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Microbiological and Physicochemical Quality of Water at Tripoli Central Hospital, Libya: an Exploratory Study

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جودة المياه الميكروبيولوجية والفيزيائية–الكيميائية في مستشفى طرابلس المركزي، ليبيا: دراسة استكشافية

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Abstract:
Background: Contaminated water in healthcare facilities can act as a reservoir for pathogens and cause healthcare-associated infections (HAIs) in vulnerable patients and staff. Data on hospital water quality in Libya are limited. This exploratory study assessed the microbiological and physicochemical quality of water at Tripoli Central Hospital (TCH), Libya. Methods: In this exploratory cross-sectional study, 30 water samples were collected from taps and wells at TCH between May and August 2025 and analyzed for Escherichia coli, total coliforms, total bacterial count, temperature, pH, turbidity, electrical conductivity (EC) and total dissolved solids (TDS). Results were compared with Libyan national standards and World Health Organization (WHO) guidance. Results: E. coli was detected in 14 of 30 samples (46.7%) and total coliforms in 18 (60.0%) the highest E. coli count (500 CFU/100 mL) was in the urology clinic. TDS exceeded 1000 mg/L in 11 samples and EC exceeded 1500 µS/cm in 28. Turbidity exceeded 1 NTU in three samples (mortuary and hospital pharmacy areas), none above 5 NTU. Conclusion: Fecal indicator bacteria and elevated EC, TDS and turbidity at several points indicate that TCH water does not consistently meet Libyan or WHO criteria and may pose a risk of waterborne disease transmission; causes were not investigated. Infrastructure improvement, point-of-use treatment, on-site water-quality monitoring and scheduled maintenance of water and sewage systems are recommended.

Keywords: Water quality; Hospital water supply; Escherichia coli; Coliforms; Healthcare-associated infections; Libya.

الملخص:

العنوان: تقييم شامل لجودة المياه الميكروبيولوجية والكيميائية في مستشفى طرابلس المركزي: دراسة استكشافية. الخلفية: تعد جودة المياه في مرافق الرعاية الصحية مصدر قلق كبير للصحة العامة. يمكن أن تعمل المياه الملوثة كخزان لمسببات الأمراض، مما يؤدي إلى العدوى المرتبطة بالرعاية الصحية التي تعرض المرضى المعرضين للخطر بالفعل وتعرض سلامة العاملين في مجال الرعاية الصحية للخطر. يتطلب مستشفى طرابلس المركزي إمدادات مياه موثوقة وآمنة لاستخدامها في الخدمات الطبية. المنهجية: كانت هذه الدراسة تصميما تجريبيا استكشافي. تم جمع ثلاثين (30) عينة مياه بشكل منهجي من نقاط مختلفة داخل نظام توزيع المياه فيTCH ، بما في ذلك منافذ الصنبور وآبار المستشفيات. تم تحليل العينات للمؤشرات الميكروبيولوجية الرئيسية (الإشريكية القولونية، إجمالي القولونيات) والمعلمات الكيميائية الفيزيائية الحرجة)إجمالي المواد الصلبة الذائبةTDS - ، الموصلية الكهربائيةEC - ، والعكارة (وفقا لطرق القياس القياسية الليبية وبروتوكولات إرشادية منظمة الصحة العالمية(WHO) . النتائج والمناقشة: كشف التحليل عن عدم امتثال كبير لمعايير السلامة. من الناحية الميكروبيولوجية، كانت 46.7٪ من العينات (ن = 14) إيجابية للإشريكية القولونية، و66.7٪ (ن = 20) كانت إيجابية لإجمالي البكتيريا القولونية. تم الحصول على العينة الأكثر تلوثا من عيادة المسالك البولية. كيميائيا، تجاوزت عدة عينات الحدود القصوى المسموح بها ل TDS و .EC علاوة على ذلك، كانت مستويات التعكر مرتفعة في أكثر من 30٪ من العينات، مع المشكلة الأكثر تحديدا في مناطق المشرحة وصيدليات المستشفيات. إن الانتشار المرتفع لبكتيريا مؤشر البراز (الإشريكية القولونية) والمعلمات الكيميائية المرتفعة والعكارة تدعم فرضية التلوث الجهازي وعدم كفاية معالجة المياه. تخلق هذه الظروف خطرا غير مقبول لانتقال الأمراض المنقولة بالمياه داخل بيئة رعاية صحية حرجة توصي النتائج باستراتيجية متعددة الجوانب بما في ذلك تحديث البنية التحتية، وتركيب وحدة معالجة المياه في نقاط الاستخدام، وإنشاء مختبر لمراقبة جودة المياه في الموقع، وتنفيذ برنامج صيانة صارم ومخطط لأنظمة المياه والصرف الصحي لحماية صحة المرضى والموظفين.

