Antibiotic Resistance Profile of Waterborne Bacterial Isolates from Drinking Water Sources.

Abstract

Background: Microbial contamination of drinking water remains a significant public health concern, particularly in developing regions. In addition to contamination, the emergence of antibiotic resistance among environmental bacterial isolates has raised serious concerns regarding the potential transmission of resistant pathogens through water sources.

Methods:A total of 246 drinking water samples were collected from urban and rural areas of Moradabad district and nearby regions. Standard culture-based techniques were used to isolate bacteria, followed by identification using conventional microbiological methods. Antibiotic susceptibility testing of 100 culture-positive isolates was performed using the Kirby–Bauer disc diffusion method against commonly used antibiotics.

Results: Out of 246 samples, 100 (40.7%) showed bacterial growth. The majority of isolates demonstrated good sensitivity to gentamicin, ciprofloxacin, and imipenem. Moderate resistance was observed against ampicillin (30.0%) and tetracycline (30.0%). Isolates from rural areas and untreated water sources exhibited relatively higher resistance compared to urban and treated sources. Organism-wise analysis revealed that Escherichia coli showed comparatively higher resistance, while Vibrio spp. remained largely sensitive.

Conclusion: The study highlights the presence of antibiotic-resistant bacteria in drinking water sources, although overall susceptibility patterns remain favorable. Continuous monitoring of water quality and rational antibiotic use are essential to prevent the emergence and spread of resistance in environmental settings.

Keywords: Drinking water, Antibiotic resistance, Waterborne bacteria, Escherichia coli, Water quality.

Highlights

- A considerable proportion (40.7%) of drinking water samples showed bacterial contamination, indicating potential public health risk.
- Antibiotic susceptibility testing revealed overall good sensitivity, with moderate resistance observed against commonly used antibiotics such as ampicillin and tetracycline.
- Higher resistance patterns were observed in isolates from rural areas and untreated water sources compared to urban and treated sources.
- Escherichia coli demonstrated relatively higher resistance among isolates, while Vibrio spp. remained largely sensitive to most antibiotics.

Background

In recent years, increasing attention has been directed toward the emergence of antibiotic resistance among environmental bacterial isolates(1). Traditionally, antibiotic resistance has been associated with clinical settings; however, environmental reservoirs such as water sources are now recognized as important contributors to the dissemination of resistant bacteria(2). Drinking water, especially when inadequately treated or improperly stored, can harbor bacteria that have been exposed to antibiotics through human, agricultural, and industrial activities, thereby facilitating the selection and persistence of resistant strains(3). The occurrence of antibiotic-resistant bacteria in drinking water is of particular concern because it poses a dual threat: it increases the risk of infection and limits the effectiveness of commonly used antimicrobial therapies(4). Moreover, these bacteria can act as reservoirs of resistance genes, which may be transferred to other pathogenic organisms, further amplifying the public health burden(5). Rural areas and regions with limited water treatment infrastructure are especially vulnerable, although contamination can also occur in urban and even packaged water sources(6). Given these concerns, evaluating the antibiotic resistance patterns of bacterial isolates from drinking water sources is essential for understanding the extent of the problem and for guiding appropriate public health interventions. Such assessments provide valuable insights into local resistance trends, help in identifying potential risks to human health, and support the development of strategies for improving water quality and antimicrobial stewardship.

Material and Methods

The present cross-sectional laboratory-based study was conducted in Moradabad district, Uttar Pradesh, India, utilizing bacterial isolates obtained from previously analyzed drinking water samples. A total of 100 culture-positive isolates recovered from 246 samples collected from both urban and rural areas, including sources such as well water, municipal tap water, rainwater harvesting systems, and bottled water, were included for antibiotic susceptibility analysis. All procedures were carried out in the Department of Microbiology, College of Paramedical Sciences, Teerthanker Mahaveer University, Moradabad. Pure isolates were obtained through subculturing and confirmed by standard microbiological and biochemical methods prior to testing. Antibiotic susceptibility testing was performed using the Kirby–Bauer disc diffusion method on Mueller–Hinton agar, with inoculum standardized to 0.5 McFarland turbidity. The antibiotics tested included ampicillin, ciprofloxacin, ceftriaxone, gentamicin, tetracycline, and imipenem. Plates were incubated at 37°C for 18–24 hours, and zones of inhibition were measured and interpreted as sensitive, intermediate, or resistant according to standard guidelines. All procedures were conducted under aseptic conditions with appropriate quality control measures, and the resulting data were analyzed using descriptive statistics, with findings expressed in terms of frequency and percentage.

