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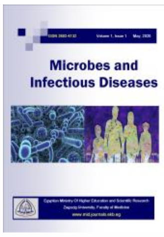

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Original article

Antibiotic resistance and pathogenic bacterial profiles in drinking and surface water in Baghdad, Iraq

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ABSTRACT

Background: Aquatic environments serve as hotspots for the dissemination of genes and micro-organisms that are resistant to antibiotics. The research sought to assess the microbiological quality of various water sources. **Methods:** The samples were analyzed for their physicochemical parameters. Standard procedures were used to enumerate and characterize pathogenic bacteria, nonfermentors, and fecal coliforms. The susceptibility of isolated bacteria to thirteen antibiotics was tested using disk diffusion techniques. **Results**: The results showed that water's pH values ranged between 6.4 and 8, while turbidity values varied from 0.88 to 9.21 NTU. The recorded electrical conductivity ranged from 52.5 to 602.4 S/cm, while the total suspended solids (TSS) values varied from 240 to 900 mg/l. Furthermore, the present findings show that chloride concentrations ranged between 188.565 and 474.866 mg/l, and dissolved oxygen levels ranged from 3.66 to 8.56 mg/l. These findings comply with the permissible limits set by WHO and Iraqi guidelines. The results were alarming for drinking water supply, surface water, residential well water, and household borehole water, with 100%, 70%, 40%, and 20% positive results, respectively. However, we detected 180 bacterial strains (20%) *Klebsiella pneumoniae*, (16%) *Pseudomonas aeruginosa*, (16%) *Escherichia coli*, (6%) *Legionella pneumophila*, (5.6%) *Citrobacter* spp., (5.2%) *Vibrio cholera*, and (4%) *Aeromonas* spp. In addition, among 80 coliforms, 56.25% were fecal coliforms, while 81.25% were total coliforms. The highest percentage of resistance was observed against ceftriaxone, ciprofloxacin, and imipenem/cilastatin (100%), cefoperazone/sulbactam comes in second at 95%, cefepime/tazobactam 92%, norfloxacin 90% and ofloxacin 90%. the lowest degree of resistance against piperacillin/tazobactam, colistin, cefotaxime, and gentamicin (47%), representing 40%, 42%, 45%, and 47%, respectively. Nonfermenting bacteria demonstrated that the strains were 100% resistant to Trimethoprim Sulfamethoxazole, cefoperazone/sulbactam, ciprofloxacin, and cefepime/tazobactam. The coliforms isolates were 100% resistant to ampicillin, cefoperazone/sulbactam, and norfloxacin. **Conclusions**: The health of community members who depend on these initiatives for their drinking water may be threatened by an abundance of antibiotic-resistant bacteria and pathogenic microbes. Our findings underscore the pressing necessity for enhanced water purification, more stringent limits on antibiotic usage, and improved surveillance to curtail the proliferation of resistance. The research underscores the significance of cohesive public health strategies and the creation of efficient monitoring and diagnostic instruments to tackle the escalating issue of aquatic antibiotic resistance.

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Introduction

A sustainable and dignified life requires access to drinkable water. Obtain it under optimal standards for quantity, quality, and availability, and cost is significantly constrained by geographic and economic factors [1]. Waterborne bacterial infections represent a significant global public health issue, attributable not only to the mortality and morbidity they induce but also to the substantial expenses associated with prevention and control [2].

In developing nations, impoverished villages and inhabitants depend on rivers, ponds, and streams for their daily water requirements. Waterborne opportunistic pathogenic microorganisms often contaminate these natural sources of water [3]. These microbes pose significant health risks to immunocompromised patients and represent a considerable problem [4]. One essential aspect of the interfacial physiology of bacteria that affects how the cell interacts with its surroundings is surface charge. Because they live in aquatic settings, bacteria need to have hydrated surfaces in order to move waste and nutrients. The predominant groups of indigenous bacteria in aquatic environments are chemoorganotrophic bacteria, categorized as saprophytes. Gram-positive cocci, which include spiral bacteria from the genera *Spirillum* and *Micrococcus*. Furthermore, bacteria belonging to the genera *Alcaligenes, Pseudomonas, Vibrio, Aeromonas,* and *Achromobacter* are typical examples of ciliated Gram-negative rods [5,6]. Nutrient-rich and extensively contaminated surface waters host a variety of both allochthonous and autochthonous for example, *Klebsiella, Pseudomonas aeruginosa, Enterobacter Escherichia coli, Arthrobacter, Proteus* and *Corynebacterium* [7].

Generally, many infectious diseases spread through water have been significantly reduced, mostly attributable to the water supply. However, water contamination affects how much of the resource is available for people to drink. This is why rural areas must have effective drinking water treatment systems and run at all times to guarantee that people living there have access to safe drinking water [8].

