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Original article

Physicochemical Quality, Microbiological Contamination, and Antibiotic Susceptibility of Bacteria in Rooftop-Harvested Rainwater in Ajdabiya City, Libya

Najma Senussi[1], Miloud Miloud[2]*

[1]*Department of Botany, Faculty of Science, University of Ajdabiya, Ajdabiya, Libya*
[2]*Department of Botany, Faculty of Arts and Sciences, University of Benghazi, Benghazi, Libya*
Corresponding Email. *Miloud.elagaily@uob.edu.ly*

Abstract
Rainwater harvesting is widely used as an alternative water source in arid and semi-arid regions. However, the quality of stored rainwater may be affected by environmental contamination and storage conditions. This study assessed the physicochemical and microbiological quality of rooftop-harvested rainwater in Ajdabiya City, Libya, and evaluated the antibiotic susceptibility patterns of isolated bacteria. A total of 70 rainwater samples were collected from household storage tanks between February and May 2025. Standard analytical methods were used to evaluate physicochemical parameters, total bacterial counts, coliform detection, bacterial isolation, and antimicrobial susceptibility testing. Most physicochemical parameters complied with the World Health Organization (WHO) drinking-water guidelines. Electrical conductivity ranged from 186 to 1186 µS/cm, while total dissolved solids were generally below 500 mg/L. pH values ranged between 5.9 and 8.5, and turbidity was not detected in any sample. Microbiological results revealed bacterial counts ranging from 30 to 295 CFU/mL. Coliform bacteria were detected in the majority of samples, with only five samples free from contamination. The most frequently isolated bacteria were *Pseudomonas aeruginosa* (38.57%), *Escherichia coli* (34.28%), and *Klebsiella pneumoniae* (27.14%). Antibiotic susceptibility testing demonstrated different resistance patterns among the bacterial isolates: *E. coli* showed susceptibility only to amikacin (87%), with complete resistance to all other antibiotics tested, while *P. aeruginosa* and *K. pneumoniae* showed susceptibility to a wider range of antibiotics. The results suggest that, despite the acceptable physicochemical quality of the harvested rainwater, microbiological contamination and the detection of multidrug-resistant E. coli may limit its suitability for drinking without appropriate treatment.
Keywords. Rainwater Harvesting, Water Quality, Bacterial Isolates, Antimicrobial Resistance, Ajdabiya.

Introduction

Rainwater harvesting is widely adopted in arid and semi-arid regions as an alternative and supplementary water source, owing to its low cost, operational simplicity, and independence from centralized water infrastructure [1]. Rooftop collection systems, in particular, are simple and cost-effective; however, the quality of harvested rainwater is not solely determined by rainfall itself, but is strongly influenced by atmospheric deposition, catchment surface conditions, and storage tank management practices [1,2]. Contamination of harvested rainwater may occur through dust, atmospheric pollutants, bird droppings, and organic matter accumulating on rooftop catchment surfaces, in addition to microbial growth and biofilm development within storage tanks themselves [1]. These pathways can introduce both fecal indicator organisms and opportunistic environmental pathogens into water intended for domestic and, in many households, potable use. A substantial body of literature has documented the presence of coliform bacteria, including *Escherichia coli*, in rooftop-harvested rainwater across diverse geographical and climatic settings, indicating a recurring risk of fecal or environmental contamination rather than an isolated phenomenon [3,4].

Opportunistic environmental bacteria such as *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* have also been frequently isolated from household rainwater storage systems, further broadening the range of microorganisms of public health concern beyond the conventional coliform indicator framework [5]. Beyond microbial contamination itself, a growing body of evidence indicates that rooftop-harvested rainwater storage tanks may also serve as environmental reservoirs for antibiotic-resistant bacteria. Studies have reported multidrug-resistant *E. coli* strains recovered from household rainwater-harvesting tanks [6], as well as antibiotic-resistant *Pseudomonas* isolates from surface water and wastewater sources [7] and clinically relevant multidrug-resistant *Klebsiella pneumoniae* lineages recovered from environmental wastewater [8]. A recent global review has further emphasized that antimicrobial resistance in rooftop-harvested rainwater remains an underexplored but geographically widespread concern, with resistance to multiple antibiotic classes reported among bacterial isolates recovered from urban catchment systems [5].