Result

A total of 246 drinking water samples collected from urban and rural areas of Moradabad district and nearby regions were analyzed, Out of 246 samples, 100 (40.7%) showed bacterial growth, while 146 (59.3%) showed no growth.

Overall antibiotic susceptibility pattern

The majority of isolates demonstrated good sensitivity to most of the antibiotics tested. However, moderate resistance was observed against ampicillin and tetracycline. Higher sensitivity was noted for gentamicin, ciprofloxacin, and imipenem (Table 1).

Table 1. Overall antibiotic susceptibility pattern of isolates (n=100)

Antibiotic	Sensitive n (%)	Intermediate n (%)	Resistant n (%)
Ampicillin	52 (52.0)	18 (18.0)	30 (30.0)
Tetracycline	58 (58.0)	12 (12.0)	30 (30.0)
Ceftriaxone	64 (64.0)	10 (10.0)	26 (26.0)
Ciprofloxacin	78 (78.0)	8 (8.0)	14 (14.0)
Gentamicin	82 (82.0)	6 (6.0)	12 (12.0)
Imipenem	94 (94.0)	3 (3.0)	3 (3.0)

Values expressed as number and percentage of total isolates tested.

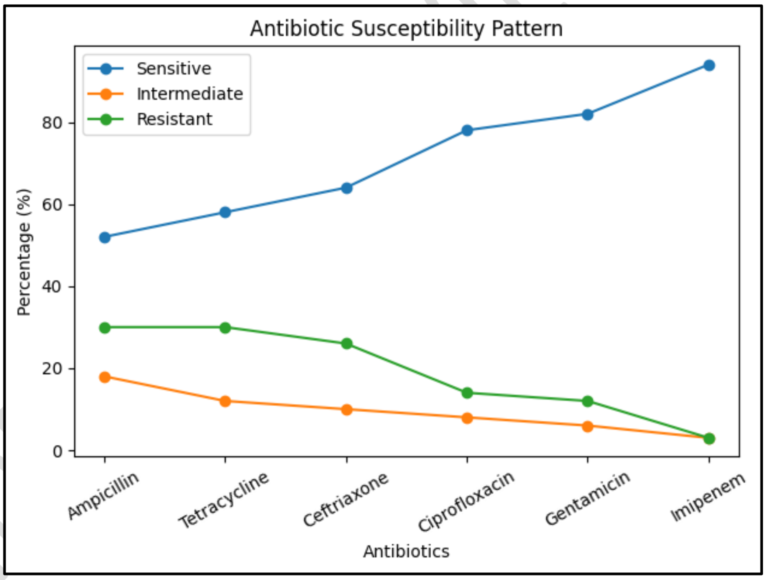

Figure 1. Antibiotic susceptibility pattern of bacterial isolates from drinking water sources.

Antibiotic susceptibility according to geographical area

When analyzed based on geographical distribution, isolates from rural areas showed slightly higher resistance compared to urban isolates, although the overall susceptibility pattern remained similar across both groups. Ampicillin resistance was more common in rural samples, while urban isolates showed comparatively higher sensitivity to most antibiotics (Table 2).

Table 2. Antibiotic resistance pattern according to geographical area

Antibiotic	Rural Resistant n (%)	Urban Resistant n (%)
Ampicillin	22 (32.4)	8 (25.0)
Tetracycline	21 (30.9)	9 (28.1)
Ceftriaxone	18 (26.5)	8 (25.0)
Ciprofloxacin	10 (14.7)	4 (12.5)
Gentamicin	9 (13.2)	3 (9.4)
Imipenem	2 (2.9)	1 (3.1)

Values expressed as number and percentage of total isolates tested.Percentages calculated within each group.