The widespread contamination of drinking and surface water with antibiotics has contributed to the rise of antibiotic resistance, a severe health problem in public health. The development of antibiotic resistance is directly linked to the increase in antibiotic use, which is in turn caused by the antibiotics' free availability, accessibility, and inappropriate use [9]. Therefore, antibiotics can enter water sources and other environments where microbes can live in a variety of ways, including sewage discharged by cities, industries, livestock, plants, and homes [10].

Interestingly, the bacterial genes in both treated and untreated sewage end up in water bodies, including ponds, reservoirs, streams, lakes, and subterranean waters [11]. Thus, the ability of microbes to persist could endanger both humans and the environment, especially in the case of diseases and antibiotic-resistant bacteria [12].

Individuals utilize numerous lakes and ponds for bathing and various religious practices. Scattered across the town are groundwater evaluation locations, comprising residential well water and household borehole water. Due to the incomplete functionality of sewage treatment facilities, there exists a risk of sewage infiltrating groundwater. This prompts an inquiry into both groundwater and surface water contamination. Considering growing worries about water quality and the potential dissemination of resistant bacteria through drinking and surface water. This study aims to evaluate the suitability of water sources in Baghdad City/ Iraq that were suitable for human consumption. Consequently, the primary goal of the research was to concentrate on characterizing their physical characteristics and assessing the prevalence of resistant bacteria, which are essential for evaluating water safety and informing public health measures.

Materials and methods

Sample collection

This research was conducted from September 2023 to August 2024 in Baghdad, Iraq, a total of 250 environmental samples were obtained from a variety of sites that were thoroughly dispersed throughout the city for sampling. It encompassed numerous municipal supply taps, residential well water, domestic borehole water, and dug wells for groundwater. Both pond and lake water were investigated for surface water. Sterile 500 ml glass bottles were employed for collecting water. The standard procedure outlined in Mackie and McCartney was followed to ensure that the samples were appropriately labeled and transferred in a cooling box to the laboratory for microbiological examination.

The physical parameters

The physical parameters of turbidity (NTU), pH, total solids, and electrical conductivity (EC) s/cm were examined. The pH was determined using a portable pH meter (WTW Germany) model. A conductivity meter (WTW LF91), the gravimetric method, and a nephelometer (ELICO India) to analyze the EC, total solids, and turbidity, respectively. The study also used chemical analysis to determine the concentrations of dissolved oxygen (Winkler's method) and chloride (Volhard's method) in the water [13,14]. Water samples under analysis were contrasted with WHO and Iraqi drinking water standards [15,16].

Microbiological analysis

The water was treated using MPN and membrane filter methods. The MPN method was employed to isolate the enteric isolates using MacConkey broth. One hundred milliliters were filtered using a membrane filter (0.45 µm) and then retained on the plate at 37°C for incubation. Subsequently, the filtration system was eliminated, and the colonies were introduced onto M-FC agar and incubated at 450°C for 24 hr. Thereafter, the isolates were evaluated for fecal coliforms. Isolates were classified as fecal coliforms if they could proliferate at 45°C in M-FC agar [17].

Characterization of bacterial isolates

Standard microbiological and biochemical techniques were employed for the first characterization and identification of the bacterial isolate, following the methods outlined by **Odeyemi *et al.*** [18].

Antimicrobial sensitivity tests

The Kirby-Bauer disc diffusion method was conducted with 25 antibiotics from several classes of frequently employed antibiotics. The subsequent antibiotic discs were utilized at the specified final concentrations: ampicillin (30µg), amikacin (30µg), ceftazidime (30µg), chloramphenicol (30µg), colistin (10µg), ciprofloxacin (5µg), cefotaxime (30 µg), cefoperazone/sulbactam (50µg), cotrimoxazole (25µg), gentamicin (120µg), cefepime/tazobactam (30µg), ceftriaxone (30µg), cefuroxime (30µg), imipenem/cilastatin (10µg), ofloxacin (5 µg), meropenem (10µg), nitrofurantoin (300 µg), minocycline (30µg), polymyxin B (300 units), piperacillin (100µg) and norfloxacin (10µg) [17]. Two to three colonies were selected from each isolate. Following 18 hours of incubation, the zone size was assessed and analyzed in accordance with Laboratory Standards Institute [19].

Statistical analysis

All data were statistically evaluated using IBM SPSS 28 (SPSS Inc., Chicago, IL). The Kolmogorov-Smirnov test employed the normal distribution. test and expressed as mean ± standard deviation (SD), comparison among three or more groups

ANOV) and multiple comparisons by LSD post hoc test. Differences with p values < 0.05 that are regarded as having statistical significance [20].