According to World Health Organization (WHO) guidelines, drinking water must not contain detectable *E. coli* in any 100 mL sample, underscoring the critical importance of routine microbiological safety monitoring for any water source used for potable purposes, including harvested rainwater [9]. Despite the increasing reliance on rooftop-harvested rainwater in Libya, particularly in regions with limited access to reliable piped water supply, data on its microbiological quality, bacterial contamination profile, and antimicrobial resistance patterns remain scarce. Information concerning the quality of harvested rainwater in Ajdabiya City specifically is, to the best of our knowledge, absent from the published literature. This gap is of particular concern given that stored rainwater in this setting is commonly used by households for drinking and cooking without prior treatment. Therefore, this study was conducted to assess the physicochemical and microbiological characteristics of rooftop-harvested rainwater collected from household storage tanks in Ajdabiya City and to evaluate the antibiotic susceptibility profiles of the bacterial species isolated. This study aimed to (i) evaluate the physicochemical and microbiological quality of rooftop-harvested rainwater in Ajdabiya City, and (ii) determine the antibiotic susceptibility

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patterns of the isolated bacterial species, in order to inform public health guidance on the safe use of this increasingly relied-upon water source.

Methods

Study Area and Sample Collection Design

This study was conducted in Ajdabiya City, Libya, to evaluate the physicochemical quality, microbiological contamination, and antibiotic susceptibility of bacteria isolated from rooftop-harvested rainwater. A total of 70 water samples were randomly collected from residential rooftop storage tanks between February and May 2025, following the end of the rainy season, with sampling conducted in intermittent batches over this period. Households were selected using a simple random sampling procedure across different neighborhoods of Ajdabiya City to ensure reasonable spatial representativeness of the study population. One sample was collected per tank (n = 70).

Culture Media

Bacteriological analyses were performed using selective and non-selective culture media. Nutrient Agar, MacConkey Agar, MacConkey Broth, Lactose Broth, and Eosin Methylene Blue (EMB) Agar were obtained from Condalab (Spain), whereas Blood Agar and Mueller–Hinton Agar were obtained from Liofilchem (Italy). Nutrient Agar was used for total viable bacterial counts and purification of bacterial isolates. MacConkey Agar and MacConkey Broth were used for the isolation of Gram-negative bacteria and differentiation of lactose-fermenting and non-lactose-fermenting isolates. Lactose Broth was used for the presumptive coliform test, while EMB Agar was used for confirmation of *Escherichia coli* and other coliform bacteria. Blood Agar was used for the isolation and preliminary characterization of bacterial isolates. Antibiotic susceptibility testing was performed on Mueller–Hinton Agar.

Staining Reagents

Gram staining was performed using Gentian Violet as the primary stain, Iodine as the mordant, Ethyl Alcohol as the decolorizing agent, and Safranin as the counterstain. Methylene Blue was used as a simple stain when required to examine the morphology of bacterial cells.

Chemical Reagents

All chemical reagents used in the physicochemical analyses were selected according to the specific parameter under investigation and are detailed individually under the corresponding analytical procedures in Section 2.4.

Antibiotic Disks

Antibiotic susceptibility testing was performed using nine standard commercial antibiotic disks (Liofilchem, Italy), as summarized in (Table 1).

