill drinking water depots (DAMIU) are a type of drinking water supply business that face a high risk of microbial contamination due to multi-stage processing and distribution, and direct contact with the surrounding environment. Several studies have shown that refilled drinking water is often contaminated with bacteria such as Escherichia coli, Klebsiella oxytoca, and Proteus sp., indicating microbiological contamination and potential health risks to consumers (Iyer et al., 2025). Furthermore, other studies have reported that the microbiological quality of refilled drinking water can be affected by equipment sanitation, the cleanliness of the filling area, and the hygiene practices of depot operators that do not meet health standards (Saimin et al., 2020). This risk of contamination can lead to waterborne diseases and increase the potential for public health problems if water quality monitoring is not conducted routinely and continuously (Alfian et al., 2023). Therefore, refilled drinking water depots are among the sources of drinking water that require strict supervision to ensure the microbiological safety of the water consumed by the public. This evidence suggests that microbiological contamination remains a primary challenge to the safety of refilled drinking water, making regular microbiological surveillance and compliance with hygiene and sanitation standards essential for protecting public health.

Previous studies have shown inconsistent findings regarding the determinants of microbiological contamination in refilled drinking water depots. (Wulandari & Pristiyaningrum, 2025) reported that equipment sanitation, operator hygiene, and storage duration were significantly associated with microbial contamination in DAMIU, whereas place sanitation and raw water sources were not statistically significant. Similarly, Arumsari et al. (2021) found that place sanitation and equipment sanitation were not significantly associated with the presence of *Escherichia coli*, whereas handler hygiene was significantly associated. In another study, Abas et al. (2025) found *Escherichia coli* contamination in several depots despite adequate sanitation conditions at the location and equipment level, suggesting that worker hygiene may remain an important factor in preventing contamination. These findings indicate that a single determinant cannot explain microbiological

contamination in DAMIU; rather, it may result from interactions among place sanitation, operator hygiene, equipment sanitation, storage duration, raw water quality, and depot operational practices.

In addition to these inconsistent findings, previous studies also have several methodological limitations. Many studies were conducted in specific local settings with relatively limited sample sizes and predominantly used cross-sectional designs. Such designs are useful for identifying associations between risk factors and microbiological contamination; however, they are limited in explaining causal relationships because exposure and outcome are measured simultaneously. For example, Arumsari et al. (2021) examined 27 depots, whereas Elsa et al. (2025) analyzedanalyzed only 5 depots and did not conduct bivariate analysis because the data were homogeneous. In addition, qualitative research by Alfian et al. (2022) provided an in-depth understanding of low levels of knowledge and poor hygiene and sanitation practices among depot operators. However, its findings remain context-specific because the study was conducted in a limited local setting with a small number of informants. These limitations indicate that the available evidence is still fragmented and may not fully explain how various determinants collectively influence the microbiological quality of refilled drinking water.

Therefore, a synthesis of recent evidence is needed to provide a more comprehensive understanding of factors affecting microbiological contamination in refilled drinking water depots. By reviewing studies published between 2020 and 2026, this literature review integrates current findings on sanitation conditions, operator hygiene, equipment maintenance, storage duration, raw water quality, and disinfection methods as they relate to *Escherichia coli* and coliform contamination. This synthesis is expected to clarify the contributions of various determinants and support evidence-based recommendations to improve the safety and microbiological quality of refilled drinking water.

The novelty of this study lies in its comprehensive review of recent evidence published between 2020 and 2026 by integrating findings on sanitation conditions, operator hygiene, equipment maintenance, and disinfection methods as determinants of microbiological quality in DAMIU. Therefore, this study aims to identify and synthesize the factors affecting the microbiological quality of refilled drinking water, particularly those related to *Escherichia coli* and coliform contamination, to support evidence-based interventions to improve drinking water safety.

Methods

This study employed a literature review design to synthesize evidence on factors affecting the microbiological quality of refill drinking water depots (DAMIU). A systematic literature search was conducted using the Scopus and Google Scholar databases. The search strategy combined keywords using Boolean operators, including ("refill drinking water" OR "refill drinking water depot" OR DAMIU) AND ("microbiological quality" OR "Escherichia coli" OR coliform), to identify studies relevant to the research objective.

