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ASSESSMENT OF WATER QUALITY IN THE DISTRIBUTION NETWORK OF SULAYMANIYAH HOSPITALS, IRAQ: AN INVESTIGATION OF PHYSICAL, CHEMICAL, AND BACTERIOLOGICAL PARAMETERS

Sarkhell Araz Fadhl[1], Seenaa Muhammed Ali[2], Salar Ibrahim Ali[3]

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Abstract

Objectives: The primary objective of this study is to assess the physicochemical and microbiological safety of the water supply in the main sources (water tank and tab water) of Sulaymaniyah city hospitals, as it directly impacts the health of patients.

Methodology: This study involved collecting and analyzing water samples from twelve major hospitals in the city of Sulaymaniyah, Iraq. The samples were collected from the main sources of water and analyzed twice to ensure accuracy of data. The physical and chemical parameters assessed included pH, TDS, EC, hardness, as well as the concentrations of calcium, magnesium, chloride, sodium, nitrate, and sulfate. Microbiological analysis was also conducted using selective and differential chromogenic coliform agar (CCA) medium to count *E. coli*, total coliform, and heterotrophic bacteria in the water samples.

Results: The physicochemical parameters of water samples in hospitals were found to be within international standards, indicating that the chemical and physical quality of the produced water did not pose any health risks. However, the microbiological results revealed that the levels of Coliform and *E. coli* contamination exceeded the permissible limit, which could potentially pose health concerns.

Conclusion: Water samples in hospitals meet international standards for physicochemical parameters, but the presence of high levels of Coliform and E. coli contamination indicates potential health concerns related to the microbiological quality of the water produced. To address this issue, appropriate measures such as implementing proper water treatment protocols and regular monitoring are recommended to ensure safe consumption.

Keywords: Hospital water, physiochemical, Microbial, Chromogenic Coliforms Agar.

[1]Ali Naji Health center/corona clinic, Sulaimaniyah General Directors of Health, Iraq, sarkhellaraz@gmail.com

[2]Department of Nursing, College of Health and Medical Technology, Sulaimani Polytechnic University, Sulaimaniyah, Iraq

[3]Department of Nursing, College of Health and Medical Technology, Sulaimani Polytechnic University, Sulaimaniyah, Iraq

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Introduction

Ensuring an adequate supply of safe and potable water remains a significant challenge for many regions worldwide. Additionally, water scarcity and contamination can have far-reaching consequences on public health, agriculture, and economic development [1]. In healthcare settings, hospital water, water-related devices, moist environments, and aqueous solutions can all serve as reservoirs for waterborne pathogens. The hospital environment is particularly vulnerable to contamination by such pathogens due to factors such as suitable water temperatures for bacterial growth, as well as the complex structure of hospital water systems that can lead to stagnation, corrosion, and biofilm formation. Various water reservoirs have been linked to nosocomial outbreaks, including potable water, sinks, faucet aerators, showers, and tub immersion toilets[2]. Hospital water may be the most underappreciated, significant, and manageable source of nosocomial bacteria despite the fact that there are many hospital sources that contribute to nosocomial epidemics [3]. *E. coli*, a bacteria commonly present in the large intestine of warm-blooded animals including humans, can have commensal or pathogenic properties. While it exists in lower numbers than other commensal bacteria, it is the most frequent cause of intestinal and extra-intestinal diseases [4-6]. As an opportunistic pathogen, E. coli can cause a range of gastrointestinal diseases, including bloody diarrhea and urinary tract infections, in humans. In addition, it has been known to cause acute kidney failure, particularly in children [7]. These bacteria are commonly found in human and animal waste, making it an easily identifiable indicator of water pollution in both above ground and underground sources [8, 9]. The presence of this bacteria in water is a reliable indicator of fecal contamination [10].