Results

In the present study, 250 water samples were collected from various sites, which included drinking water supply, residential well water, household borehole water and surface water bodies like lakes and ponds. The main water source for Baghdad comes from the Tigris River, in addition to local wells and springs.

Physio-chemical parameters of water samples

The requirements for these indicators according to Iraqi and WHO guidelines are presented in **table (1)**.

The obtained samples are displayed in **table (2) and figure (1).** The turbidity values in this study were varied across the samples, ranging from 0.88 to 9.21 NTU. However, the highest value (9.21NTU) was recorded in surface water, while the lowest value (0.88 NTU) was observed in drinking water supply and residential well water samples. The EC ranged from 52.5 to 602.4 us/cm. The pH was between 6.4 and 8 of all the samples that were collected, the one from surface water (lakes and ponds) had the highest pH (8).

The total dissolved solids (TDS) ranged between 240 and 900 mg/l of the water samples. Based on physicochemical parameters in various water sources, the highest TDS value was identified in surface water. Chlorides ranged from 188.565 to

474.866 mg/l and were measured at each sampling location. The amount of chlorine in the surface water sample was high. Surface water indicates the highest chloride content. Dissolved oxygen concentrations were highest in surface water (8.56 mg/l) and residential well water (6.72 mg/l), while the lowest levels were recorded in drinking water supply (3.66 mg/l), followed by household borehole water (5.61 mg/l).

Prevalence of bacterial isolates

All samples underwent diverse microbiological investigations. In the present findings, of the 250 samples, 68 exhibited excellent or adequate findings based on the MPN (most probable number) count. The remaining 182 samples had inadequate MPN (most probable number) counts, which were ≥10. The membrane filter method was employed to process these samples **(Table 3)**. Out of 250 water samples, 100 were obtained from drinking water supply, 40 from residential well water, 40 from household borehole water, and 70 from surface water bodies. The microbiological evaluation indicated 100% positivity in surface water, followed by 76% drinking water supply, 50% residential well water, and 40% in household borehole water (40%) as summarized in **table (3)**. Among the 250 positive samples, a total of 182 bacterial isolates were identified, including 50 (20%) *Klebsiella pneumonia (K. pneumonia)* isolates, 40 (16%) *Pseudomonas aeruginosa (P. aeruginosa)*, 40 (16%) *E. coli*, 15 (6%) *L. pneumophila*, 14 (5.6%) *Citrobacter*, 13 (5.2%) *V. cholera* and 10 (4%) *Aeromonas*. Moreover, out of 80 coliforms, 45 (56.25%) were fecal coliforms, and 65 (81.25%) were total coliforms, as shown in **figure (2)**.

Antibiotic susceptibility testing

Regarding the resistance pattern, Notably, all isolates were considered multidrug-resistant (MDR) as they demonstrated resistance to three or more classes of antimicrobial agents, with the highest prevalence of MDR isolates found in drinking supply and surface water, and the lowest in groundwater.

Among the 182 test isolates, ceftriaxone, ciprofloxacin and Imipenem/cilastatin exhibited the highest resistance (100%), followed by cefoperazone/Sulbactam (95%), cefepime/tazobactam (92%), norfloxacin (90%), cotrimoxazole (86%) and minocycline (82%). The least resistance was observed in piperacillin/tazobactam (40%), colistin (42%) cefotaxime (45%) and gentamicin (47%) antibiotics, as illustrated in **table (4)**.

Regarding nonfermentors, including *Pseudomonas* spp. and *Aeromonas* spp., they constituted 20% of total isolates. The majority were found in surface water followed by drinking water supply. All isolates tested 100% resistant for ciprofloxacin, trimethoprim-sulfamethoxazole, cefoperazone/sulbactam, and cefepime/tazobactam, according to the resistance pattern. All isolates showed susceptibility to ciprofloxacin, cefixime, amikacin, gentamicin, and cotrimoxazole, as indicated in **table (5).**

Table 1. The bacteriological and physico-chemical drinking water criteria for Iraq and WHO.

Characteristic	**Iraqi standards** [16], **maximum allowable limit**	**WHO standards** [15]
Natural characteristics		
Turbidity (NTU)	5	5
Conductivity µS/cm	-	1500
pH value	6.5-8.5	6.5-8.5
Chemical characteristics (mg/L)		
Total dissolved solids (TDS)	1000	600
Nitrite (NO $^{-1}$) 2	3	3
Total hardness (T.H)	500	500
FRC (Cl)	-	0.3-5
Calcium (Ca^{+2})	100	100
Chloride (Cl^{-})	3 0	250
Magnesium (Mg^{+2})	100	30
Sulfates (SO $^{-2}$)	400	250
Nitrate (NO $^{-1}$) 3	50	50
Biological characteristics, colony forming unit (CFU)		
Escherichia coli	<1.1	0
Coliform bacteria	<1.1	0

Table 2. Water quality assessment based on physicochemical factors across various water sources.

