Trends in Antibiotic Resistance Among Bacterial Isolates from Diverse Water Samples Across Dhaka city, Bangladesh

Humayra Zaman Himi[1], Sanjida Chowdhury Ivy[1], Samsunnahar Begum[1], Mohiuddin Ahmed Bhuiyan[1], Md Rabiul Islam[2], Syed Masudur Rahman Dewan[3] and Mohammad Shahriar[1]

[1]Pharmaceutical Microbiology Research Lab, School of Pharmacy, Department of Pharmacy
University of Asia Pacific, Dhaka, Bangladesh
[2]School of Pharmacy, BRAC University, Dhaka, Bangladesh
[3]School of Life Sciences, Department of Pharmacy, United International University, Dhaka, Bangladesh

(Received: June 27, 2024; Accepted: July 07, 2025; Published (web): December 25, 2025)

ABSTRACT: The study aimed to explore whether there is any relationship between microbial contamination and its resistance ratio in drinking water samples of Dhaka city. This study will provide insights into the state of water processing in Dhaka, offering a comprehensive view of the situation. A prospective prevalence study was done on different water samples from different locations in Dhaka, Bangladesh. The study involved collecting fifty samples from July to December 2023. All isolates were identified using bacterial culture and a panel of biochemical tests. For each identified isolate, antibiogram profiles were established using the agar diffusion test following the Clinical and Laboratory Standards Institute (CLSI) guidelines. 50 specimens were grown. Among the isolates, gram-positive and gram-negative were 47.80% and 52.20%, respectively. The distribution of these bacteria in different water sources varied significantly based on the research results. Notable gram-negative bacteria like *E. coli*, *Enterobacter* sp., *Salmonella paratyphii*, *Vibrio cholerae*, and *Shigella* sp. were identified in the sources. Jar water from street vendors displayed a comparable distribution, with a greater incidence of gram-negative bacteria at 53.85% versus gram-positive bacteria at 46.15%. *Pseudomonas aeruginosa*, *Salmonella typhii*, *Salmonella paratyphii*, and *Shigella* sp. were dominant among gram-negative isolates, while *Staphylococcus* sp., *S. aureus*, and *S. epidermidis* were the leading gram-positive contaminants. Filtered water from electronic sources showed a slight shift, with more gram-positive bacteria at 53.57% and dominant isolates like *Micrococcus* sp., *S. aureus*, and *Streptococcus* sp. *Klebsiella pneumoniae* being the primary gram-negative bacteria in this category. In the jar water from other sources, gram-negative bacteria accounted for 51.72% of isolates, with *Klebsiella* sp., *Proteus mirabilis*, and *Pseudomonas aeruginosa* as the main contaminants, while gram-positive bacteria like *S. epidermidis* and *Micrococcus* sp. were also present. These findings highlight the diverse bacterial isolates that showed resistance to azithromycin, ceftriaxone, aztreonam, nalidixic acid and cefepime. In this study, the isolation of pathogenic bacteria from drinking water indicates that they can be vehicles for disease transmission. The finding of the study indicates a rising trend in antimicrobial resistance among bacterial isolates over time. To combat rising antimicrobial resistance, policymakers and water authorities must adopt a proactive, multi-pronged approach. This includes increasing surveillance, updating water treatment, encouraging ethical antibiotic use, funding research, creating public awareness and promoting international cooperation. These concerted activities are critical for slowing the spread of resistance while protecting public health and the environment.

Key words: Antibiotic resistance, isolates (bacterial), gram-positive bacteria, gram-negative bacteria, selective media.

INTRODUCTION

The delivery of potable water, a public health triumph, faces challenges like waterborne illness outbreaks in affluent towns due to insufficient personnel training and global risks as seen in the Haitian cholera case, highlighting the need for preventative management via Water Safety Plans (WSPs) akin to the food industry's HACCP approach. This emphasizes the universal importance of proactive water system management across all countries, despite the arbitrary differentiation of

Correspondence to: Mohammad Shahriar
E-mail address: shahriar@uap-bd.edu
Mobile: +8801841844259

Dhaka Univ. J. Pharm. Sci. **24**(2): 121-130, 2025 (December)
DOI: https://doi.org/10.3329/dujps.v24i2.86352

pathogen hazards between developed and developing regions.[1,2]