The article selection process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, consisting of identification, duplicate removal, title and abstract screening, full-text eligibility assessment, and final inclusion of eligible studies (Figure 1). Records identified from both databases were screened sequentially based on their titles and abstracts, followed by full-text evaluation to determine their eligibility for inclusion in the review.

The inclusion criteria comprised peer-reviewed journal articles published between 2020 and 2026, written in English or Indonesian, fully accessible in full text, and specifically investigating the microbiological quality or determinants of microbiological contamination in refill drinking water depots, particularly Escherichia coli and coliform contamination. Articles were excluded if they were duplicate records, unavailable in full text, irrelevant to the review objectives, or did not report outcomes related to microbiological quality.

Data extracted from the included studies included the authors, publication year, study location, study design, sample characteristics, microbiological outcomes, and determinants of microbiological

contamination. The findings were synthesized narratively by categorizing the reported determinants into major themes, including sanitation conditions, operator hygiene, equipment sanitation, raw water quality, storage duration, and disinfection practices.

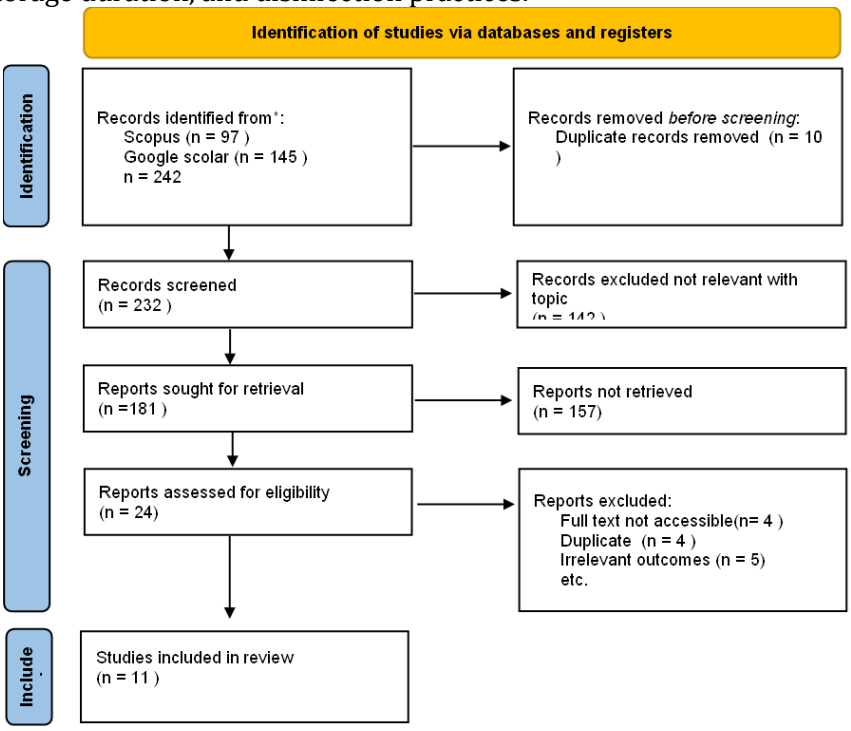

Figure 1. PRISMA Flow Diagram

Results and Discussions

Results

After conducting a keyword-based search, 11 scientific journal articles were found that met the research criteria.

Table 1. Scientific articles that met the research criteria

No.	Authors & Year	Title	Method & Sample	Conclusion
1	M. Karjono, Silvia Ni Nyoman Sintari (2023)	Hygiene and Sanitation Are Very Important to Maintain the Drinking Water Quality of Refill Water Depots in East Lombok Regency	Cross-sectional, 50 drinking water depots	There was a significant relationship between hygiene and sanitation practices and the quality of drinking water at refill water depots in East Lombok Regency.
2	Asmawati Badun (2021)	The Relationship of Drinking Water Depot Sanitation with the Presence of Coliform and Escherichia coli	Cross-sectional, 13 drinking water depot samples	There was a relationship between the hygiene and sanitation conditions at drinking water depots and the presence of coliform bacteria and *Escherichia coli* in Kendari District.