	Mean ± SD					
Sample sites	**EC (nm hos/m)**	**DO (mg/L)**	**TDS (mg/L)**	**Turbidity (NTU)**	**pH**	**Chloride (mg/L)**
Drinking water supply water	52.33±1.26	3.66±0.01	240.00±1.00	0.88±0.01	6.50±0.10	188.56±0.98
Residential well water	602.57±1.06	6.73±0.01	630.00±1.00	6.77±0.02	6.70±0.10	280.76±1.00
Household borehole water	56.00±1.00	5.62±0.01	606.00±1.00	0.87±0.01	6.20±0.10	436.33±1.00
Surface water	433.40±1.20	8.56±0.01	900.00±1.00	9.21±0.01	8.00±1.00	474.87±1.00
LSD	2.136	0.019	1.883	0.022	0.955	1.878
***p*-value**	0.0001*	0.0002*	0.0001*	0.0001*	0.011*	0.0001*

Table 3. Bacterial strains were detected from diverse water sources.

Site	No. of culture	% of positive culture	Isolates	Growth	NG
Drinking water supply	100	76%	*Legionella pneumophila* *Klebsiella pneumonia* *Escherichia coli* *Pseudomonas aeruginosa*	15 26 19 16	2 12 6 4
Residential well water	40	50%	*Pseudomonas aeruginosa* *Citrobacter* spp.	6 14	4 16
Household borehole water	40	40%	*Escherichia coli* *Aeromonas* spp.	6 10	8 16
Surface water	70	100%	*Pseudomonas aeruginosa* *Vibrio cholerae* *Klebsiella pneumonia* *Escherichia coli*	18 13 24 15	0

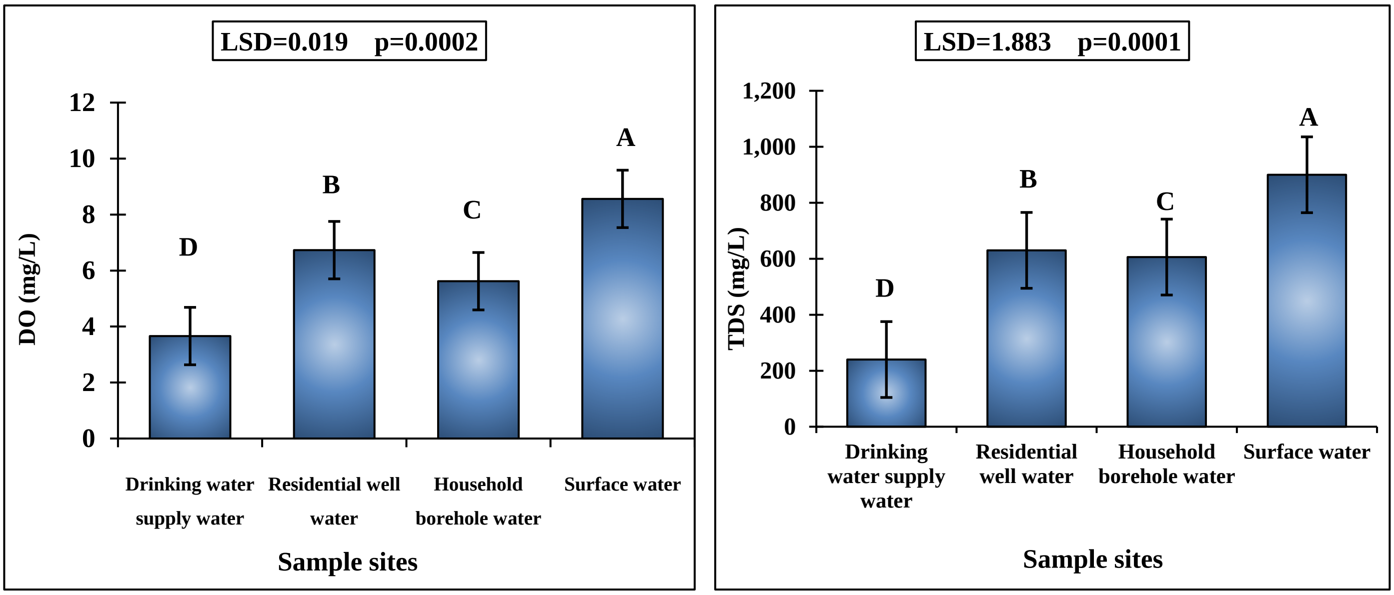
Table 4. Antibiotic Resistance Patterns from rom various water sources.