الكلمات المفتاحية: جودة المياه، التلوث الميكروبيولوجي، التحاليل الكيميائية، إمدادات المياه في المستشفيات، مستشفى طرابلس المركزي، ليبيا.

Introduction:

Water is essential in healthcare settings, where the highest standards of hygiene and safety are required. In hospitals, water is used not only for drinking but also for cleaning, disinfection, medication preparation, sterilization of surgical instruments, and overall patient care. Water quality can be defined as the set of physical, chemical, and microbiological properties that determine the suitability of water for its intended use, including drinking and use in hospitals [1].

Chemical indicators of water quality must remain within defined limits to ensure that water is safe to use. These include pH (6.5–8.5, to prevent pipe corrosion and skin irritation), the concentrations of salts and minerals such as sodium, calcium and magnesium, which affect taste and suitability for use, heavy metals such as lead, mercury and arsenic, which are toxic even at low concentrations, and organic matter, which may indicate biological or industrial contamination [2].

Microbiological assessment of water determines the presence or absence of microorganisms, including *E. coli*, a major indicator of fecal contamination; *Staphylococcus aureus*, which may cause skin and respiratory infections; fungi and yeasts, which may affect patients with weakened immune systems; and parasites such as *Giardia* spp. and amoebae, which are transmitted through contaminated water.

Water-quality standards are set by international organizations such as the World Health Organization (WHO), the United States Environmental Protection Agency (EPA), and the International Organization for Standardization (ISO), as well as by national bodies; in Libya, the standards are issued by the National Center for Standards and Metrology (NCSM).

In Libya, health and environmental institutions face increasing challenges related to infrastructure, fluctuating water services, and the absence of control systems. Tripoli Central Hospital (TCH) is one of the largest and most important healthcare facilities in Tripoli, receiving thousands of patients annually and housing vital departments such as the intensive care units (ICUs) and the dialysis unit.

Despite the importance of water quality in hospitals, local studies in Libya remain limited; most research addresses public or residential drinking water rather than water used within health institutions. For example, a study conducted in Sabha and published in 2014 reported that dialysis water in one health center contained high concentrations of salts and heavy metals, which may adversely affect patients undergoing dialysis.

Another study in Zawiya reported microbiological contamination in water produced by desalination plants, raising concerns about the efficiency of the purification systems used [3]. Studies in several

countries have assessed water quality in hospitals, and microbiological contamination is among the most prominent challenges, especially in hospitals that rely on water sources that are not regularly monitored.

A study in Maharashtra, India, reported that water used in government hospitals was unsuitable for clinical use, with *Klebsiella* spp. and *Pseudomonas aeruginosa* detected in 52% of the water samples; these bacteria are associated with nosocomial infections [4]

A study in Egypt detected *E. coli* in some samples from dialysis units and operating rooms in governmental hospitals and attributed the contamination to wastewater [5] Hospital water supplies are a reconized source of nosocomial infections [6] Studies of hospital water and effluent have been reported from several countries. In southwestern Nigeria, effluent from a teaching hospital complex significantly degraded the physicochemical quality of the receiving stream, with sulfate, total organic carbon, ammonium, phosphate and biochemical oxygen demand more than three times higher at impacted than at unimpacted sites [7]. In five secondary health facilities in Bayelsa State, Nigeria, pH, electrical conductivity, TDS and iron concentrations were within WHO-recommended ranges [8]. In a tertiary care institute in northern India, some tap, cooler and pump samples were bacteriologically unsatisfactory, and *E. coli*, *Klebsiella* spp. and *Pseudomonas* spp. were isolated from unsatisfactory or intermediate samples, whereas groundwater and UV-filtered water were of good quality [9]. A systems-based assessment of a healthcare facility's water distribution network identified chronic contamination at specific points and found that an ultrafiltration unit did not significantly reduce microbial load [10].

In urban households in Patiala, India, 28% of tap-water samples and 4% of filtered-water samples were unsatisfactory or questionable microbiologically, and some chemical parameters, such as hardness, chloride and fluoride, exceeded permissible limits [11]. A review of waterborne diseases noted that these diseases continue to affect millions of people, with Africa and Asia the most affected regions, and identified inadequate access to treated piped water and fecal contamination of surface water as key contributors [12].