Dhaka, the capital of Bangladesh, relies heavily on groundwater for its drinking needs, extracting about 1,950 million liters daily, with 87% coming from underground sources. This extensive and unregulated extraction has severely depleted groundwater reserves, making further large-scale extraction both technically difficult and economically unsustainable.[3] The depletion raises environmental and public health concerns, including the risk of increased arsenic concentrations in the water supply. With 12.5 million population growing annually by over 5%, Dhaka faces significant water challenges due to rapid urbanization.[4] The Dhaka Water Supply Authority (DWASA) has increased deep tube well installations to meet clean water demand, yet groundwater extraction often outpaces replenishment, leading to dwindling supplies. There is an urgent need to reduce reliance on these aquifers by diversifying water sources, including environmentally sustainable options. A balanced approach, incorporating both groundwater and surface water, is crucial, though the challenge is compounded by the contamination of peripheral rivers from untreated urban and industrial waste. Water scarcity affects nearly a fifth of the global population, with an additional 500 million people on the brink, due to increased freshwater use and the dwindling availability of accessible sources.[5] The agriculture sector and urban areas are the main consumers of water, whereas, in cities, it supports both human and ecological needs. Urban water management relies on local watersheds, which influence water quality and treatment costs. To combat water scarcity and ensure environmental and public health safety, strategies often include the reuse of water. About 1.8 billion people are exposed to water contaminated with fecal matter, leading to 2 million annual deaths from diarrheal diseases, which also contribute to severe health problems in children, such as cognitive issues and stunted growth.[6] Emerging contaminants from municipal wastewater, which threats such as endocrine disruption, highlight the urgent need for clean drinking water and environmental conservation. The necessity of water purification to mitigate adulteration and enhance the grade of drinking water is underscored by the WHO's focus on point-of-use water treatment methods. In the United States alone, diseases such as vibriosis, triggered by various *Vibrio* species, account for 80,000 cases a year, with *Vibrio cholerae* notably causing cholera.[7] This is especially prevalent in areas like the Indian subcontinent, where water contamination is widespread. Despite progress towards achieving the Sustainable Development Goal of universal access to safe water, as evidenced by 97.1% of Bangladesh's population having access to improved water sources, the quality of water remains a major concern due to significant levels of contamination.[8] Research highlights a strong link between water quality and the incidence of diarrheal diseases, yet establishing this connection is complicated by factors such as water quality, variability and the precision of indicator bacteria. In Bangladesh, for instance, studies have shown that water contamination is a major contributor to diarrheal diseases, illustrating the complex interplay between declining water supply quality and public health risks.[9] In Dhaka, a rapidly expanding megacity with dense populations and swift urbanization, the interplay between contaminated drinking water and antibiotic resistance amplifies public health and environmental concerns. The city's water sources, plagued by pollution, act as pathways for antibiotic-resistant bacteria to circulate among both humans and animals. This dual threat not only complicates efforts to fight infectious diseases but also highlights a broader environmental health emergency.[10] Dhaka's unique position at this crossroads of antibiotic resistance and water contamination demands immediate and focused initiatives to enhance water purity and implement prudent antibiotic stewardship. Tackling these intertwined challenges is crucial for protecting the health of Dhaka's residents and maintaining global access to effective health treatments.

The study has three main objectives: First, to isolate and identify bacteria from water samples collected in Dhaka, Bangladesh, using standard microbiological methods and classify them based on their physical and biochemical characteristics. Second, to determine the antibiotic resistance profiles of these bacterial isolates by testing them against commonly used antibiotics, addressing the rising public health concerns of antibiotic resistance. Third, to assess the public health and environmental risks, associated with the presence of antibiotic-resistant bacteria in water sources and to explore potential management and mitigation strategies.

In future studies, we intend to use a mix of culture-based and molecular approaches (such as PCR and sequencing) to discover and quantify resistant bacteria. We will also examine water samples from a broader range of geographic areas and seasons in order to better understand temporal and spatial differences. This broader breadth will aid in the understanding of the possible health hazards connected with antibiotic-resistant bacteria in drinking water, as well as the development of effective mitigation techniques.

MATERIALS AND METHODS

A total of 50 samples (e.g., municipal water supply, electronically (UV/RO) filtered water, jar water from other sources and water sold by street vendors) of drinking water were collected from various places of Dhaka city, Bangladesh. The samples were collected between July 2023 to December 2023. The samples were meticulously and aseptically moved to the lab for additional analysis.

Identification assay of the isolated organisms. Particular media were employed in this study to identify various microorganisms. MacConkey agar was used to isolate *E. coli*, *Klebsiella* sp. and *Pseudomonas* sp., mannitol salt agar was used for *Staphylococcus* sp., and Salmonella-Shigella (SS) agar was used for *Shigella* sp.

Biochemical tests. These tests are essential for the precise detection of isolated microorganisms. In this context, tests such as the catalase test, citrate utilization tests, triple sugar iron agar test, bile solubility tests, and optochin susceptibility test were conducted to achieve this specific identification.

Antibiotic susceptibility test. Antibiotic sensitivity testing of specimens was conducted on Mueller-Hinton agar medium using the disk diffusion technique, following the guidelines set by the CLSI 33rd edition (formerly known as NCCLS in 1997). Nine disks were impregnated with the following antibiotics: azithromycin (15 µg), levofloxacin (5 µg), cefuroxime (30 µg), imipenem (10 µg), meropenam (10 µg), cefepime (30 µg), ceftriaxone (30 µg), nalidixic acid (30 µg) and aztreonam (30 µg). The plates that were inoculated were positioned in an incubator at 37°C and allowed to incubate 18 hours. Subsequently, the sizes of the inhibition zones were assessed, and the results were evaluated based on the CLSI guidelines.[11]

RESULTS AND DISCUSSION

The total number of samples was 50. Of these samples, 19 types of bacterial isolates were identified in different water samples from Dhaka city. Of these isolates, 52.20% were gram-negative bacteria and 47.80% were gram-positive bacteria (Figure 1).

Table 1 illustrates the distribution of the identified bacterial growth with organisms isolated from municipal water supply, jar water from street vendors, filtered water and jar water from various sources across different areas of Dhaka city.

Figure 2 shows the percentage (%) of gram-negative and gram-positive bacterial isolates in the municipal water supply (MWS) system (54% and 46%, respectively), jar water from street vendors (SV) (53.85% and 46.15%, respectively), filtered water (FW) (46.43% and 53.57%, respectively) and jar water (JW) from various sources (51.72% and 48.28% respectively).