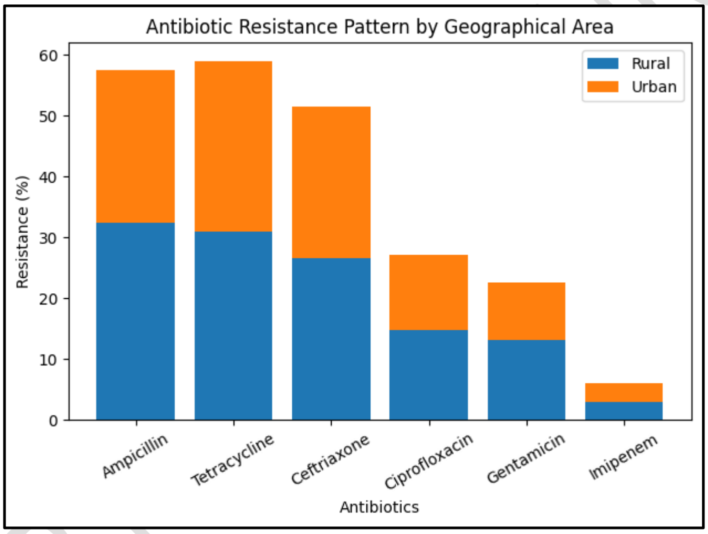

Figure 2. Antibiotic resistance pattern of bacterial isolates according to geographical area.

Antibiotic susceptibility according to water source

Variations in antibiotic resistance were observed among isolates from different water sources. Isolates from well water and rainwater harvesting systems showed relatively higher resistance compared to municipal tap water and bottled water. Bottled water isolates demonstrated the highest sensitivity across all antibiotics tested (Table 3).

Table 3. Antibiotic resistance pattern according to water source (percentage resistant)

Antibiotic	Well water (%)	Rainwater (%)	Tap water (%)	Bottled water (%)
Ampicillin	35.0	32.1	22.5	12.5

Tetracycline	33.3	30.0	20.0	10.0
Ceftriaxone	28.3	26.7	18.0	8.3
Ciprofloxacin	16.7	15.0	10.0	5.0
Gentamicin	15.0	13.3	8.0	3.0
Imipenem	3.3	2.5	2.0	0.0

Values expressed as number and percentage of total isolates tested.

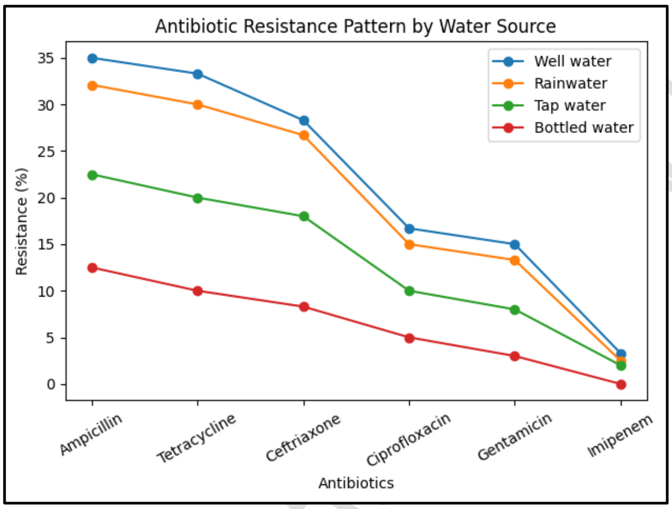

Figure 3. Antibiotic resistance pattern of bacterial isolates according to water source.

Organism-wise antibiotic susceptibility pattern

Among the identified isolates, Escherichia coli showed moderate resistance to ampicillin and tetracycline, while maintaining good sensitivity to ciprofloxacin, gentamicin, and imipenem. Salmonella spp. and Shigella spp. demonstrated similar susceptibility patterns, with relatively lower resistance levels. Vibrio spp. isolates were largely sensitive to most of the antibiotics tested, with only minimal resistance observed Table 4.