Libyan studies have mostly addressed bottled, ground and desalinated water. Bottled water brands sold in Surman [13] and Tripoli [14] complied with national standards for the parameters tested and showed no microbial contamination, although 11 of the 30 Tripoli brands had TDS below the Libyan minimum [14]. Groundwater samples from agricultural zones around Jadu frequently exceeded permissible limits for salinity, hardness and sodium and showed widespread bacterial contamination, whereas desalinated water was free of microbial contaminants but lacked essential minerals [15]. In Tobruk, *E. coli* was present in some wells before treatment and was eliminated after treatment, but several physicochemical parameters remained above WHO limits [16]. Other Libyan water sources studied include the Sabha man-made lake [17].

These studies point to the importance of continuous monitoring of water quality in healthcare institutions as a pivotal element in ensuring patient safety and protecting medical staff. To our knowledge, no field studies of water quality at Tripoli Central Hospital have been published, a knowledge gap that limits the ability of decision-makers to act on accurate and reliable data. In addition, most Libyan hospitals reportedly lack dedicated microbiology laboratories which further complicates the situation. Systematic research and the necessary laboratory infrastructure are needed to ensure a safe and sustainable health environment within healthcare facilities.

The objectives of this study were to evaluate the chemical and microbiological quality of the water used at TCH; to determine total coliforms and *E. coli* as indicators of water quality; to determine the percentage of samples with microbiological and chemical non-compliance; to compare the results with the standards approved by the WHO and the Libyan National Center for Standards and Metrology (NCSM); to identify weaknesses in the water supply and purification system within the hospital; and to provide practical recommendations to improve water quality and ensure its safety in the future.

The research question was whether the water of Tripoli Central Hospital is microbiologically and chemically safe for use by staff and patients.

Materials and Methods:

Study design:

An exploratory cross-sectional study was conducted to evaluate the chemical and microbiological quality of the water supply of Tripoli Central Hospital in Tripoli, Libya. The aims were to analyze the physicochemical properties of the hospital water, detect microorganisms indicating fecal contamination, and determine the suitability of the water for use.

Study site:

Tripoli Central Hospital, also known as Al-Zawiya Street Hospital, was established in 1910 and is one of the oldest major hospitals in Tripoli. It hosts a national organ transplantation program, described as the first of its kind in Libya, and serves as a main accident center in central Tripoli. The hospital comprises outpatient clinics, emergency and accident units, intensive care units, operating rooms, a

dialysis unit, a kitchen (washing water and cooking), water tanks, an administrative building, a hospital pharmacy, and urology, surgery, orthopedic, pathology, physical therapy, medical equipment, mortuary, anesthesia, cardiology, ENT emergency, communicable diseases, accident surgery and internal medicine departments. Samples were collected from 30 points in the hospital, from tap water and wells.

Samples:

A total of 30 water samples were collected from taps and wells within Tripoli Central Hospital between May and August 2025. All samples were analyzed at the Environmental Sanitation Directorate Laboratory. Sterile tools were used for sample collection, including sterile bottles, temperature-controlled containers, and adhesive labels for recording sample data

Sampling method:

Samplers washed and disinfected their hands and wore personal protective equipment (gloves and laboratory coats). Before sampling, the faucet was opened for 2–3 minutes, and its nozzle was disinfected externally with a 95% alcohol spray and briefly exposed to flame. The water flow was then reduced to prevent splashing during bottle filling. Bottles were filled to the designated level without introducing excess air, sealed tightly, and labeled with the sample location. Samples were immediately placed in a refrigerated container and were delivered within one hour to the Environmental Sanitation Directorate Laboratory, affiliated with the Ministry of Local Governance, which performs microbiological and chemical water analyses Results were interpreted using the standards shown in Tables 1, 2 and 3.

Analytical parameters:

- **pH:** pH expresses the acidity or alkalinity of water on a scale of 0–14: values below 7 are acidic, 7 is neutral, and values above 7 are alkaline. Deviations may indicate chemical reactions and pipe corrosion. The measuring range of the device was 0.00–14.00. The permissible range according to Libyan standards is 6.5–8.5.
- **Electrical conductivity (EC):** EC measures the ability of water to conduct electric current and indicates the concentration of salts in water; it was measured in µS/cm over a device range of 0–19,999 µS/cm The maximum permissible limit according to Libyan standards is 1500 µS/cm.
- **Total dissolved solids (TDS):** TDS is the total concentration of dissolved salts and minerals in water, measured in ppm (mg/L) over a device range of 0–9999 ppm. According to Libyan standards, the maximum is 1000 mg/L and the minimum is 100 mg/L.
- **Turbidity:** Turbidity measures the cloudiness of water caused by suspended particles such as mud or algae, expressed in nephelometric turbidity units (NTU) over a device range of 0–1000 NTU. The Libyan standard maximum is 5 NTU.
- **Escherichia coli and coliform enumeration:** E. coli was enumerated as evidence of possible fecal contamination and expressed as colony-forming units (CFU) per 100 mL.
- **Total bacterial count:** Bacterial colonies developing on culture media were counted with a colony counter and expressed as colonies per plate. Libyan standards used by the Environmental Sanitation Laboratory for non-bottled drinking water were applied in this work.