The distribution of microbial isolates across various water sources reveals a varied profile of gram-positive and gram-negative bacteria. In the municipal water supply of the Dhaka region, gram-negative bacteria were prevalent, accounting for 54% of the isolates, while gram-positive bacteria made up the remaining 46%. Notable gram-negative bacteria in municipal water supply included *Salmonella paratyphii* (62.50%), *E. coli* (50%), *Enterobacter* sp.

(50%), *Vibrio cholerae* (50%), and *Shigella* sp. (33.33%). In contrast, jar water from street vendors had a similar distribution, with gram-negative bacteria at 53.85% and gram-positive bacteria at 46.15%. Among gram-negative isolates, *Salmonella typhii* (80%), *Pseudomonas aeruginosa* (46.15%), *Salmonella paratyphii* (37.50%) and *Shigella* sp. (33.33%) were the dominant pathogens. For gram-positive bacteria, *Staphylococcus* sp. (42.88%), *S. aureus* (31.25%) and *S. epidermidis* (26.66%) were the leading contaminants (Tables 2 and 3).

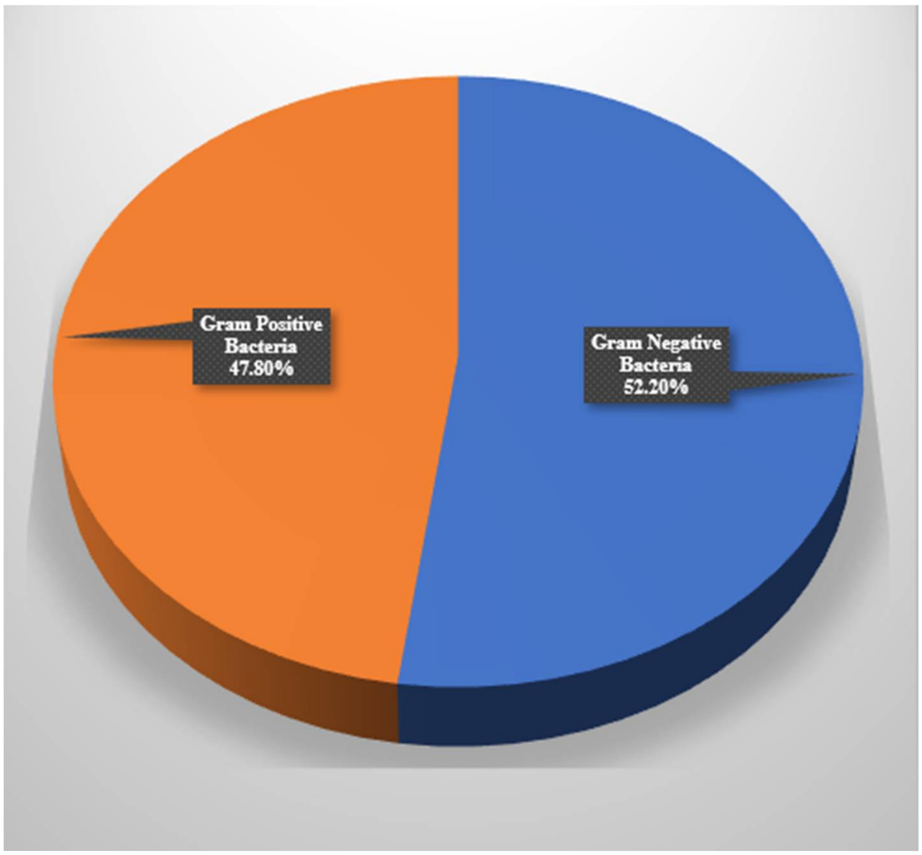

Figure 1. Ratio of isolated gram-positive and gram-negative organisms.

Table 1. Distribution of growth and organisms isolated from municipal water supply, jar water from street vendors, filtered water and jar water from various sources across different areas of Dhaka city.

Water source(s)	Total no. of sample (s)	Samples with growth (%)	Key organism(s) isolated
Municipal water supply	14	14 (100%)	*Vibrio Cholerae, Shigella* sp., *S. paratyphi,* Enterobacter sp., *Acinetobacter* sp., *Escherichia coli, Providencia* sp., *Pseudomonas aeruginosa, Salmonella typhi, Staphylococcus aureus, Streptococcus* sp., *S. epidermidis, Micrococcus* sp., Normal flora
Jar water from street vendor	13	13 (100%)	*Shigella* sp., *S. paratyphi, Proteus mirabilis, Serratia* sp., *Pseudomonas aeruginosa, Salmonella typhi, Staphylococcus aureus, Streptococcus* sp., *S. epidermidis, Micrococcus* sp., normal flora
Filtered water	12	12 (100%)	*Enterobacter* sp., *Klebsiella pneumoniae*., *Pseudomonas aeruginosa, Staphylococcus aureus, Streptococci* sp., *S. epidermidis, Micrococcus* sp., normal flora
Jar water from various sources	11	11 (100%)	*Klebsiella* sp., *Klebsiella pneumoniae, Pseudomonas aeruginosa, Staphylococcus aureus, S. epidermidis, Micrococcus* sp.,