Assessing the quality of a particular water source typically involves analyzing physical, chemical, and biological parameters, with human health risks arising when these values exceed prescribed limits [11, 12]. Water contains various dissolved substances, suspended solids, and dissolved gases, including certain mineral compounds that can be beneficial as essential nutrients, but when present in concentrations that exceed permissible levels, they may lead to various health problems and disorders Ensuring water quality is maintained typically involves safeguarding water sources, managing water treatment processes, and monitoring water quality during transmission and distribution through the network. Guidelines and regulations are based on regional and national conditions (socially, economically, and culturally). The importance of chemical constituents differs from microbial agents. Unlike microbial agents, which need a short time to show their impacts, chemical constituents need a longer time to show their impacts. In many conditions, it has been seen that water is inconsumable because of its taste, odor, and insufficient clarity of water [13, 14]. Chloride is a naturally occurring substance found in drinking water, as well as in domestic and industrial wastewater, urban runoff containing divalent salts, and the infiltration of saltwater into freshwater sources. However, high concentrations of chloride in drinking water can lead to corrosion in distribution networks [15]. The cause of water hardness is due to calcium and lesser magnesium and usually declaration as calcium carbonate. Depending on the content of the alkalinity, a hardness of more than 200 mg/l can create precipitation, especially when the water is heated. Waters with a hardness lesser than 100 mg/l have a little buffer capacity and may cause corrosion in pipes, Sulfate concentrations greater than 500 mg/L may cause an unpleasant taste and corrosion of pipes and installations [16, 17]. Mineral deposits in the water are the main source of sodium (Na). Deficiency or decrease in sodium levels in people causes low blood pressure, fatigue, mental apathy, and depression and an increase in level may cause brain stroke, kidney problems, nausea, headaches, hypertension, and stomach problem [18], On the other hand, the lack of basic cations such as calcium (Ca) and magnesium (Mg) can cause cardiovascular disease [19]. The basic and important element for myoglobin and hemoglobin and for numerous other enzymes is iron [20]. The higher level of iron (Fe) in the body also causes many health problems such as weakening of cardiovascular tissue, central nervous system, kidney, and liver, blood problems, vomiting, and diarrhea [21]. Under natural conditions, nitrate concentration in surface and underground water is very low. Nitrate can enter the water through different ways such as agricultural runoff, human or animal waste, and ammonia oxidation [22]. Water pollution affects the use of water and can pose risks to public health through the spread of diseases [23].

Access to safe and clean water in hospitals is crucial to protect the health of patients, visitors, and staff. However, there is a lack of recent research on the quality of water supply networks in hospitals, highlighting the need for continuous monitoring. To address this gap, the purpose of this study is to provide a detailed evaluation of the physical, chemical, and microbial quality of water sources in the distribution network of general hospitals in Sulaymaniyah city of. By filling this knowledge gap, this study aims to provide valuable insights that can help improve the safety and quality of hospital water supply networks, and ultimately enhance the well-being of patients, visitors, and staff.

Methods and Materials:

The current research is a descriptive-cross-sectional study that evaluates the water quality in all hospitals (12 hospitals) located in the center of Sulaymaniyah city. Water samples of 100 ml were collected in sterilized glass container from the main water supply tank of each hospital and transported to the laboratory for physical and chemical tests within 2-4 hours after collection. The tests were carried out based on standard methods for water and sewage examination. The laboratory tests included measuring the concentration of nitrite iron, sulfate, and manganese ions in water using a DR5000 model spectrophotometer. The parameters of hardness and alkalinity were determined by titration method. Total Dissolved Solid was measured according to the manual of standard gravimetric method at a temperature of 103-105 degrees Celsius. Magnesium, sodium, and potassium were measured using atomic absorption and flame photometric method. Sulfate was measured by colorimetry with turbidity and nitrate concentration was measured using the spectrophotometer method at a wavelength of 530 nm [24].

The microbial quality of the water in each hospital was assessed by collecting samples from seven different locations, namely the main tank, laundry, laboratory, sterilization room, staff area, ward, and main faucet. These samples were then tested for E. coli and coliforms, as well as the total aerobic plate counts. Specialized filtration paper with a thickness of 0.45 mm was used to filter 100 ml of each water sample, and the filter paper was placed on the surface of Chromogenic Coliforms Agar [1]. After inoculating the plates, they were incubated at 37°C for 24 hours, and the growth was quantified. The sampling process was conducted twice to ensure accuracy.

After recording the data in Excel software, statistical analysis of the data was conducted. The results were compared with international standards to evaluate the water quality in hospitals located in the center of Sulaymaniyah city.