Data analysis:

Results are presented descriptively as measured values and as the number and percentage of samples exceeding the applicable limits.

Table (1): Physical and chemical water quality standards (NCSM)

No.	Parameter	Measurement unit	Maximum limit
1	Color	True Cobalt Unit (TCU)	15
2	Turbidity	Nephelometric turbidity unit (NTU)	5
3	Taste	-	Acceptable
4	Odor	Threshold odor number (TON)	Acceptable
5	pH	pH units	6.5–8.5
6	Conductivity	Micro-siemens per centimeter (µS/cm), often measured at 25 °C	1500*

Table (2): Total dissolved solids standard (NCSM).

No.	Parameter	Maximum level (mg/L)
1	Total Dissolved Solids	1000

Table (3): Microbiological water quality standards (NCSM).

Water situation	Indicator	Maximum accepted level	Notes
	Total count of bacteria incubated at 37 °C for 24 h	50 colonies/mL	-
Treated water entering urban water network	Total coliform bacteria	0/100 mL	-
	Thermotolerant coliform bacteria (intestinal E. coli)	0/100 mL	-
	Total count of bacteria incubated at 37 °C for 24 h	50–100 colonies/mL	-
	Total coliform bacteria	0/100 mL	-
Treated water entering urban water network	Total coliform bacteria that withstand high temperature at 45 °C (intestinal E. coli)	0/100 mL	-
	Total count of bacteria at 37 °C for 72 h	500 colonies/mL	-
	Total coliform bacteria	3/100 mL	-
Untreated water	Total coliform bacteria that withstand high temperature (intestinal E. coli)	0/100 mL	100/3 mL continuous sampling

Results and discussion:

Thirty water samples from different departments of Tripoli Central Hospital were analyzed for physical parameters (temperature, turbidity, pH), chemical parameters (TDS, EC) and microbiological parameters (total bacterial count, total coliforms and *E. coli*) (Table 4). Water quality differed markedly between departments; this is attributed to each department being supplied from a specific well No statistical test of between-department differences was performed.

Table (4): Water quality analysis across hospital departments.

Sample source	Temp.	pH	TDS	EC	NTU	E. coli	Total coliforms	Total count†
Nutrition Service	22.0	6.014	66.5	120.1	0.17	0	0	0
Kitchen	22.5	7.028	744.7	1490	0.10	0	0	0
Central Pharmacy Preparation Room	22.5	7.450	1171	2343	1.47	12	100	0
Urology Department	23.0	7.559	773.5	1544	0.21	0	0	0
Orthopedic Surgery Department	22.4	7.628	780.8	1562	0.15	0	0	0
Central Pharmacy Restroom	22.5	7.682	1246	2489	2.18	3	100	0
Pathology Department	22.4	7.628	1265	2530	0.56	49	0	0
Physical Therapy Department	22.4	7.530	816.5	1633	0.28	56	100	0
Medical Equipment Department	23.8	7.416	1267	2534	0.79	2	100	0
General Administration Building	22.1	7.520	807.7	1613	0.07	1	0	0
Mortuary	22.6	7.583	1246	2499	3.09	1	82	0
Anesthesiology Department	22.6	7.712	1264	2522	0.61	72	100	1
Cardiology Department	25.5	6.86	1289	2584	0.60	1	100	22
ENT Emergency Unit	25.5	7.14	802.6	1602	0.77	0	1	5
ENT Sterilization Room	25.0	7.73	804	1604	0.64	0	70	26
Communicable Diseases Department	24.7	8.10	1320	2644	0.53	0	100	22