NO	Antibiotic	Resistant N (%)	Susceptibility N (%)
1	Amikacin	91 (50%)	91 (50%)
2	Ampicillin	149 (82%)	15 (18%)
3	Chloramphenicol	136 (75%)	46 (25%)
4	Colistin	76 (42%)	106 (58%)
5	Ceftazidime	154 (85%)	28 (15%)
6	Cefoperazone/Sulbactam	173 (95%)	9 (5%)
7	Ciprofloxacin	182 (100%)	0 (0%)
8	Cefepime/Tazobactam	167 (92%)	15 (8%)
9	Cotrimoxazole	157 (86%)	13 (7%)
10	Ceftriaxone	180 (100%)	0 (0%)
11	Cefotaxime	82 (45%)	100 (55%)
12	Cefuroxime	182 (100%)	0 (0%)
13	Gentamicin	86 (47%)	96 (53%)
14	Imipenem/cilastatin	182 (100%)	0 (0%)
15	Minocycline	149 (82%)	14 (15%)
16	Meropenem	162 (89%)	20 (11%)
17	Norfloxacin	163 (90%)	19 (10%)
18	Ofloxacin	163 (90%)	19 (10%)
19	Piperacillin/tazobactam	73 (40%)	109 (60%)

Table 5. The antibiotic pattern of nonfermentor strains.

NO.	Antibiotic	Resistance N(%)	Susceptibility N(%)
1	Ciprofloxacin	50 (100%)	0
2	Amikacin		
3	Ceftazidime	40 (80%)	10 (25%)
4	Cefxime	25 (50%)	25 (50%)
5	Cefoperazone/Sulbactam	50 (100%)	0
6	Ciprofloxacin	25 (50%)	25 (50%)
7	Cefepime/Tazobactam	50 (100%)	0
8	Cotrimoxazole	25 (50%)	25 (50%)
9	Gentamicin	25 (50%)	25 (50%)
10	Imipenem/cilastatin	38 (76%)	12 (25%)
11	Meropenem	42 (84%)	8 (16%)
12	Norfloxacin	48 (96%)	2 (4%)
13	Ofloxacin	25 (50%)	25 (50%)
14	Trimethoprim Sulfamethoxazole	50 (100%)	0
15	Piperacillin/tazobactam	25 (50%)	25 (50%)
16	Polymyxin-B	25 (50%)	25 (50%)

Figure 1. Water quality assessment based on physicochemical factors across various water sources. **(A):** DO, **(B):** TDS, **(C):** EC, **(D):** Chlorine, **(E):** Turbidity, **(F):** pH.