Results:

Table 1 presents data on the physical and chemical factors of water samples collected from various hospitals. The mean values for electrical conductivity (EC), total dissolved solids (TDS), temperature, hardness (as $CaCO_3$), pH, chloride (Cl^-), sodium (Na^+), calcium ($CaCO_3^{++}$), magnesium (Mg^{++}), nitrate (as NO_3^-), and sulfate (SO_4^-) were 382.0 μS/cm, 321.8 mg/L, 22.27 °C, 293.9 mg/L, 7.4, 14.3 mg/L, 18.7 mg/L, 93.9 mg/L, 63.8 mg/L, 7.1 mg/L, and 34.2 mg/L, respectively. These mean values were compared against the WHO standards, the results showed that the physical-chemical parameters observed in the hospital settings generally met the established standards set by WHO.

Table 1: The Mean Physical and Chemical Parameters of Water Distribution Network Tanks in Hospitals

	Physical factors				Chemicals factors						
Hospitals	**EC, (electricals Conductivity)**	**Total Dissolved Solid**	**Temperature**	**Hardness (asCaCO3)**	**pH (Standard Units)**	**Chloride**	**Sodium Na+**	**Calcium Caco3++**	**Magnesium Mg++**	**Nitrate (as NO3-)**	**Sulfate SO4**
Shar hospital (General hospital)	706	451	24	220	7.1	20	4.3	136	84	3	71
Dr.Jamal hospital (Pediatric hospital)	376	369	19.5	242	7.1	11	5.3	59	53	4	43
Maternity Hospital	364	233	20.4	260	7.8	10	4.8	72	56	5	11
General Teaching hospital	302	193	16.2	260	7.6	14	19.3	80	55	0	30
Burn Surgery Hospital	329	210	18.4	200	7.2	8	11.5	48	43	0	34.8
Shahid Hemn hospital (Internal medical teaching hospital)	309	431	19.7	211	7.1	17	14.1	61	71	0	31
Sulaymaniyah cardiac hospital	311	199	19.8	240	7.6	20	20.7	64	52	5	21
Shahid Ghareb hospital (Dukan General hospital)	655	419	26.3	396	7.2	16	9.4	104	86	3	75
Hiwa hospital (Oncology hospital)	302	184	23.1	268	7.6	16	18.9	83	50	0	25
Shahid Aso hospital (eye and neurosurgical hospital)	290	230	22	260	7.6	19	18.3	79	62	11	21
Shahid salah hospital (Male psychiatric hospital)	284	467	29.5	490	7.4	8	47	176	63	20	25
Soz hospital (Female psychiatric hospital)	356	476	28.4	480	7.1	13	51	165	90	34	23
WHO standards	1000 µS/cm	1000 ppm	25 °C	500 mg/l	6.5 - 8.5	250 mg/l	200 mg/l	150 mg/l	100 mg/l	50 mg/l	250 mg/l
Mean Concentration	382.0	321.8	22.27	293.9	7.4	14.3	18.7	93.9	63.8	7.1	34.2

According to Figure 1: All the physical and chemical result are within the WHO standard.