General Administration Building (2)	25.0	7.97	800.4	1602	0.22	0	0	0
Intensive Care Unit	24.7	7.88	785.3	1611	0.27	0	0	0
Department of Surgery	24.8	7.82	792	1567	0.20	0	0	0
Neonatal Unit	25.0	7.90	796	1599	0.22	1	1	0
Internal Medicine Care Unit	24.6	7.81	799	1588	0.73	0	0	0
Dialysis Unit	24.4	7.92	812.4	1618	0.46	0	0	3
Internal Medicine Department	25.8	6.907	1216	2433	0.92	5	100	12
Infectious & Dermatology Department	24.8	7.475	1246	2517	0.24	1	17	4
Urology Clinic	25.1	7.641	1096	2194	0.25	500	100	500
Maintenance, Safety, and Security Department	25.5	7.605	810.4	1614	0.27	0	19	6
Accident & Emergency Department	24.6	7.750	795.7	1598	0.16	0	1	1
General Surgery and Organ Transplant	24.9	8.090	799.2	1603	0.25	0	0	27
Transportation Department	25.2	8.062	789.8	1577	0.24	0	3	500
Technical Support Shift Unit	19.1	8.283	989.7	1968	0.40	2	100	16

Temp.: temperature (°C); **TDS:** total dissolved solids (mg/L); **EC:** electrical conductivity (µS/cm); **NTU:** nephelometric turbidity units; **E. coli and total coliforms:** CFU/100 mL. †Unit to be confirmed

Physical and chemical properties:

The temperature of the water samples (Figure 1) ranged from 19.1 °C (Technical Support Shift Unit) to 25.8 °C (Internal Medicine Department).

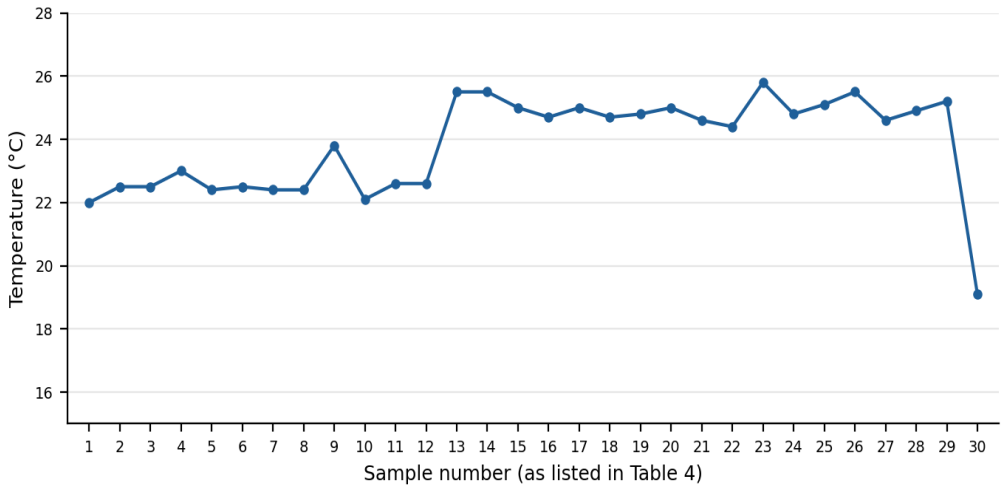


Figure (1): Temperature range of hospital water samples.

The pH of the water samples ranged from 6.014 to 8.283 (Figure 2). The lowest value, in the Nutrition Service sample (pH 6.014), was below the Libyan lower limit of 6.5 and was the only sample outside the permissible range of 6.5–8.5; the highest value (8.283) was recorded in the Technical Support Shift Unit and was within the permissible range.

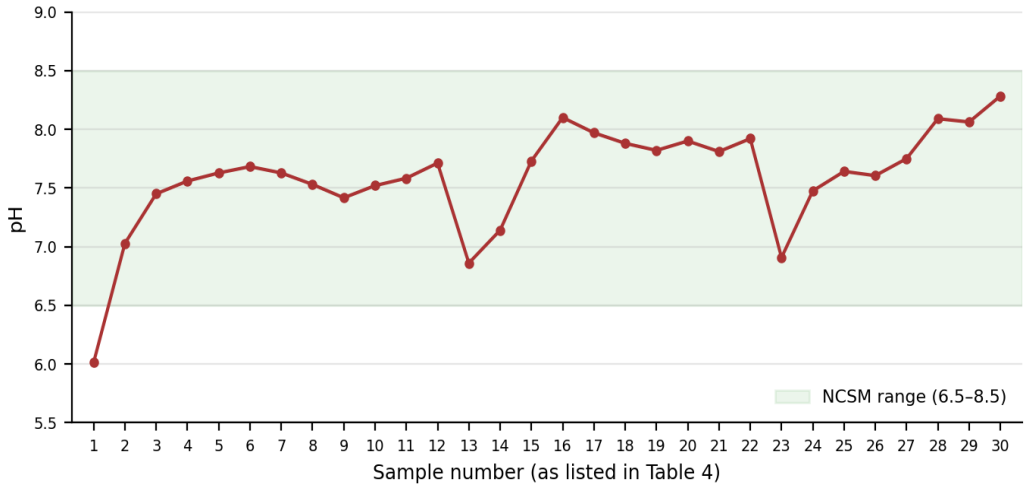


Figure (2): pH range of hospital water samples.