Table 1. Antibiotics used for susceptibility testing

No.	Antibiotic	Abbreviation	Manufacturer	Concentration (µg/disc)
1	Amikacin	AK	Liofilchem	30
2	Gentamicin	GN	Liofilchem	10
3	Tobramycin	TOB	Liofilchem	10
4	Levofloxacin	LEV	Liofilchem	5
5	Norfloxacin	NOR	Liofilchem	10
6	Amoxicillin-Clavulanic acid	AMC	Liofilchem	30
7	Imipenem	IPM	Liofilchem	10
8	Meropenem	MEM	Liofilchem	10
9	Trimethoprim/Sulfamethoxazole	SXT	Liofilchem	25

Sample Collection Procedure

Sample containers were selected according to the type of analysis to be performed, in accordance with WHO guidelines [9] for drinking-water quality sampling. Bacteriological samples were collected in sterile 250 mL glass bottles (Pyrex, England). Prior to sterilization, 1 mL of sodium thiosulfate solution was added to each bottle to neutralize residual chlorine; bottles were then sealed and sterilized by dry-heat oven sterilization and stored under refrigeration until use. At the sampling site, the bottle neck was wrapped in sterile cloth, the bottle was submerged fully into the storage tank, filled, resealed aseptically, and immediately placed in a cooling box at 4°C without the addition of preservatives, then transported to the laboratory for analysis. Physicochemical samples were collected in sterilized 2-liter containers. pH was measured in situ at the time of collection, while all other chemical parameters were analyzed upon arrival at the laboratory to assess compliance with WHO drinking-water quality standards [9].

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Physicochemical Analysis

Physicochemical parameters of the collected water samples were determined using standard analytical methods, reagents, and instruments specified for each parameter, as summarized in Table 2. To assess compliance and water quality safety, all analytical results were benchmarked against the World Health Organization (WHO) guidelines for drinking-water quality [9].

Table 2. Physicochemical analysis methods, reagents, and instruments

Parameter	Method / Reagents	Instrument
Taste and Odor	Sensory evaluation by trained personnel	—
Color	Comparison with standard potassium chloroplatinate/cobalt-potassium dichromate dilutions	Hellige Comparator (Fisher Scientific, USA)
Turbidity	Nephelometric method	Turbidity Spectrophotometer (HACH, USA)
pH	Electrometric method	pH-meter (WTW, Germany)
Electrical Conductivity	Electrometric method	EC-meter (WTW, Germany)
Total Dissolved Solids	Gravimetric/electrometric method	Digital TDS-meter (WTW, Germany)
Nitrate (NO_3^-)	Brucine–sulfuric acid colorimetric method	Lovibond Comparator (Tintometer Ltd, England)
Nitrite (NO_2^-)	Sulphanilic acid / α-naphthylamine / sodium acetate colorimetric method	Beckman photometer
Ammonia (NH_3)	Nessler method (zinc sulphate, sodium arsenite, sodium hydroxide, Rochelle salt)	Hellige Comparator
Chloride	Argentometric titration (silver nitrate, potassium chromate indicator)	—
Residual Chlorine	Ortho-tolidine colorimetric method	Lovibond Comparator
Calcium	EDTA titration (0.01 M), sodium hydroxide buffer, Murexide indicator	—
Magnesium / Total Hardness	EDTA titration (0.01 M), ammonia/ammonium chloride buffer, Eriochrome Black T indicator	—
Iron	Hydroxylamine / ortho-phenanthroline colorimetric method	Beckman photometer
Carbonate / Bicarbonate	Acid–base titration (phenolphthalein and methyl orange indicators, sulphuric acid titrant)	—
Silica	Ammonium molybdate colorimetric method (ammonium hydroxide, calcium chloride, hydrochloric acid)	Hellige Comparator

Microbiological Analysis

Microbiological examination aimed to detect fecal/sewage contamination indicators and to enumerate and identify culturable bacteria, in accordance with standard water quality assessment protocols [9], and comprised two components: coliform bacteria testing and total plate count.