No.	Authors & Year	Title	Method & Sample	Conclusion
3	Widiyatmoko, E.; Suswati, E. (2025)	Hygiene-Sanitation as a Predictor of the Presence of Coliform Bacteria in Drinking Water Depot Products	Cross-sectional, 80 drinking water depots	There was a relationship between hygiene and sanitation conditions at drinking water depots and the presence of coliform bacteria in depot products.
4	Virdha Amartya Librianti, Tri Joko, Nikie Astorina Yunita Dewanti (2023)	The Relationship Between Place Sanitation, Equipment Sanitation, and Handler Hygiene with Coliform Bacteria in Drinking Water Depots in Sukmajaya District	Cross-sectional, 31 drinking water depot units	There was no relationship between general hygiene-sanitation conditions and the presence of *Escherichia coli*, whereas there was a relationship between equipment sanitation and the presence of Escherichia coli.
5	Syahrul Ramadhan, Retno Adriyani, Adella Atika Larasati, Ahmad Husaini, Shaharuddin Bin Mohd Sham (2023)	Relationship Between Operator Knowledge and Hygiene with Bacteriological Quality of Refill Drinking Water in Banyuwangi, Indonesia: A Cross-Sectional Study	Cross-sectional, 33 refill drinking water depots	There was a significant relationship between operators/handlers and the presence of *Escherichia coli* bacteria.
6	Aliana Putri, Ramadhan Tosepu, Hartati Bahar (2025)	Analysis of Drinking Water Quality in Refill Drinking Water Depots in Kambu Village in 2025	Descriptive observational, 15 drinking water depot samples	The operator/handler category met the required standards in all 15 samples (100%).
7	Surya Kusuma Purba, Myrnawati Crie Handini, Asima Sirait (2023)	Determinants of the Presence of *E. coli* Bacteria in Drinking Water: A Survey of Refill Drinking Water Depots (DAMIU) in Medan Belawan District, Medan City	Cross-sectional, 30 drinking water depot samples	There was a significant relationship between handler conditions and the presence of *Escherichia coli* bacteria.
8	Oktavia Rostiana	The Relationship Between Place Sanitation, Equipment Maintenance, and Operator Hygiene of Refill Drinking Water Depots with Bacteriological Quality (*Escherichia coli*) in Cempaka Putih District in 2021	Cross-sectional, 30 samples	There was a relationship between equipment maintenance and the presence of *Escherichia coli*.

No.	Authors & Year	Title	Method & Sample	Conclusion
9	Erni, E.; Baharuddin, A.; AP, A.R.A.; et al.	*E. coli* Bacterial Contamination and Sanitation Hygiene in Refill Drinking Water During the COVID-19 Pandemic	Cross-sectional, 32 samples	There was a relationship between the hygiene and sanitation of processing equipment in refill drinking water depots and bacteriological contamination.
10	Ester Saripati Harianja, Apriska Dewi Sipayung, Sri Dearmaita Purba, Tengkuindah Abdilla (2022)	Equipment Maintenance and Processing Supervision of Refill Drinking Water Depots with *Escherichia coli* Contamination in Drinking Water	Cross-sectional, 15 refill drinking water depots	There was a significant relationship between equipment maintenance and the presence of *Escherichia coli* bacteria.
11	Muhamad Iqbal (2022)	Comparison of Reverse Osmosis and Non-Reverse Osmosis Disinfection Methods for Drinking Water Depots	Cross-sectional, 30 drinking water depots	The reverse osmosis method was the most effective in reducing microbiological contamination compared to non-reverse osmosis methods.