Turbidity exceeded 1 NTU, the level recommended by the WHO for effective disinfection, in three of 30 samples (10%): the mortuary (3.09 NTU), the central pharmacy restroom (2.18 NTU) and the central pharmacy preparation room (1.47 NTU) (Table 5 and Figure 3) \ No sample exceeded the Libyan limit of 5 NTU.

Table (5): Departments exceeding the WHO turbidity limit (1 NTU).

No.	Sample source	Turbidity (NTU)
1	Central pharmacy preparation room	1.47
2	Central pharmacy restroom	2.18
3	Mortuary	3.09

NTU: nephelometric turbidity units.

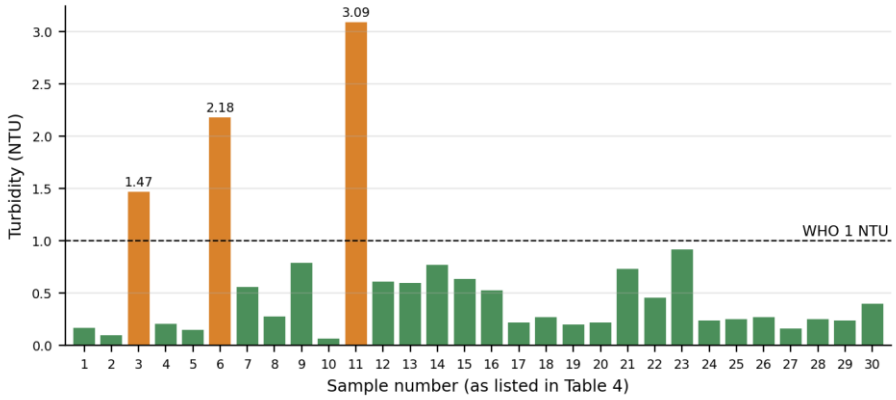


Figure (3): Turbidity levels across hospital departments.

TDS exceeded the Libyan maximum of 1000 mg/L in 11 of 30 samples (36.7%), with the highest value in the communicable diseases department (TDS 1320 mg/L; EC 2644 µS/cm) (Figure 4). EC exceeded 1500 µS/cm in 28 of 30 samples (93.3%); only the Nutrition Service (120.1 µS/cm) and kitchen (1490 µS/cm) samples were within the limit. The Nutrition Service sample (TDS 66.5 mg/L) was below the Libyan minimum of 100 mg/L. Elevated TDS and EC indicate a high content of dissolved salts and minerals.

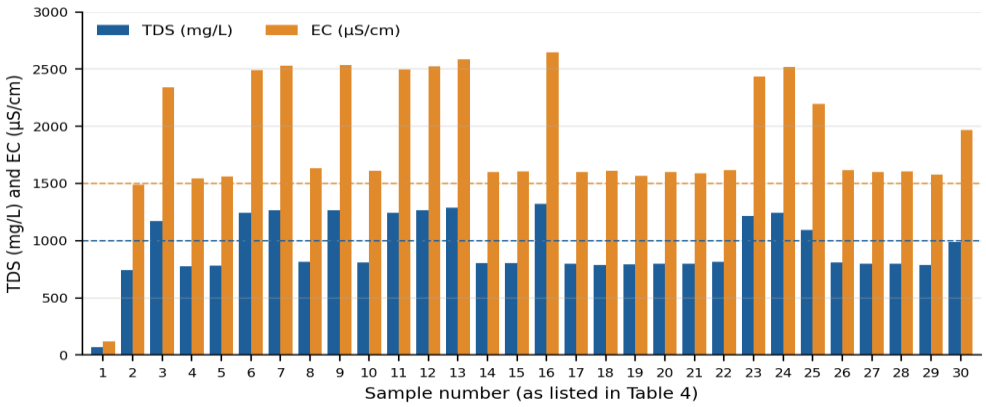


Figure (4): Total dissolved solids (TDS) and electrical conductivity (EC) in water samples.