Table 4. Organism-wise antibiotic susceptibility pattern (n, %)

Organism	**Antibiotic**	**Sensitive n (%)**	**Intermediate n (%)**	**Resistant n (%)**
Escherichia coli (n=41)	Ampicillin	21 (51.2)	7 (17.1)	13 (31.7)
	Tetracycline	22 (53.7)	6 (14.6)	13 (31.7)
	Ceftriaxone	25 (61.0)	5 (12.2)	11 (26.8)
	Ciprofloxacin	31 (75.6)	4 (9.8)	6 (14.6)

	Gentamicin	33 (80.5)	3 (7.3)	5 (12.2)
	Imipenem	39 (95.1)	1 (2.4)	1 (2.4)
Salmonella spp. (n=18)	Ampicillin	10 (55.6)	3 (16.7)	5 (27.8)
	Tetracycline	11 (61.1)	2 (11.1)	5 (27.8)
	Ceftriaxone	12 (66.7)	2 (11.1)	4 (22.2)
	Ciprofloxacin	14 (77.8)	2 (11.1)	2 (11.1)
	Gentamicin	15 (83.3)	1 (5.6)	2 (11.1)
	Imipenem	17 (94.4)	1 (5.6)	0 (0.0)
Shigella spp. (n=12)	Ampicillin	7 (58.3)	2 (16.7)	3 (25.0)
	Tetracycline	8 (66.7)	1 (8.3)	3 (25.0)
	Ceftriaxone	8 (66.7)	2 (16.7)	2 (16.7)
	Ciprofloxacin	10 (83.3)	1 (8.3)	1 (8.3)
	Gentamicin	10 (83.3)	1 (8.3)	1 (8.3)
	Imipenem	11 (91.7)	1 (8.3)	0 (0.0)
Vibrio spp. (n=9)	Ampicillin	6 (66.7)	1 (11.1)	2 (22.2)
	Tetracycline	7 (77.8)	1 (11.1)	1 (11.1)
	Ceftriaxone	7 (77.8)	1 (11.1)	1 (11.1)
	Ciprofloxacin	8 (88.9)	1 (11.1)	0 (0.0)
	Gentamicin	8 (88.9)	1 (11.1)	0 (0.0)
	Imipenem	9 (100)	0 (0.0)	0 (0.0)

Values expressed as number and percentage of total isolates tested.

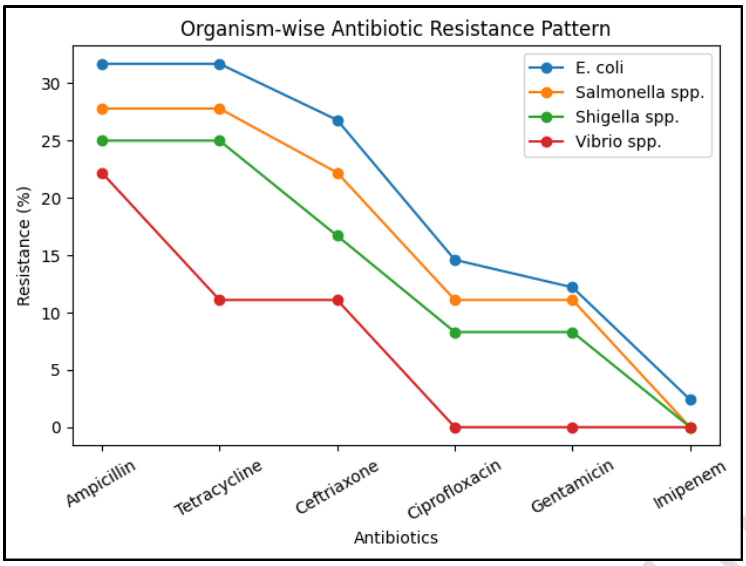

Figure 4. Organism-wise antibiotic resistance pattern of bacterial isolates from drinking water sources.