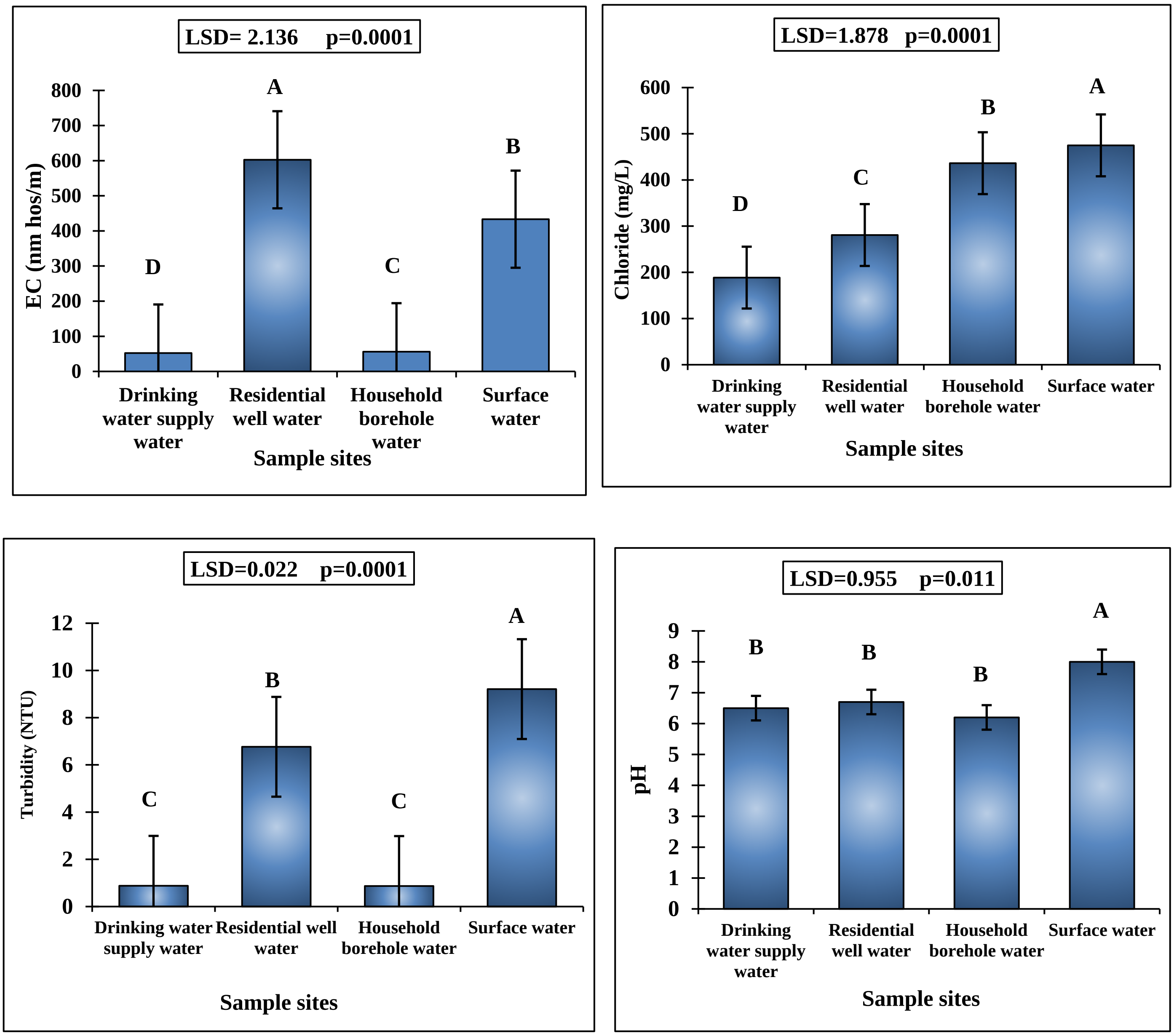
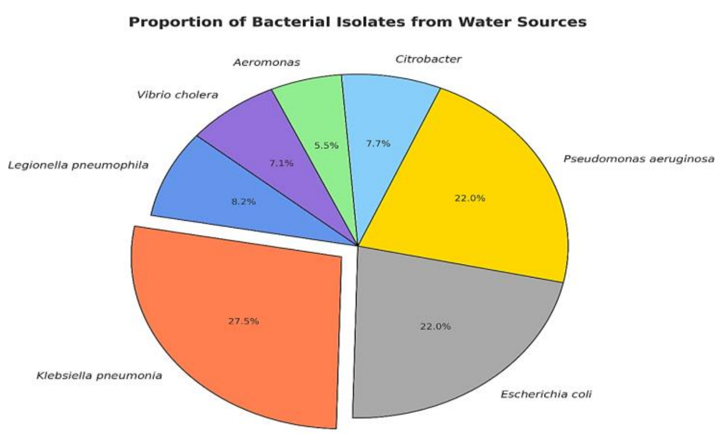


Figure 2. Graphical depiction of bacterial isolates identified from diverse water sources.



Discussion

Water is a fundamental natural resource vital for the sustenance of life on Earth, and its quality is a crucial determinant for the survival and welfare of all living beings [21]. Globally, human activities are significantly dependent on water resources. Water sources are increasingly vulnerable to a range of contaminants, both biological and non-biological, due to expansion and development. The identification of biological pollutants, such as waterborne infections, in diverse water sources has elicited global apprehension. Waterborne outbreaks have emerged in numerous nations, mostly due to pathogenic microorganisms [22].

The World Health Organization predicted that 485,000 fatalities annually are attributable to diarrheal illnesses, predominantly related to water and food that were contaminated by microorganisms [23].

Important multi-use components, including sources of drinking water, fishery, energy production, and irrigation, are found in streams, rivers, and lakes. Industrial, domestic, and animal pollutants have contaminated water sources that are used for agriculture, recreation, and drinking, as a result of increased industrialization and population growth. Consequently, it has emerged as the primary method of transmitting numerous infectious diseases [24].

In current results, the turbidity ranged from 0.88 to 9.21 NTU. This goes beyond the permissible limits of WHO guidelines and Iraqi standards. The combination of colloidal substances, suspended particles, asbestos minerals, clay particulates, leachates from organic materials, and residential refuse from diverse sources can elevate water turbidity. The turbidity of water indicates the presence of pollution [25].