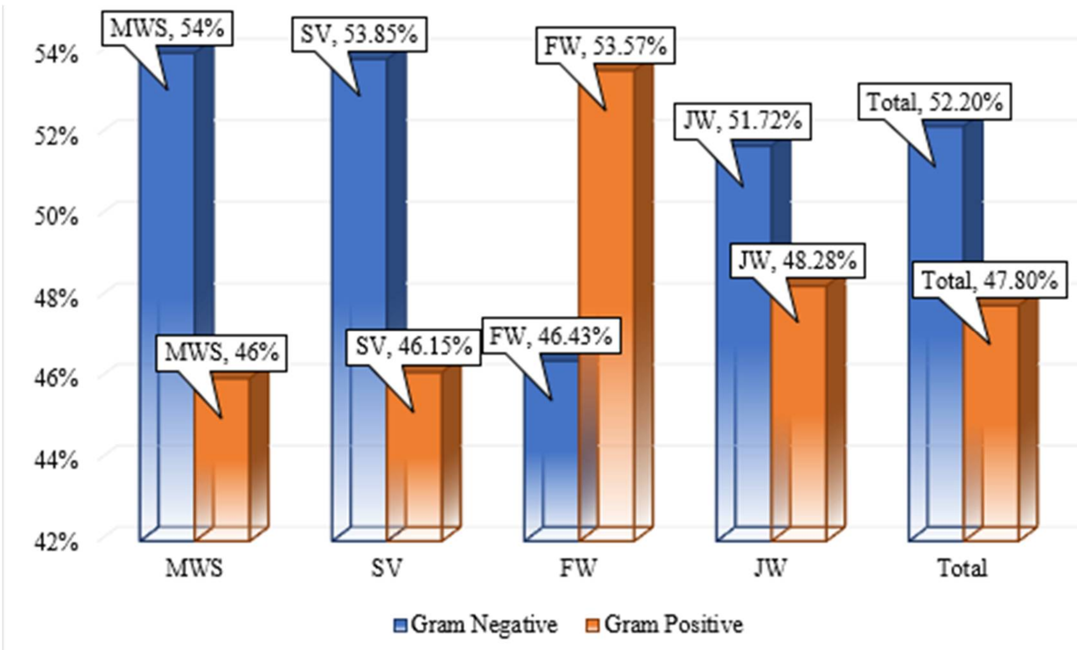

Figure 2. Fraction of bacterial isolates in municipal water supply (MWS), jar water from street vendors (SV), filtered water (FW) and jar water from various sources (JW).

Table 2. Percentage (%) of gram-negative bacterial isolates in municipal water supply, jar water from street vendor, filtered water and jar water from various sources across different areas of Dhaka city.

Name of the Organisms	Municipal water supply	Jar water from street vendor	Filtered water	Jar water from various sources
	Number with growth (%)			
Acinetobacter sp. (2)	2 (100)	-	-	-
Escherichia coli (6)	3 (50)	2 (33.33)	-	1 (16.67)
Enterobacter sp. (12)	6 (50)	2 (16.67)	3 (25)	1 (8.33)
Klebsiella pneumoniae (5)	-	1 (20)	2 (40)	2 (40)
Klebsiella sp. (11)	2 (18.18)	3 (27.28)	2 (18.18)	4 (36.36)
Proteus mirabilis (3)	-	1 (33.33)	-	2 (66.67)
Providencia sp. (2)	2 (100)	-	-	-
Pseudomonas aeruginosa (13)	1 (7.69)	6 (46.15)	3 (23.07)	3 (23.07)
Salmonella paratyphi (8)	5 (62.50)	3 (37.50)		
Salmonella typhi (5)	1 (20)	4 (80)	-	
Serratia sp. (3)	-	1 (33.33)	1 (33.33)	1 (33.33)
Shigella sp. (9)	3 (33.33)	3 (33.33)	2 (22.22)	1 (11.11)
Vibrio cholerae (4)	2 (50)	2 (50)	-	-

Filtered water from electronic (UV/RO) sources displayed a slight shift, with gram-positive bacteria comprising 53.57% and gram-negative bacteria at 46.43%. In this category the dominant gram-positive isolates included *S. aureus* (31.25%), *Micrococcus* sp. (20%), and *Streptococcus* sp. (20%). *Klebsiella pneumoniae* (40%) was the leading gram-negative bacterium in this category. Lastly, in jar water from various sources gram-negative bacteria accounted for 51.72% of the isolates, with gram-positive bacteria at 48.28%. In the category of jar water from various sources, the primary gram-negative contaminants were *Proteus mirabilis* (66.67%), *Klebsiella* sp. (40%), and *Pseudomonas aeruginosa* (23.07%); and the gram-positive isolates included *S. epidermidis* (26.66%) and *Micrococcus* sp. (26.66%) (Table 2 and 3). These distributions underscore the varied bacterial contamination of different water sources.

Table 3. Percentage (%) of gram-positive bacterial isolates in municipal water supply, jar water from street vendor, filtered water and jar water from various sources across different areas of Dhaka city.

Name of the organisms	Municipal water supply	Jar water from street vendor	Filtered water	Jar water from various sources
	Number with growth (%)			
Micrococcus sp. (15)	3 (20)	5 (33.33)	3 (20)	4 (26.66)
Normal flora (6)	3 (50)	2 (33.33)	1 (16.66)	-
S. aureus (16)	4 (25)	5 (31.25)	5 (31.25)	2 (12.50)
S. epidermidis (15)	5 (33.33)	4 (26.66)	2 (13.33)	4 (26.66)
Staphylococcus sp. (14)	3 (21.42)	6 (42.88)	2 (14.28)	3 (21.42)
Streptococcus sp. (10)	5 (50)	2 (20)	2 (20)	1 (10)

In Figure 3, the percentage of antibiotic-resistant bacteria out of all the grown bacteria (159) reveals variation levels of resistance. The highest resistance rates were observed for cefepime (CPM) at 27% and azatreonam (AT) at 24%, indicating significant challenges in combating resistance to these antibiotics. Conversely, levofloxacin (LEV) exhibited the lowest resistance at 1%. Among the other antibiotics, azithromycin (AZM) showed a resistance rate of 10%, cefuroxime (CXM) 14%, meropenem (MEM) 2%, imipenem (IPM) 3%, ceftriaxone (CRO) 8% and nalidixic acid (NA) 11% respectively. This data underscores the critical need for effective strategies to address antibiotic resistance and accentuates the significance of continuous monitoring and the evolution of new antimicrobial agents to affray this growing threat.