Microbiological analysis:

E. coli was detected in 14 of 30 samples (46.7%; Table 4 and Figure 5). Counts ranged from 1 to 500 CFU/100 mL; the highest counts were in the urology clinic (500), the anesthesiology department (72), the physical therapy department (56) and the pathology department (49).

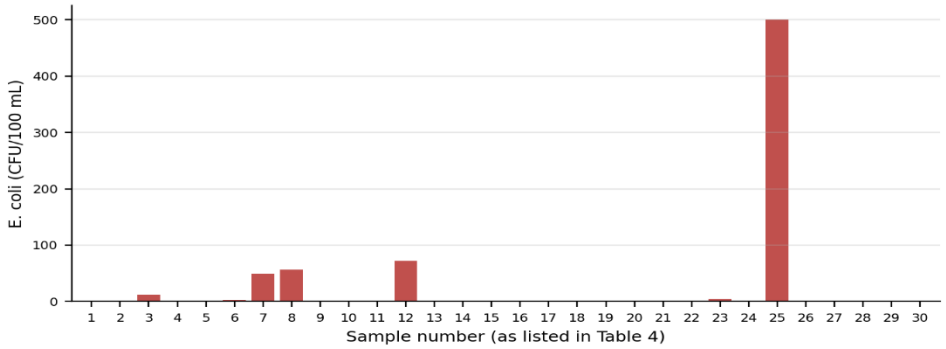


Figure (5): *E. coli* counts in water samples.

Total coliforms were detected in 18 of 30 samples (60.0%) (Table 4 and Figure 6)] A count of 100 CFU/100 mL was recorded in 10 samples, which may represent the upper counting limit of the method the other positive samples ranged from 1 to 82 CFU/100 mL. The presence of coliform bacteria indicates possible fecal contamination. According to WHO guidance, hospital water should be free of coliforms.

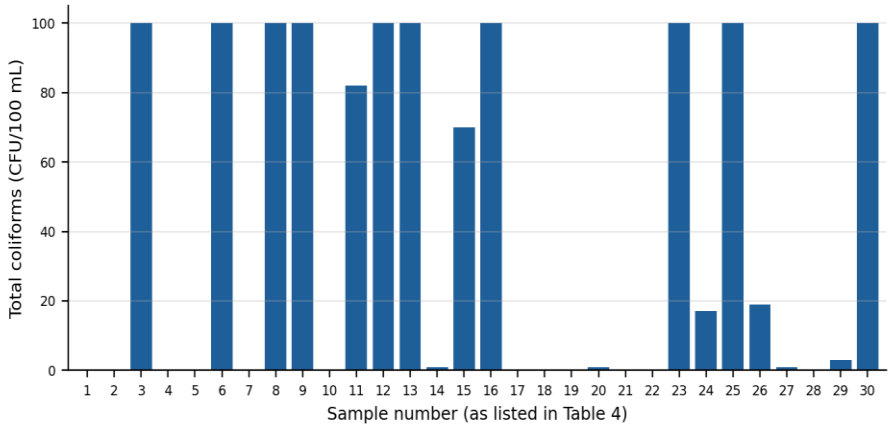


Figure (6): Total coliform counts in water samples.

The total bacterial count was above zero in 14 of 30 samples (46.7%) (Figure 7) The highest counts were in the urology clinic and the transportation department (500 each), followed by the general surgery and organ transplant department (27), the ENT sterilization room (26), and the cardiology and

communicable diseases departments (22 each). High counts may pose a risk to immunocompromised patients.

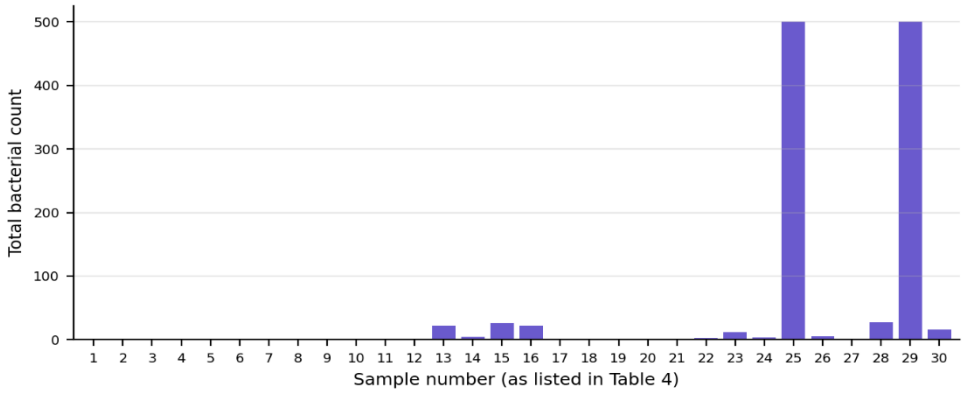


Figure (7): Total bacterial count in water samples.