Coliform Bacteria Test

The presence of the coliform group, including *E. coli*, used as the primary fecal contamination indicator, was assessed through a standard three-stage procedure based on lactose fermentation with acid and gas production [9]. a) Presumptive Test: Nine tubes of lactose broth or MacConkey broth (Condalab, Spain) were inoculated per sample: three tubes of double-strength broth inoculated with 10 mL of sample, three tubes of single-strength broth inoculated with 1.0 mL of sample, and three tubes of single-strength broth inoculated with 0.1 mL of sample. Tubes were incubated at 37°C and examined at 24 and 48 hours; gas production within 24 hours was recorded as positive, while gas production only after 48 hours was considered doubtful/negative. The number of positive tubes at each dilution was used to determine the Most Probable Number (MPN) of total coliforms per 100 mL using standard MPN tables [9]. b) Confirmed Test: A loopful from each positive or doubtful presumptive tube was streaked onto Eosin Methylene Blue (EMB) Agar and incubated at 37°C for 24–48 hours. Colonies exhibiting a characteristic greenish metallic sheen were recorded as presumptive *E. coli*. c) Completed Test: Colonies from positive EMB plates were sub-cultured onto lactose broth and a nutrient agar slant and incubated at 37°C. Gas production in the lactose broth combined with Gram-negative bacilli on the agar slant confirmed the presence of the coliform group.

Total Plate Count (TPC)

Total viable bacterial counts were determined by the streak plate method on Nutrient Agar (Biotec, England). Approximately 0.03 mL of each water sample was streaked in triplicate, and plates were incubated at 37°C for 24 hours. Colonies were

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enumerated using a colony counter (Gallenkamp, England); only plates yielding between 30 and 300 colonies were considered valid, and results were expressed as the mean colony-forming units per milliliter (CFU/mL) [10].

Isolation and Identification of Bacterial Species

Following presumptive and confirmatory coliform testing, bacterial isolates were streaked onto MacConkey Agar and Blood Agar to differentiate colonies based on morphology, pigmentation, and lactose fermentation ability. Lactose-fermenting isolates producing a characteristic greenish metallic sheen on Eosin Methylene Blue (EMB) Agar were presumptively identified as *E. coli*, while large, mucoid, pink lactose-fermenting colonies lacking the metallic sheen were presumptively identified as K. pneumoniae. Non-lactose-fermenting isolates recovered on Blood Agar, showing flat, irregular colonies with a characteristic blue-green diffusible pigment (pyocyanin), were presumptively identified as *P. aeruginosa*. Pure isolates were sub-cultured onto nutrient agar slants and maintained at 4°C for confirmatory testing. Gram staining was performed to confirm cell morphology and Gram reaction. Species-level identification was subsequently confirmed using the following biochemical tests, performed according to [11]: Catalase Test: A loopful of the bacterial isolate was placed on a glass slide and mixed with a drop of 3% hydrogen peroxide (H_2O_2). The evolution of oxygen bubbles indicated a positive result, while their absence indicated a negative result. Oxidase Test: A loopful of the bacterial isolate was applied to filter paper impregnated with Tetramethyl-p-phenylenediamine dihydrochloride reagent. A color change to purple within 10 seconds indicated a positive result; no color change was recorded as negative. Indole Test: Isolates were inoculated into tryptone water medium and incubated at 37°C for 24 hours. Following incubation, 0.5 mL of Kovacs reagent (Liofilchem, Italy) was added. Formation of a red ring at the surface indicated a positive result, while no color change indicated a negative result. Citrate Utilization Test: Isolates were inoculated onto Simmons Citrate Agar slants (Liofilchem, Italy) and incubated at 37°C for 24 hours. A change in medium color from green to blue indicated a positive result (citrate utilization), while no color change indicated a negative result. Actual biochemical identification results for the recovered isolates are presented in Section 3.2.4 (Table 6).

Antibiotic Susceptibility Testing

Antibiotic susceptibility of Gram-negative bacterial isolates (*E. coli, P. aeruginosa, and K. pneumoniae*) was determined using the disk diffusion method [12] on Mueller-Hinton Agar. Bacterial suspensions from overnight cultures were standardized to 0.5 McFarland (1.5×10^8 CFU/mL) according to CLSI guidelines [13], and the medium was inoculated with the standardized suspension. Nine antibiotics were tested (Table 1) following standard procedures, and plates were incubated at 37°C for 24 hours. After incubation, inhibition zone diameters were measured; to ensure measurement consistency, each zone was measured twice in perpendicular directions, and the mean value was recorded. All experiments were performed in triplicate [14]. Drug susceptibility patterns were examined and interpreted according to CLSI guidelines [15]. Quality control was performed using reference strains *Escherichia coli ATCC 25922* and *Pseudomonas aeruginosa ATCC 27853*, with the former also serving as a general quality control reference for the *K. pneumoniae isolates*, given their shared classification within the family Enterobacteriaceae [15].