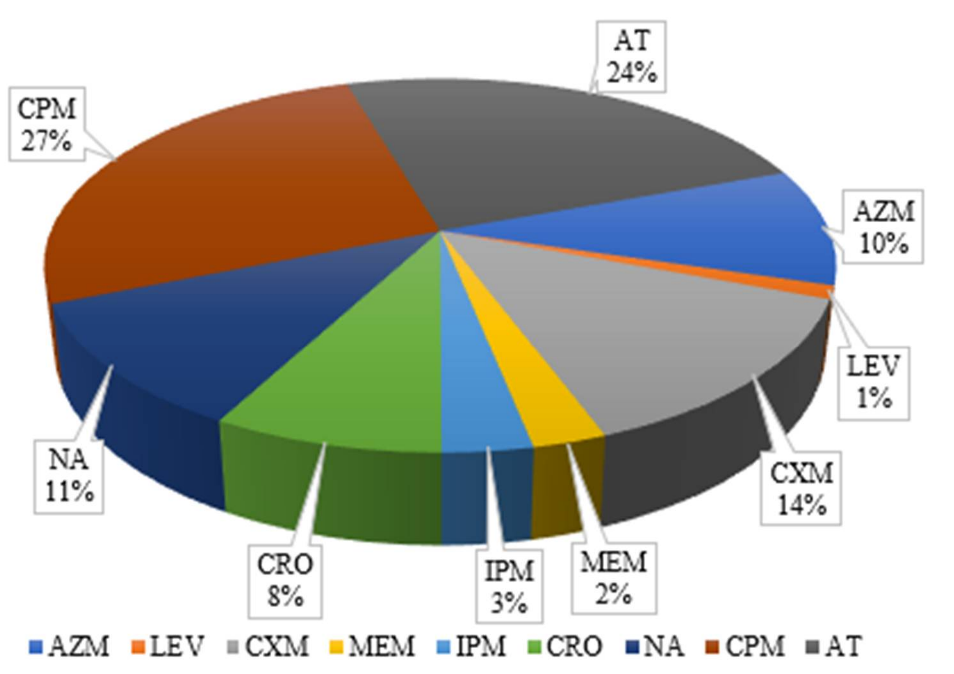

Figure 3. Percentage of antibiotic-resistant bacteria out of all the grown bacteria.

The data in figure 4 reveals that among the gram-negative bacteria, which have a total number of 83, the highest resistance was observed for AT 26% and CPM 20%. Notably, LEV exhibited the lowest resistance at 0%. The resistance percentages for the other antibiotics were as follows: AZM 10%, CXM 19%, MEM 3%, IPM 3%, CRO 9%, and NA 10% respectively.

The data on antibiotic-resistant gram-positive bacteria having a total number of 76 (Figure 5) reveals a spectrum of resistance levels, with AT and CPM exhibiting the highest resistance rates at 28% and 28%, respectively. In contrast, LEV demonstrated the lowest resistance at 2%. The resistance rates for other antibiotics were AZM 11%, CXM 8%, MEM 1%, IPM 3%, CRO 6%, and NA 13%.

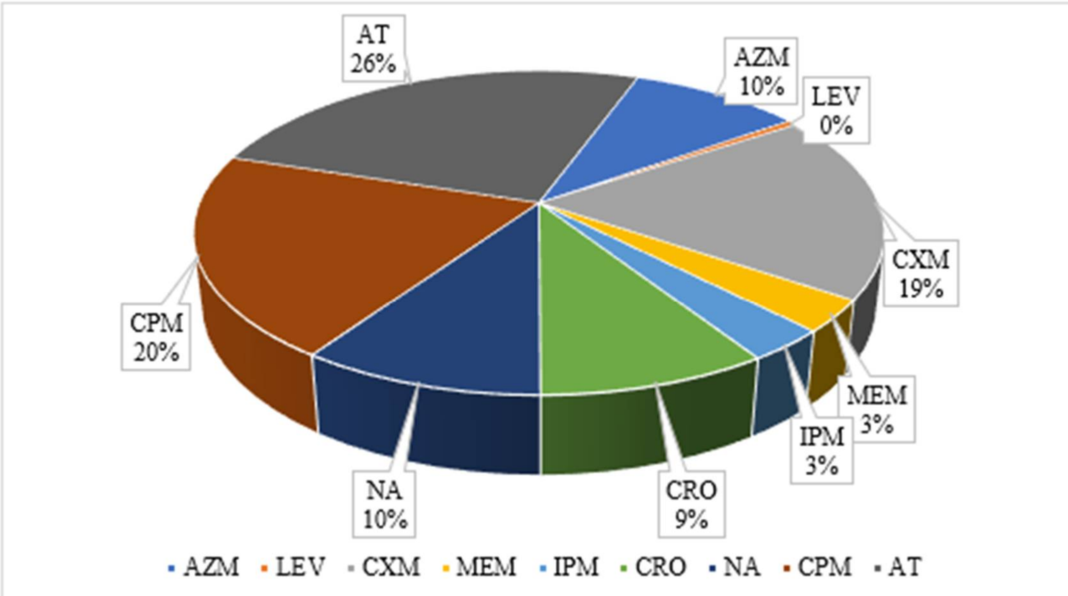

Figure 4. Percentage of antibiotic-resistant gram-negative bacteria out of all the grown bacteria.