Overall, the 11 included studies were predominantly conducted in Indonesia using a cross-sectional design, with sample sizes ranging from 13 to 80 refill drinking water depots. Most studies focused on evaluating the association between hygiene-sanitation practices, handler hygiene, equipment maintenance, and microbiological contamination, particularly Escherichia coli and coliform bacteria. The reviewed evidence consistently emphasized microbiological safety as the primary outcome, although variations were observed in the significance of specific determinants across different study settings. These findings indicate that research on DAMIU has largely focused on identifying operational and environmental factors that influence microbiological quality, thereby providing a foundation for synthesizing the major determinants discussed below.

The reviewed studies consistently identified four major categories of determinants influencing the microbiological quality of refill drinking water depots, namely sanitation conditions, handler hygiene, equipment maintenance, and disinfection methods. Although the significance of individual determinants varied across studies, the overall evidence suggests that microbiological contamination is a multifactorial problem arising from interactions among environmental sanitation, human behavior, operational practices, and treatment technology. Therefore, the following discussion synthesizes the evidence according to these thematic determinants and highlights possible explanations for the differences observed among studies.

Discussion 1: DAMIU Sanitation Factors

DAMIU sanitation hygiene is an effort to control risk factors for drinking water contamination and ensure its safety. Contamination with Escherichia coli and coliform bacteria can be caused by poor sanitation hygiene in a given location. The results of this study indicate a significant relationship between sanitation hygiene and drinking water quality at depots in East Lombok Regency ($p=0.001<0.05$), with a positive, moderate strength ($r=0.51$). This finding aligns with research by Karjono and Sintari (2023), which also confirmed that implementing good sanitation hygiene improves the microbiological quality of drinking water.

A literature review by Badun (2021) indicates that the locations of drinking water depots along roadsides and in bushy areas can increase the presence of vectors and disease-carrying animals. These conditions can impact the depot's environmental sanitation quality. Accordingly, Fisher's Exact Test showed a p-value of 0.014 (<0.05), indicating a significant relationship between on-site sanitation hygiene and the presence of coliform bacteria and Escherichia coli in Kendari District.

According to research by Widiyatmoko et al. (2025), the analysis showed a relationship between the hygiene of drinking water depot sanitation and the presence of coliform bacteria in refilled drinking water products. This finding confirms that depot sanitation hygiene is a predictor of coliform contamination. Despite being categorized as having good sanitation hygiene, depots still do not meet microbiological quality standards, with a proportion similar to that of depots with poor sanitation. Poor hygiene practices can lead to coliform bacteria contamination, which can originate from dust and dried feces.

This finding is inconsistent with research by Librianti et al. (2023). The chi-square test showed a p-value of 0.537 (p>0.05), indicating no significant relationship between sanitation and the presence of coliform bacteria in refilled drinking water. This indicates that bacterial contamination is not solely influenced by sanitation but can also be influenced by other environmental factors, such as temperature, radiation, and changes in environmental conditions around the depot, which also influence the growth of microorganisms.

Overall, the reviewed studies consistently indicate that sanitation hygiene is an important determinant of the microbiological quality of refill drinking water depots. Most studies reported that inadequate environmental sanitation increases the likelihood of Escherichia coli and coliform contamination, although one study found no statistically significant association. These inconsistent findings may be explained by differences in environmental conditions, sanitation compliance, operational practices, sample characteristics, and local microbiological exposure across study settings (Badun, 2021; Karjono & Sintari, 2023; Librianti et al., 2023; Widiyatmoko et al., 2025). From a practical perspective, these findings suggest that routine sanitation inspections, environmental hygiene monitoring, and consistent implementation of sanitation standards should be prioritized to minimize microbiological contamination in refill drinking water depots.

Discussion 2: Handler hygiene factors

Handler hygiene is an important determinant in maintaining the microbiological quality of refilled drinking water. Hygiene practices and behavior of handlers during the processing, filling, and storage of water can become sources of contamination if they do not adhere to good hygiene principles, thereby increasing the risk of pathogenic bacteria such as coliforms and Escherichia coli. Research results (Syahrul Ramadhan1 et al., 2024) showed that operator hygiene practices were significantly related to total coliform in refilled drinking water. Refill drinking water depots whose operator hygiene practices did not meet requirements had an 8.4-fold higher risk of coliform contamination than depots that met operator hygiene requirements. This is in line with research (Purba et al., 2023), which showed that handler conditions were significantly related to E. coli in refilled drinking water, with the probability of E. coli presence being 1.094 times greater after controlling for the refilled drinking water treatment facility. Handler conditions were the dominant determinant of E. coli content in refilled drinking water depots in Belawan District, compared with processing sanitation, equipment conditions, and raw water source conditions.