Results

Physicochemical Characteristics

All collected rainwater samples showed acceptable organoleptic properties, with no noticeable differences in taste or odor. Color values were within the acceptable limit (≤5 CU), and no turbidity was detected in any of the analyzed samples. The physicochemical characteristics of the collected rainwater samples are presented in (Table 3).

Table 3. Physicochemical characteristics of rooftop-harvested rainwater samples (n = 70)

Parameter	Result
Taste	Acceptable in all samples
Odor	Acceptable in all samples
Color (CU)	≤5 in all samples
Turbidity (NTU)	Not detected
pH	5.9 – 8.5
Electrical Conductivity (µS/cm)	186 – 1186 (1 sample >1000)
Total Dissolved Solids (mg/L)	≤500 in 69 samples; 780 in 1 sample
Nitrate (mg/L)	2.2 – 13.2
Nitrite (mg/L)	Not detected
Ammonia (mg/L)	0.06 – 0.65
Chloride (mg/L)	6.38 – 85.08 (66 samples); >100 (4 samples)
Calcium (mg/L)	5.61 – 48.98 (64 samples ≤40; 6 samples higher)
Magnesium (mg/L)	60.75 – 99.84 (60 samples); ≤60.75 (10 samples)
Bicarbonate (mg/L)	61 – 400
Carbonate (mg/L)	Not detected in 55 samples; ≤36 mg/L in 15 samples
Silica (mg/L)	Not detected in 4 samples; 2 – 20 mg/L in 66 samples

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Iron (mg/L)	Not detected
Total Hardness (mg/L)	200 – 450
Residual Chlorine (mg/L)	Not detected

Electrical conductivity (EC) ranged from 186 to 1186 µS/cm, with only one sample exceeding 1000 µS/cm. Total dissolved solids (TDS) were below 500 mg/L in 69 samples, whereas one sample recorded 780 mg/L. The pH values ranged from 5.9 to 8.5. Nitrate concentrations ranged from 2.2 to 13.2 mg/L, whereas nitrite was not detected in any sample. Ammonia concentrations ranged from 0.06 to 0.65 mg/L. Chloride concentrations ranged from 6.38 to 85.08 mg/L in 66 samples, while four samples contained more than 100 mg/L. Calcium and magnesium concentrations varied among samples, whereas bicarbonate, carbonate, and silica were detected at relatively low concentrations. Iron and residual chlorine were not detected in any sample. Total hardness ranged from 200 to 450 mg/L.

Bacterial Examination

Total Bacterial Count

Total viable bacterial counts ranged from 30 to 295 CFU/mL among the 70 rainwater samples analyzed. The microbiological characteristics of the collected samples are summarized in (Table 4).

Table 4. Microbiological quality of rooftop-harvested rainwater samples (n = 70)

Parameter	Result
Total bacterial count (CFU/mL)	30-295 CFU/mL
Coliform detection	Detected in 65/70 samples
Coliform-free samples	5/70 samples

Bacterial Isolation and Distribution

A total of 70 bacterial isolates were recovered from the 70 rainwater samples and identified as three bacterial species, as presented in (Table 5).

Table 5. Bacterial isolate distribution in rooftop harvested rainwater samples (n = 70)

Bacterial species	Frequency (n)	Percentage (%)
P. aeruginosa	27	38.57
E. coli	24	34.28
K. pneumoniae	19	27.14
Total	70	100%

Coliform Bacteria Detection

The Most Probable Number (MPN) method using the multiple-tube fermentation technique was used for the detection of coliform bacteria. Coliforms were detected in 65 of the 70 analyzed samples, whereas no coliform bacteria were detected in the remaining five samples (MPN = 0).