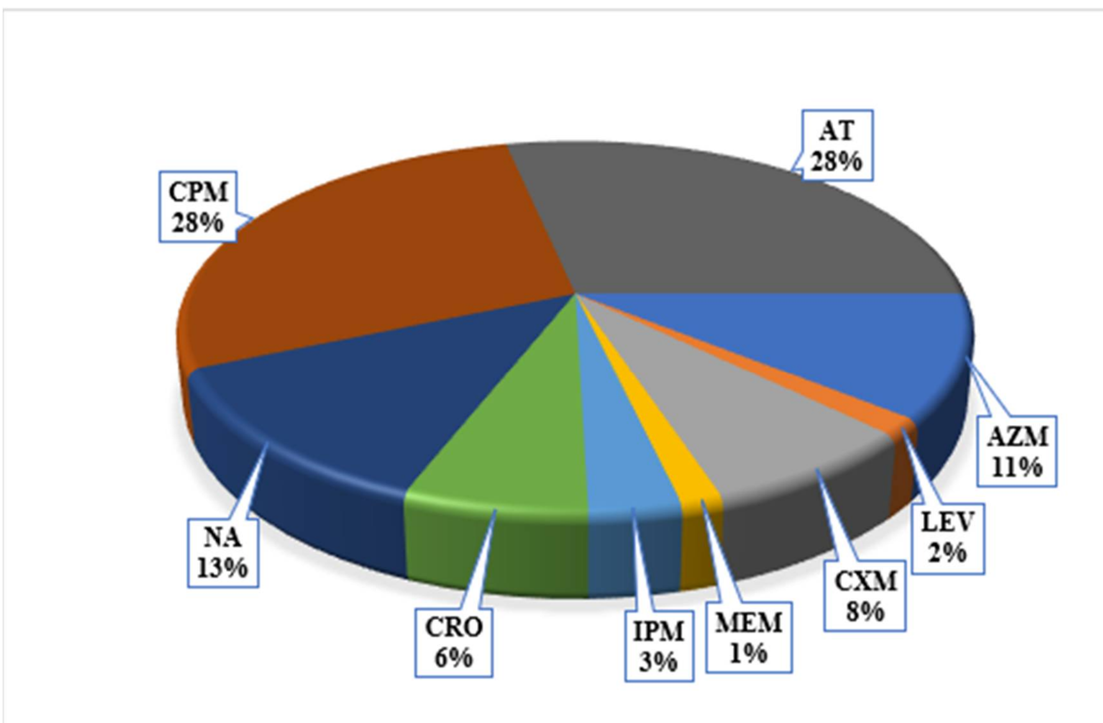

Figure 5. Percentage of antibiotic-resistant gram-positive bacteria out of all the grown bacteria.

Table 4. Percentage (%) of resistance of all the bacterial isolates against commonly used antibiotics.

Name of the organisms	AZM	LEV	CXM	MEM	IPM	CRO	NA	CPM	AT
Acinetobater sp. (2)	1 (50)	-	2 (100)	-	-	-	-	2 (100)	2 (100)
Escherichia coli (6)	1(16.66)	-	3 (50)	-	-	2 (33.33)	-	5 (83.33)	6 (100)
Enterobactor sp. (12)	7 (58.33)	-	9 (75)	3 (25)	-	3 (25)	2 (16.66)	10 (83.33)	10 (83.33)
Klebsiella pneumoniae (5)	1 (20)	-	5 (100)	-	-	2 (40)	-	5 (100)	3 (60)
Klebsiella sp. (11)	4 (36.36)	-	10 (90.90)	4 (36.36)	-	2(18.18)	3 (27.27)	11 (100)	11 (100)
Proteus mirabilis (3)	2 (66.66)	-	-	-	-	-	-	3 (100)	-
Providencia sp. (2)	1 (50)	-	-	-	-	-	2 (100)	2 (100)	-
Pseudomonas aeruginosa (13)	3 (27.27)	-	10 (76.92)	-	2 (18.18)	7(63.63)	6(46.15)	13 (100)	8 (61.53)
Salmonella paratyphii (8)	4 (50)	2 (25)	3 (37.5)	2 (25)	2 (25)	3 (37.5)	4 (50)	5 (62.5)	6 (75)
Salmonella typhi (5)	1 (20)	-	5 (100)	1 (20)	5 (100)	3 (60)	4 (80)	5 (100)	4 (80)
Serratia sp. (3)	-	-	3 (100)	-	-	3 (100)	2 (66.66)	3 (100)	3 (100)
Shigella sp. (9)	-	-	4 (44.44)	-	-	2(22.22)	3 (33.33)	9 (100)	6 (66.66)
Vibrio cholerae (4)	4 (100)	-	2(50)	-	-	-	3 (75)	4 (100)	2 (50)
Micrococcus sp. (15)	8 (53.33)	-	6(40)	-	-	4 (26.66)	5 (33.33)	15 (100)	15 (100)
Normal flora (6)	5 (83.33)	-	3 (50)	1 (16.66)	-	2 (33.33)	4 (66.66)	6 (100)	5 (83.33)
S. aureus (16)	6 (37.5)	-	4 (25)	1 (6.25)	2 (12.5)	2 (12.5)	5 (83.33)	16 (100)	16 (100)
S. epidermidis (15)	3 (20)	1 (6.66)	6 (40)	2 (13.33)	2 (13.33)	7 (46.66)	10 (66.66)	15 (100)	15(100)
Staphylococcus sp. (14)	6 (42.85)	-	4 (28.57)	-	3 (21.42)	2 (14.28)	5 (35.71)	13 (92.85)	14 (100)
Streptococcus sp. (10)	5 (50)	3(30)	-	-	1 (10)	-	4(40)	8 (80)	9 (90)