Based on research by Putri (2026) at 15 refill drinking water depots (DAMIU) in Kambu Village, Kambu District, Kendari City, all handlers demonstrated good sanitation hygiene behaviors, such as wearing clean, tidy clothing and practicing hygiene when serving customers. This condition aligns with the assessment results, which showed that all handlers met the requirements (100%). Implementing good handler hygiene can reduce the risk of bacterial contamination in the drinking water produced.

Overall, the reviewed evidence consistently identifies handler hygiene as one of the strongest determinants of microbiological quality in refill drinking water depots. Although the magnitude of the reported associations varied across studies, appropriate personal hygiene practices, including hand hygiene, clean work clothing, and hygienic water handling procedures, were repeatedly associated with a lower risk of Escherichia coli and coliform contamination (Purba et al., 2023; Putri et al., 2026; Syahrul Ramadhan et al., 2024). Differences in operator training, adherence to hygiene protocols, and supervision practices may explain the variation in contamination risks observed among studies. Differences in operator training, adherence to hygiene protocols, and supervision practices may explain the variation in contamination risks observed among studies.

Discussion 3: Equipment Factors

Theoretically, there is a relationship between equipment maintenance and Escherichia coli contamination. This can be caused by machines and equipment that come into direct contact. Equipment, both raw materials and final products, must be cleaned and maintained regularly. At refillable drinking water depots, equipment is regularly maintained according to its type. Once it has reached the end of its service life, it must be replaced in accordance with applicable technical regulations. This is in line with research by Harianja et al. (2022), which found a significant relationship between equipment maintenance and Escherichia coli contamination in refillable drinking water. To prevent bacterial contamination of drinking water, regular maintenance is essential. For example, if a machine has reached the end of its useful life, it must be replaced in accordance with its technical regulations. Equipment surfaces that come into contact with raw materials and drinking water must also be clean and sanitized daily, and surfaces that come into contact with drinking water must be free of scale and other residues. The filling and capping processes are carried out in a hygienic environment to ensure the resulting drinking water meets health requirements.

The results of statistical tests in the study (Erni et al., 2023) showed a p-value of 0.011 (<0.05), indicating a significant relationship between the sanitation and hygiene of refill drinking water depot processing equipment and bacteriological content (MPN Escherichia coli) in the Layang Community Health Center (Puskesmas) work area. Based on observations at 32 depots, most of the food-grade equipment, such as stainless steel and polyvinyl chloride, and disinfection equipment were still suitable for use. Furthermore, the raw water reservoirs were kept closed and protected from sunlight, and the gallon containers were cleaned before filling. These practices demonstrate that good equipment hygiene helps maintain the microbiological quality of the drinking water produced.

In line with research by Rostiana (2023), a study of 30 refillable drinking water samples in Cempaka Putih District found that 14 samples (46.67%) met DAMIU equipment requirements, while 16 (53.33%) did not. This finding indicates that some depots still do not meet equipment standards, particularly in sterilization systems, microfilter cleanliness, and gallon-washing processes. Further analysis revealed that 19 (63.3%) depots had Escherichia coli test results that met the requirements, while 11 (36.7%) did not. The statistical test results yielded a p-value of 0.017 ($p < 0.05$), indicating a significant difference between equipment maintenance conditions and the presence of E. coli in refillable drinking water.