Biochemical Identification of Bacterial Isolates

The recovered bacterial isolates were identified based on Gram staining and biochemical tests, including catalase, oxidase, indole, and citrate utilization tests. The results are presented in (Table 6).

Table 6. Biochemical characteristics of bacterial isolates identified from rainwater samples

Bacterial isolates	Gram stain	Catalase	Oxidase	Indole	Citrate utilization
E. coli	-	+	-	+	-
K. pneumoniae	-	+	-	-	+
P. aeruginosa	-	+	+	-	+

Note: + = positive reaction; – = negative reaction

All identified isolates were Gram-negative bacilli and catalase-positive. *E. coli* showed a positive indole reaction and negative citrate utilization, whereas K. pneumoniae showed a negative indole reaction and positive citrate utilization. *P. aeruginosa* was characterized by a positive oxidase reaction, which differentiated it from the other oxidase-negative isolates.

Antibiotic Susceptibility Patterns of Bacterial Isolates

The antibiotic susceptibility patterns of the identified bacterial isolates are presented in Table 7. *E. coli* isolates showed susceptibility only to amikacin (AK, 87%), while all isolates were resistant to the other tested antibiotics, including meropenem (MEM), imipenem (IPM), levofloxacin (LEV), tobramycin (TOB), trimethoprim-sulfamethoxazole (SXT), gentamicin (GN), norfloxacin (NOR), and amoxicillin-clavulanate (AMC). *P. aeruginosa* isolates showed the highest susceptibility rates to gentamicin (GN, 81%) and tobramycin (TOB, 70%), followed by amikacin (AK, 55%). Lower

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susceptibility rates were observed for norfloxacin (NOR, 48%) and levofloxacin (LEV, 44%). All isolates were resistant to meropenem (MEM), imipenem (IPM), trimethoprim-sulfamethoxazole (SXT), and amoxicillin-clavulanate (AMC). *K. pneumoniae* isolates showed susceptibility rates of 84% to amikacin (AK), trimethoprim-sulfamethoxazole (SXT), amoxicillin-clavulanate (AMC), and imipenem (IPM). Susceptibility was also observed for gentamicin (GN, 78%), meropenem (MEM, 73%), and levofloxacin (LEV, 63%), whereas tobramycin (TOB) showed a lower susceptibility rate (57%). All isolates were resistant to norfloxacin (NOR).

Table 7. Antibiotic susceptibility profile of bacterial isolates (% susceptible)

Bacterial isolate	**AK** 30µg	**MEM** 10µg	**IPM** 10µg	**LEV** 5µg	**TOB** 10µg	**SXT** 25µg	**GN** 10µg	**NOR** 10µg	**AMC** 30µg
E. coli	87	R	R	R	R	R	R	R	R
P. aeruginosa	55	R	R	44	70	R	81	48	R
K. pneumoniae	84	73	84	63	57	84	78	R	84

R = Resistant. Values indicate the percentage of susceptible isolates.

Discussion

The physicochemical characteristics of the rooftop-harvested rainwater samples were generally within the acceptable limits for drinking water. All samples had acceptable taste, odor, and color, and turbidity was not detected, indicating good physical water quality. The pH values ranged from 5.9 to 8.5, which are largely consistent with the range recommended for drinking water. The slightly acidic values observed in some samples may be related to atmospheric wet deposition before contact with rooftop catchment surfaces [2]. Electrical conductivity and total dissolved solids exceeded the recommended limits in only one sample, suggesting localized variations rather than widespread contamination. Similarly, chloride concentrations exceeded 100 mg/L in four samples, an elevation that may be attributable to the proximity of Ajdabiya City to the Mediterranean coast (approximately 6 km inland), where wind-driven marine aerosol deposition on rooftop catchment surfaces can introduce additional chloride into harvested rainwater, an effect potentially amplified by evaporative concentration during prolonged storage under the region's arid climatic conditions. Total hardness ranged from 200 to 450 mg/L, indicating relatively high hardness levels, which may be associated with the geological characteristics of the study area and the deposition of calcium- and magnesium-containing dust on rooftop catchment surfaces. Ammonia was detected in 56 of the 70 samples, whereas nitrite was not detected. This finding may indicate recent organic inputs, possibly originating from bird droppings, dust, or organic debris accumulated on rooftop surfaces before rainfall. Similar observations have been reported in previous studies investigating rooftop-harvested rainwater quality.