Comparing the data, it is evident that the gram-negative bacteria exhibited higher resistance to CXM and CRO compared to the gram-positive bacteria. Conversely, the gram-positive bacteria showed higher resistance to AZM, CPM and AT compared to the gram-negative bacteria. The data suggests a concerning level of antibiotic resistance, particularly for CPM and AT, which had the highest resistance percentages among gram-negative and gram-positive bacteria. This highlights the need for continued monitoring, the execution of effective antibiotic oversight programs, and the expansion of new antimicrobial agents to encounter the growing hazardous incidence of antibiotic resistance.

Based on the antimicrobial resistance in India's scoping report, the state data of antimicrobial resistance (AMR) in India, focusing on human health and the animal food industry is alarming.[12] In humans, a staggering over 70% of *Escherichia coli*, *Klebsiella pneumoniae* and *Acinetobacter baumannii* isolates, along with nearly 50% of *Pseudomonas aeruginosa* isolates, were found to be resistant to third-generation cephalosporins and fluoroquinolones. 35% of the *Escherichia coli* and *Pseudomonas aeruginosa* showed resistant to the drug combination of piperacillin-tazobactam, but 65% of *Klebsiella pneumoniae* isolates showed resistance due to multiple genes, including carbapenems. *Acinetobacter baumannii* displayed a 71% resistance rate to carbapenems, prompting increased colistin use, with resistance rates below 1% overall, except for a 4.1% rate. Furthermore, colistin-resistant *Klebsiella pneumoniae* infections had a high mortality rate of 70%. In gram-positive bacteria, 42.6% of *Staphylococcus aureus* and 10.5% of *Enterococcus faecium* isolates were resistant to methicillin and vancomycin, respectively. *Shigella* sp. and *Salmonella typhi* were resistant to ciprofloxacin at about 82% and 28%, to ceftriaxone at about 0.6% and 12%, and to co-trimoxazole at about 2.3% and 80%, respectively. Tetracycline resistance in *Vibrio cholerae* stretched from 17% to 75%.[13] In case of our present study, only *Salmonella paratyphii* and *Streptococcus epidermidis* were observed to be resistant to all the antibiotics used in this study. On the other hand, *Proteus mirabilis* showed resistant to only two antibiotics (azithromycin, cefepime) (Table 4).

The study underscores that total fecal coliform, particularly *E. coli*, are widely recognized as key indicators of microbial water contamination. WHO guidelines stipulate that potable water should ideally have lower coliform colony-forming unit per 100 ml and no *E. coli* type 1 per 100 ml.[14]

From the above study, 69% of the water samples tested positive for coliforms whereas 43.55% contained *E. coli*. Compared to other regions in Bangladesh, these percentages are relatively lower. It's observed that water layers up to 400 feet in Chittagong frequently contain *E. coli*, but many Jar Water treatment plants source water from below this depth, according to discussions with engineers and plant employees. The proliferation of businesses selling contaminated water in containers across various parts of the country, largely due to inadequate monitoring and regulation, poses significant health risks. This study's findings indicate that the bacterial density in drinking water is comparatively higher, especially from unprotected sources. The existence of *E. coli* is indicative of excretory coliforms and enteric pathogens. *E. coli*, known for its propensity to develop resistance, serves as an effective bioindicator for antimicrobial resistance surveillance studies. Antimicrobial resistance testing in this study used the disc diffusion method with seven different antibiotics against *E. coli*. The results showed intermediate sensitivity to amoxicillin (7.4%) and ceftriaxone (3.7%), but high resistance to ampicillin (81.48%), amoxicillin (70.3%), colistinsulphate (74.02%), ceftriaxone (70.3%), and gentamicin (7.42%).[15] In the present study, *E. coli* partitions exhibited abundant levels of resistant to several antibiotics, particularly aztreonam (100%), cefepime (83.33%), and cefuroxime (50%), respectively. However, no resistance was observed for levofloxacin, meropenem, imipenem and nalidixic acid (Table 4).

As previously reported in eastern Ethiopia, *Pseudomonas aeruginosa* isolates displayed increased resistance to cephalosporins like ceftazidime and cefepime, with resistance rates ranging from 18% to meropenem, 77.8% to ceftazidime and cefepime. Conversely, these isolates exhibited higher susceptibility to gentamicin.[16] Another study[17] assessed the microbiological quality and antibacterial resistance profiles of *E. coli* variants secluded from six distinct aquatic resources. The quality of all water sources was found to be poor. Bacteria such as *E. coli*, *Enterobacter* sp., *Klebsiella* sp., and others were identified through analytical profile index and classic approaches. The antimicrobial sensitivity of these bacteria was tested applying the Kirby-Bauer technique. Experiments showed a 49.48% multi drug resistant *E. coli*. These strains demonstrated high resistance to tetracycline (21.45%), erythromycin (23.71%), cefuroxime (28.87%) and penicillin (32.99%), but were more prone to nitrofurantoin (93.8%), amikacin and cefotaxime (91.75%), and other antibiotics. About 63% of these resistant strains had a multidrug resistance index over 0.2, suggesting significant resistance. The study recommends using more effective antibiotics, like nitrofurantoin, for treating waterborne bacterial diseases.[17] In the current investigation, most of the bacterial isolates did not exhibit substantial levels of antibiotic resistance to levofloxacin followed by meropenem and imipenem. However, almost all the gram-positive and gram-negative bacterial isolates have shown resistance to cefepime and aztreonam respectively (Table 4).