Discussion

The present study demonstrated that 40.7% of drinking water samples showed bacterial contamination, indicating a substantial burden of microbiological pollution in the study area. These findings are consistent with recent studies conducted in low- and middle-income countries, where unsafe water sources remain a major contributor to the transmission of waterborne pathogens. **Quansah et al (2025)**conducted in Ghana reported significant contamination of untreated water sources, particularly well and surface water, with Escherichia coli and other enteric bacteria (7). Similar observations have been highlighted in**Maurya et al (2025)** contemporary reviews, which emphasize that drinking water systems, especially untreated or poorly managed sources, act as important reservoirs for microbial contamination and antibiotic resistance (8).In the present study, the majority of isolates demonstrated good sensitivity to antibiotics such as gentamicin, ciprofloxacin, and imipenem, whereas moderate resistance was observed against ampicillin and tetracycline. This pattern agrees with recent reports indicating that older and commonly used antibiotics tend to show higher resistance due to their widespread and often indiscriminate use. For instance, **Ahmed et al (2022)** have shown that environmental isolates of E. coli from drinking water frequently exhibit resistance to commonly used antibiotics, while retaining susceptibility to higher-generation drugs(9). The continued effectiveness of drugs such as imipenem and gentamicin in the present study may be attributed to their restricted use and limited environmental exposure(10).The slightly higher resistance observed among isolates from rural areas in the present study aligns with **Purohit et al (2017)**, which report increased microbial contamination and resistance patterns in regions with inadequate sanitation and water treatment facilities(11). **Pandey et al (2014)**have demonstrated that rural and untreated water sources are more prone to contamination and may facilitate the persistence and dissemination of antibiotic-resistant bacteria due to environmental exposure and lack of proper infrastructure (12). Furthermore, environmental factors such as agricultural runoff, improper waste disposal, and antibiotic usage in livestock have been identified as key contributors to the development and spread of resistance in water systems (13).Source-wise analysis in the present study revealed higher resistance among isolates from well water and rainwater harvesting systems, whereas municipal tap water and bottled water showed comparatively lower resistance levels. These findings are consistent with **Abebe et al (2024)**, which have reported that treated water sources generally exhibit lower microbial contamination and resistance due to effective filtration and disinfection processes(14). In contrast, untreated sources remain vulnerable to contamination and act as reservoirs for resistant organisms .Organism-wise analysis showed that Escherichia coli exhibited moderate resistance to ampicillin and tetracycline, while Salmonella spp. and Shigella spp. demonstrated relatively lower resistance levels. Vibrio spp. isolates were largely sensitive to most antibiotics tested. These findings are comparable with recent studies where E. coli has been identified as a key indicator organism showing higher resistance due to its widespread presence and adaptability in diverse environmental conditions **Quansah et al (2025)**(7). Additionally, several studies have emphasized that environmental E. coli strains serve as important indicators for monitoring antibiotic resistance trends in water sources.

Conclusion

The present study demonstrates that drinking water sources in the study area are moderately contaminated with bacterial pathogens, with a subset exhibiting resistance to commonly used antibiotics. Although the overall susceptibility pattern remains favorable, the presence of resistance, particularly to ampicillin and tetracycline, indicates emerging environmental pressure likely associated with widespread antibiotic use. Higher resistance observed in rural and untreated water sources further emphasizes the role of environmental and infrastructural factors in shaping resistance patterns. These findings underscore the need for regular surveillance of drinking water quality, improvement in water treatment and sanitation practices, and promotion of rational antibiotic usage to minimize the risk of dissemination of resistant bacteria through environmental pathways.

Declarations:

- **Ethical Approval:** Not Applicable
- **Informed Consent:** Informed consent was obtained where applicable.
- **Conflict of Interest:** The authors declare no conflict of interest.
- **Funding:** The authors received no external funding for this study.
- **Data Availability:** Data supporting the findings of this study are available from the corresponding author upon reasonable request.
- **Author Contributions:** SB, conceptualized the study, conducted laboratory analysis, performed data interpretation, and drafted the manuscript. MF, supervised the research work, contributed to study design, critically revised the manuscript, and approved the final version for publication.

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