The EC ranged from 52.5 to 602.4 μS/cm, which complies with the WHO Health Organization and Iraqi guidelines. EC serves as an adequate indicator for assessing the total dissolved solids in water and their cleanliness. Furthermore, it is a rapid method for detecting alterations in the natural aquatic ecosystem and the dissolved constituents [26]. However, electricity is more readily conducted by salty water than by pure water. Groundwater and surface waters have higher EC levels than tap water [27].

pH is a master variable that affects aquatic organisms' growth, physiology, and metabolism due to the many proteins and enzymes influenced by high or low pH levels [28]. The study found a pH range of 6.4 to 8, which aligns with the findings of **Bhandari *et al.*** [14], who revealed a pH range of 6.38 to 6.9. The current results revealed that surface water (pond and lake) had the highest pH of 8. The groundwater was measured within the minimum pH range of 6.2-6.7. All pipeline water samples in the present analysis are closely within the WHO and Iraqi standards, as the WHO specifies an acceptable pH range of 6.5 to 8.5. In a small number of instances, groundwater has a pH that is lower than the recommended level. This may be attributed to the infiltration of precipitation and the elevated iron level of the soil [29].

The term total dissolved solids were used to describe the inorganic and organic materials dissolved in water. A certain concentration of these ions is generally considered a significant nutrient for aquatic life [30]. In this study, the TDS values ranged from 240 to 900 mg/l, which complies with WHO and Iraqi guidelines. **Prajapati *et al.*** [13], conducted a study where TDS concentrations ranged from 200.00 to 1500.00 mg/l. The current findings detected chlorides at all sampling sites, with values ranging from 188.565 to 474.866 mg/l. The drinking water supply recorded a chloride level within the Iraqi and WHO drinking water quality guidelines, while the rest of the sample displayed higher chloride levels, in line with **Prajapati *et al.*** [13], who found that the chloride values ranged from 82.260 to 555.966 mg/l at all sampling sites.

Dissolved oxygen is one of the most critical criteria for water quality assessment. The higher the dissolved oxygen concentration, the better the quality of water [31]. Dissolved oxygen was low in drinking water supply, followed by household borehole water, but high in surface water and residential well water, which is agreed with **Prajapati *et al.*** [13].

A bacteriological analysis showed that 180 isolates were present. These included *P. aeruginosa, K. pneumonia, E. coli, Citrobacter, Aeromonas, L. pneumophila, and V. cholera* bacteria. **Karungamye *et al.*** [32] found a similar distribution of bacteria from hospital wastewater.

The bacterial community's rapid evolution of antibiotic resistance is an ecological phenomenon, but it also poses one of the most significant risks to the global human and veterinary medical communities [33]. Furthermore, resistance to antibiotics in organisms that are not classified as primary pathogens is significant due to their potential to transmit resistance to other organisms through transmissible resistance factors [34]. Antimicrobial-resistant bacteria emerge in environments due to unnecessary antimicrobial use [35]. Researchers have found that many bacteria, especially Gram-negative ones, are resistant to antibiotics [36]. This is a problem because these environmental strains store resistance genes that can be transferred to other bacteria. This makes treating infections harder and costs more [37].

The results of the present study conducted rigorous experiments on the bacterial isolates to assess their susceptibility to various antibiotics. All isolates demonstrated resistance to at least one antibiotic in three or more categories, as indicated by the results of this study. Imipenem/cilastatin, ceftriaxone, and ciprofloxacin exhibited the highest resistance with a total of 100%. Cefoperazone/sulbactam comes in second at 95%, cefepime/tazobactam 92%, norfloxacin 90%, ofloxacin 90%, cotrimoxazole 86%, ceftazidime 85%, meropenem 89%, and minocycline 82%. Also, the findings detected lower resistance rates in piperacillin/tazobactam (40%), colistin (42%), cefotaxime (45%), and gentamicin (47%).

In this study, nonfermentors, such as *P. aeruginosa* and *Aeromonas* spp., accounted for 20% of the total isolates. The study isolated *Aeromonas* from both lake and residential well water. The significance of identifying *Aeromonas* has escalated owing to public health issues, as well as their frequency and distribution in natural water sources, and their potential pathogenicity [38]. Chlorination kills free *Aeromonas*, but it spreads widely in water distribution systems by forming biofilms. Prior research has documented the isolation of *Aeromonas* species from several sources, including drinking water, vegetables, fish, and freshwater environments including rivers and lakes [39].

This study detected 40 *P. aeruginosa* isolates, including 18 from surface water, 14 from the drinking water supply, and 6 from residential well water. This bacterium has become known as a water-borne pathogen. They frequently produce biofilms that shield them from disinfectant substances, chemicals, and harsh environments [40,41]. This explains the detection of increased levels of this organism in water supply systems, even after chlorination [42].