Chemical quality:

Elevated turbidity in the mortuary and central pharmacy samples may reflect organic or mineral deposits, contamination from old pipes, or poor storage; these explanations were not tested in this study. Similar findings were reported in a hospital water study in Syria, which linked high turbidity to inadequate primary water treatment [18]

Microbiological quality:

The detection of *E. coli* and total coliforms at multiple sampling points, including critical departments such as anesthesiology, cardiology and urology, represents a potential risk to patients, particularly those with weakened immunity. A Saudi study reported that conventional water treatment does not remove antibiotic-resistant bacteria, increasing the risk of infection within hospitals [19]

Comparison with standards:

Drinking water should contain no detectable *E. coli* or coliform bacteria in any 100 mL sample, and the WHO recommends turbidity below 1 NTU for effective disinfection. By these criteria, 14 of 30 samples (46.7%) failed for *E. coli*, 18 (60.0%) for total coliforms and 3 (10%) for turbidity. Against the Libyan standards, 11 samples (36.7%) exceeded the TDS limit and 28 (93.3%) exceeded the EC limit. These results show that water at many sampling points does not meet the criteria. Network deterioration and sewage intrusion are plausible explanations but were not investigated in this study.

Study limitations:

This exploratory study has several limitations. Sampling covered four months (May–August 2025) and temporal variability within points could not be. Residual chlorine, heavy metals, nitrate, hardness and opportunistic pathogens such as *Pseudomonas aeruginosa* and *Legionella* were not measured, although they are relevant to hospital water. The upper limits and units of some microbiological counts require clarification (Q5, Q8), and no statistical analysis was performed. The causes of contamination were not investigated.

Challenges:

The authors identified the following challenges; these were not assessed systematically in this study.

1. Lack of approved, clear standards and specifications for evaluating and monitoring the quality of water used in health facilities.
2. Lack of an equipped microbiology laboratory or qualified official external inspection bodies to monitor and analyze water quality.
3. Failure to provide sufficient financial allocations to finance the periodic and preventive maintenance programs necessary to maintain the efficiency of the water and wastewater infrastructure.
4. Lack of organized, continuous awareness programs to raise health and environmental awareness among hospital staff.

Conclusions:

This exploratory study found microbiological indicators of fecal contamination (*E. coli* in 46.7% and total coliforms in 60.0% of samples) and elevated EC and TDS in water samples from Tripoli Central Hospital. The cause was not investigated; mixing of wastewater with potable and utility water is a possible explanation that requires confirmation. These findings indicate a potential risk to patients and staff within the hospital environment. Of the 30 samples collected from water sources across the hospital departments, many did not meet Libyan national standards or WHO criteria for drinking water

with respect to microbiological indicators, EC, TDS or turbidity. Corrective measures are therefore needed, including improved water treatment, regular monitoring and strict quality control protocols to ensure a safe environment for patients and healthcare workers. Further studies with repeated sampling, residual chlorine measurement and investigation of contamination sources are recommended.

Recommendations:

1. Infrastructure. Sewage wells should be located far from potable water wells so that mixing cannot occur in the event of leaks or network failures.
2. Health awareness. Workers should be educated (capacity building) about the health risks of using contaminated water, whether for drinking or for other uses inside the hospital.
3. Technical training. Technical staff should be prepared, with a rapid-response plan, for leaks or collapse of the water networks and related water supply problems.
4. Biannual inspections. Inspections and periodic maintenance, for example every six months, should be conducted to solve small problems before they worsen and to avoid heavy losses.
5. Water treatment. A water purification system should be available in the hospital, particularly because it includes a dialysis department and many critical-care units and the water must comply with Libyan standards.
6. Microbiology laboratory. A microbiology laboratory should be available in the hospital to detect viable microorganisms.
7. Periodic control. Environmental inspection and supervision of staff should be strengthened to prevent negligence.
8. Budget. A dedicated budget should be allocated for the periodic maintenance and replacement of water and sewage networks.

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- **Conflicts of interest:** The authors declare no conflicts of interest related to this study.
- **Author contributions:** The authors contributed to the study conception and design, data collection, analysis and interpretation, manuscript preparation, and critical revision. All authors read and approved the final version of the manuscript.

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