Overall, the reviewed studies demonstrate that equipment sanitation and maintenance play an essential role in maintaining microbiological quality. Regular cleaning, timely replacement of filtration systems, and proper maintenance of processing equipment consistently reduced the likelihood of Escherichia coli contamination (Erni et al., 2023; Harianja et al., 2022; Rostiana, 2023). Variations in the reported strength of association may reflect differences in equipment age, maintenance frequency, replacement schedules, and compliance with operational standards among refill drinking water depots. These findings indicate that preventive maintenance programs and

periodic inspection of treatment equipment should become routine practices to ensure microbiological safety.

Discussion 4: Type of Disinfection

The type of disinfection is a critical factor in determining the microbiological quality of refillable drinking water, as the effectiveness of the treatment process depends heavily on the method used. Research results (Erni et al., 2023) show that drinking water depots in the Layang Community Health Center (Puskesmas) work area use two types of treatment: a combination of Reverse Osmosis (RO) and ultraviolet (UV) treatment, and UV treatment alone. Of the 19 depots using a combination of RO and UV, 14 (73.7%) were free of Escherichia coli contamination, while 5 (26.3%) tested positive. Meanwhile, of the 13 depots using UV alone, 10 (76.9%) were free of contamination, and 3 (23.1%) tested positive for E. coli. This indicates that both methods are effective in suppressing microbiological contamination, although their effectiveness can be affected by operational conditions and equipment maintenance. Interviews with several residents at the depots indicated that many preferred water sterilized using a combination of ultraviolet (UV) and Reverse Osmosis (RO) over water sterilized using ultraviolet (UV) alone.

Based on the results of a study (Iqbal & Ane, 2022) in Bandung City with a cross-sectional design, involving 60 drinking water depots, 30 using the Reverse Osmosis/RO method and 30 using non-RO methods, it was found that the RO method was more effective in reducing bacterial contamination. The bacterial reduction rate in the RO method reached 100%, whereas non-RO methods such as ultraviolet (UV) and ozone achieved only 43.33%. The results of the statistical analysis showed a significant difference between the two methods ($p<0.05$) for both coliform and Escherichia coli parameters. Technically, the superiority of RO lies in its ability to filter microorganisms and dissolved contaminants through a high-pressure membrane, resulting in higher-quality water. In contrast, non-RO methods such as UV and ozone function primarily as disinfectants, whose effectiveness is highly dependent on operational conditions, including irradiation intensity and contact time. Therefore, the RO method is considered superior in ensuring the microbiological quality of refilled drinking water, although it still requires additional treatment.

Overall, the reviewed evidence suggests that both ultraviolet and reverse osmosis systems help reduce microbiological contamination; however, reverse osmosis generally provides more consistent removal of microorganisms because it combines physical membrane filtration with subsequent disinfection processes (Erni et al., 2023; Iqbal & Ane, 2022). Differences in effectiveness among studies are likely influenced by operational conditions, membrane maintenance, ultraviolet intensity, contact time, and equipment performance during routine operation. These findings suggest that selecting an appropriate disinfection technology should be accompanied by regular maintenance and operational quality control to ensure consistent microbiological safety.

Conclusion

This literature review demonstrates that the microbiological quality of refilled drinking water is determined by the interaction of multiple factors, including depot sanitation, operator hygiene, equipment conditions, and disinfection methods. Among these factors, inadequate sanitation practices, poor operator hygiene, and insufficient equipment maintenance consistently emerged as major contributors to Escherichia coli and coliform contamination across the reviewed studies. In addition, Reverse Osmosis (RO) was identified as the most effective disinfection method for reducing microbiological contamination compared with ultraviolet (UV) and ozone-based systems.

The main contribution of this review is the integration of recent evidence from various studies to provide a comprehensive understanding of the determinants of microbiological quality in refill drinking water depots (DAMIU). The findings highlight that improving drinking water safety requires

not only effective treatment technology but also the consistent implementation of sanitation and hygiene practices throughout the water-processing chain.

This review is subject to several limitations. The included studies were predominantly cross-sectional in design, limiting causal interpretation. In addition, variations in study settings, sample sizes, and assessment methods may affect the comparability of findings. Future research is recommended to employ longitudinal or intervention-based approaches and to explore additional environmental and operational factors that influence microbiological water quality.

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