CONCLUSION

Our antibiotic resistance surveillance program in Bangladesh has shown that water supply systems play an important role in spreading antibiotic resistance in the available water sources. We found a substantial presence of antibiotic-resistant bacteria in these systems, with various resistance patterns. To control AMR in water, systematic molecular monitoring is required to detect resistant bacteria and antibiotic residues. Personnel training and the enforcement of AMR surveillance and water quality requirements are critical for long-term control and public health protection. This study focused solely on water sources in Dhaka city, limiting the potential to extrapolate the findings to the entire country. To acquire a more comprehensive and accurate picture of antibiotic resistance patterns in Bangladesh, further sampling from various geographic sites across the country is required. Expanding the scope of both sampling and analytical procedures will improve data reliability and enable more effective intervention strategies.

REFERENCES

1. Roeger, A. and Tavares, A.F. 2018. Water safety plans by utilities: a review of research on implementation, utilities policy. *Elsevier* **53**, 15-24.
2. Beer, K.D., Gargano, J.W., Roberts, V.A., Hill, V.R., Garrison, L.E., Kutty, P.K. and Yoder, J.S. 2015. Surveillance for waterborne disease outbreaks associated with drinking water-United States, 2011-2012. *Morb. Mort. Weekly Rep*. **64**, 842.
3. Bodrud-Doza, M., Islam, S.D.U., Rume, T., Quraishi, S.B., Rahman, M.S. and Bhuiyan, M.A.H. 2020. Groundwater quality and human health risk assessment for safe and sustainable water supply of Dhaka city dwellers in Bangladesh, groundwater for sustainable development. *Elsevier* **10**, 100-134.
4. McDonald, R.I., Weber, K.F., Padowski, J., Boucher, T. and Shemie, D. 2016. Estimating watershed degradation over the last century and its impact on water-treatment costs for the world’s large cities. *Proc. Nat. Acad Sci. USA*. **113**, 9117-9122.
5. Ye, Q., Li, Y., Zhuo, L., Zhang, W., Xiong, W., Wang, C. and Wang, P. 2018. Optimal allocation of physical water resources integrated with virtual water trade in water-scarce regions: a case study for Beijing, China. *Water Res*. **129**, 264-276.
6. Shevah, Y. 2014. Water scarcity, water reuse, and environmental safety. *Pure Appl. Chem.*. **86**, 1205-1214.
7. Islam, M.S., Hassan-uz-Zaman, M., Islam, M.S., Clemens, J.D. and Ahmed, N. 2020. *In*: *Waterborne Pathogens: Detection and Treatment* (Prasad, M.N.V and Grobelak, A., Eds.), Butterworth-Heinemann, Oxford, Chapter 3, pp. 43-56.
8. Sultana, M., Mahumud, R.A. and Sarker, A. 2015. Emerging patterns of mortality and morbidity in district level hospitals in Bangladesh. *Ann Public Health Res*. **2**, 2-4.
9. Luby, S.P., Halder, A.K., Huda, T.M., Unicomb, L., Islam, M.S., Arnold, B.F. and Johnston, R.B. 2015. Microbiological contamination of drinking water associated with subsequent child diarrhea. *Am. J. Trop. Med. Hyg.* **93**, 904-911.
10. Ajiero, I. and Campbell, D. 2018. Benchmarking water use in the UK food and drink sector: case study of three water-intensive dairy products. *Water Conver. Sci. English* **3**, 1-17.
11. National Committee for Clinical Laboratory Standards, Methods for dilution antimicrobial susceptibility tests for bacteria that grow aerobically, 3rd Edition, approved standard (NCCLS, Pennsylvania, Document M7-A3, 1997).
12. Gandra, S., Joshi, J., Trett, A., Lamkang, A., Laxminarayan, R. 2017. Scoping report on antimicrobial resistance in India Available from: http://www. dbtindia.nic.in/wp-content/ uploads/ Scopingreporton Antimicrobial resistance inIndia.pdf. pp. 1-146:
13. Taneja, N. and Sharma, M. 2019. Antimicrobial resistance in the environment: the Indian scenario. *Indian J. Med. Res.* **149**, 119.
14. Cheesbrough, M. 2000. Medical laboratory manual for tropical countries. Vol. II, Microbiology, M. Cheesbrough. pp. 65-69.
15. Ahmed, I., Rabbi, M.B. and Sultana, S. 2019. Antibiotic resistance in Bangladesh: a systematic review. *Int. J. Infect. Dis.* **80**, 54-61.
16. Teshome, A., Alemayehu, T., Deriba, W. and Ayele, Y. 2020. Antibiotic resistance profile of bacteria isolated from wastewater systems in eastern Ethiopia. *J. Environ. Pub. Health* **54**, 16-21.
17. Odonkor, S.T. and Addo, K.K. 2018. Prevalence of multidrug-resistant *Escherichia coli* isolated from drinking water sources. *Int. J. Microbiol.* **2018**, 7204013.