Nonfermentors exhibited varying levels of resistance and susceptibility to antibiotics. The isolates were 100% resistant to trimethoprim sulfamethoxazole, cefoperazone/sulbactam, ciprofloxacin, and cefepime/tazobactam. The isolates were resistant to norfloxacin 96%, meropenem 84%, ceftazidime 80%, and finally imipenem/cilastatin 76%. However, they were all susceptible to ciprofloxacin, cefxime, amikacin, gentamicin, and cotrimoxazole. A study by **Govender *et al.*** [43] found that *Aeromonas* spp. isolates were not sensitive to ampicillin, polymyxin B, trimethoprim-sulphamethoxazole, or colistin. The isolates showed lower levels of resistance to impanel, levofloxacin, and meropenem; 5% to cefixime and ceftazidime; 3% to minocycline; and 2% to ciprofloxacin, but none to ofloxacin. A significant proportion of *Pseudomonas* spp. isolates exhibited resistance to minocycline, ampicillin, polymyxin B, and cefixime.

Unfortunately, these resistant bacterial strains could seriously impact the control of human and fish diseases due to the high similarity between antibiotic classes used in veterinary medicine and those employed to combat human illnesses [44]. As a result, it becomes critical to evaluate the occurrence of clinically significant coliform bacteria in the environment and the analysis of their antibiotic resistance profiles.

The current results found 100% contamination of surface water, out of which fecal coliform was identified in 56.25% of water samples. It was found that the isolates were completely resistant to ampicillin, cefoperazone/sulbactam, and norfloxacin. However, they were all able to handle gentamycin. **Adinortey *et al.*** [45] study found that the coliforms from fish farms showed 96.83% resistance to ampicillin, and 6.4% resistance to gentamycin, which aligns with our current findings. Conversely, **Štefunková** [46] discovered gentamicin-resistant coliforms in lakes and rivers, potentially contributing to the spread of this resistance.

As a consequence, our tests of the drinking and surface water quality in Baghdad city provide alarming information on the levels of microbiological contamination. Thus, build state-of-the-art wastewater treatment facilities that can clean all urban and industrial effluents to fulfill environmental discharge regulations before releasing them. This will greatly lessen the contamination of nearby waterways.

Enforce stricter anti-pollution laws on companies, establishing clear, practical thresholds and sanctions for infractions. Commission additional research on groundwater as well as surface water in Baghdad, pinpointing areas of high pollution and measuring the effects on the environment and human health. Encourage cooperation between local communities, non-governmental groups, and government agencies to guarantee the sustainability of interventions and carry out the suggested actions in an efficient manner.

Conclusion

In the results of the current investigation, although all samples fulfilled all physical characteristics, the most concerning finding regarding microbial contamination. The surface water bodies were not appropriate for human consumption. On multiple occasions, even the water supply was polluted. The groundwater exhibited the lowest levels of contamination, primarily attributable to environmental microorganisms in most instances. In the current findings, both supply and surface water were predominantly contaminated by coliforms, primarily of nonfermentors and fecal origin. The most concerning aspect of the isolates' resistance to antibiotics is that they belonged to the multidrug-resistant (MDR) category.

The results of this study could have a big influence on public wellness and management of water quality in Baghdad city. Adopting the suggested actions can lower the prevalence of waterborne illnesses, enhance people's quality of life, and support international efforts to guarantee that everyone has access to clean drinking water. Additionally, there must be a thorough investigation into sewage contamination, close monitoring of sewage treatment plant implementation, and increased adherence to disinfection protocols for supply water since most isolates are of fecal origin, suggesting sewage contamination of water.

Limitation of the study

This research possesses multiple limitations. The geographic emphasis and sample size may restrict the generalizability of the results, and the temporal breadth failed to consider seasonal fluctuations in water quality. The antibiotic susceptibility testing was confined to a narrow spectrum of antibiotics, and molecular analysis of resistance pathways was not performed. The study also failed to examine other pollutants, including viruses and heavy metals, and did not evaluate the efficacy of chlorination in water treatment. Subsequent research should examine these elements for a more thorough comprehension.

Declaration

I confirm that I am the sole author of all the tables and figures included in the manuscript.

Conflicts of interest

There are no conflicts of interest.

Ethical approval

Ethical approval for this study was secured from the Institutional Review Board of Al-Nahrain University. The research complied with the university's ethical norms, guaranteeing the confidentiality and integrity of all participant data. All participants provided informed consent, and precautions were implemented to mitigate any potential dangers related to the study. The ethical approval process encompassed a comprehensive evaluation of the study protocol to guarantee adherence to national and international ethical standards for research involving human beings.

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