The detection of coliform bacteria in 65 of 70 samples (92.9%) indicates a high level of microbiological contamination in rooftop-harvested rainwater storage systems in the study area. This finding agrees with previous studies on rooftop-harvested rainwater, which have reported that contamination of catchment surfaces, storage conditions, and lack of regular disinfection are important factors affecting microbial quality [3,4]. The isolation of *P. aeruginosa*, *E. coli*, and *K. pneumoniae* highlights the presence of both indicator organisms and opportunistic bacterial species in stored rainwater. The detection of *P. aeruginosa* is particularly relevant because this bacterium is widely distributed in aquatic environments and can survive under nutrient-limited conditions, including household water storage systems.

The antibiotic susceptibility profiles differed among the three bacterial species isolated in this study. *E. coli* isolates showed the highest level of resistance, with susceptibility detected only to amikacin (87%), while resistance was observed against the remaining tested antibiotics, including meropenem, imipenem, levofloxacin, and norfloxacin. The presence of multidrug-resistant *E. coli* in household rainwater storage tanks has also been reported in previous studies, indicating that harvested rainwater may serve as a potential source of antibiotic-resistant bacteria, particularly when used without treatment [6]. Similarly, previous investigations of rooftop-harvested rainwater have reported resistance to multiple antibiotic groups among bacterial isolates recovered from storage systems [5]. *P. aeruginosa* isolates showed higher susceptibility to gentamicin (GN, 81%) and tobramycin (TOB, 70%), which agrees with previous reports describing relatively good activity of aminoglycosides against environmental *P. aeruginosa* isolates [7]. However, resistance to MEM, IPM, SXT, and AMC was observed among the isolates in this study. *K. pneumoniae* showed a comparatively broader susceptibility pattern, with susceptibility rates ≥84% for several tested antibiotics, whereas resistance was mainly observed against NOR. Although this profile was less resistant than that of *E. coli*, the detection of fluoroquinolone resistance remains important due to the increasing occurrence of resistant *K. pneumoniae* strains in environmental and clinical settings [8]. Overall, the findings indicate that rooftop-harvested rainwater stored in household tanks in Ajdabiya City may represent a potential environmental source of antibiotic-resistant Gram-negative bacteria. The detection of multidrug-resistant isolates, particularly *E. coli*, highlights the importance of appropriate treatment and regular microbiological monitoring before using harvested rainwater for drinking purposes.

Conclusion

This study showed that rooftop-harvested rainwater collected from household storage tanks in Ajdabiya City had generally acceptable physicochemical characteristics; however, microbiological contamination was detected in most samples.

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Coliform bacteria were detected in 65 of 70 samples (92.9%), and three bacterial species were identified: *P. aeruginosa*, *E. coli*, and *K. pneumoniae*. Among the isolated bacteria, *E. coli* showed the highest level of antibiotic resistance, with susceptibility observed only to amikacin. These findings suggest that untreated stored rainwater may not be suitable for direct drinking or cooking purposes due to the presence of bacterial contamination and antibiotic-resistant isolates. Regular microbiological monitoring, proper cleaning and disinfection of storage tanks, and awareness regarding safe rainwater use are recommended. Further studies using molecular identification methods and resistance gene analysis are needed to investigate the sources and characteristics of antibiotic-resistant bacteria in household rainwater harvesting systems.

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Conflicts of Interest
The authors declare no conflicts of interest.

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