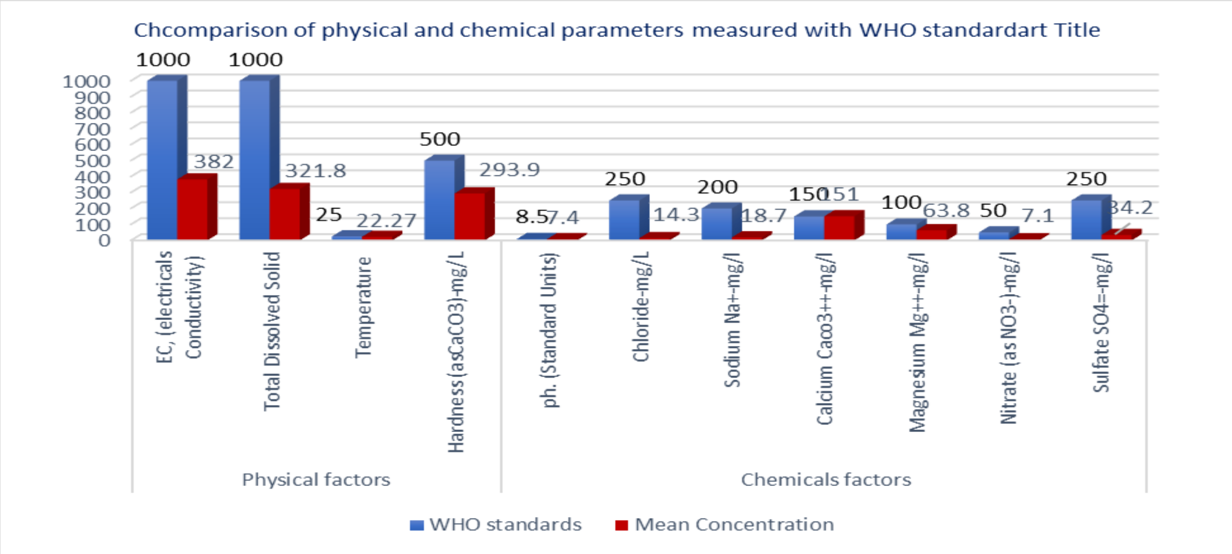
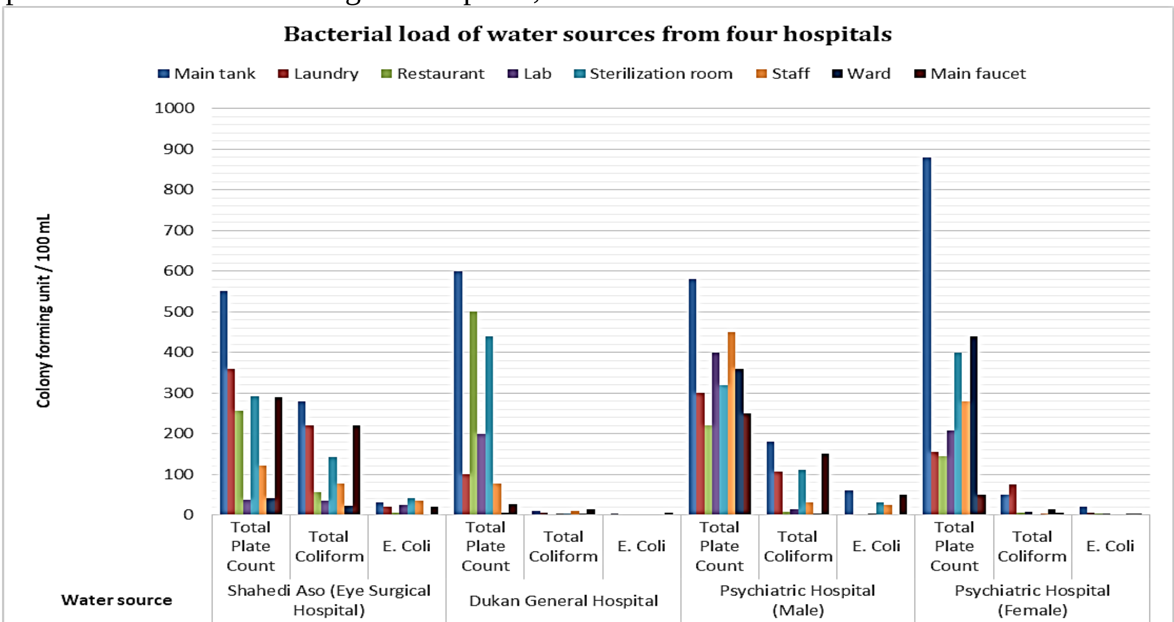


Figure 1: comparison of physical and chemical parameters measured with WHO standard

As illustrated in Figure 2, the microbiological investigation revealed that four out of the twelve hospitals had contaminated water. The results indicated that both E. coli and coliform bacteria were present in all water sources sampled from these four hospitals. The Psychiatric Hospital (Female) had the highest total plate count of water among the hospitals, while Shahidi Aso Hospital had the highest number of coliform and E. coli bacteria compared to the other hospitals. These findings emphasize the importance of implementing appropriate water management and disinfection measures in hospitals to ensure the safety of patients and staff.



Water source	Shahedi Aso (Eye Surgical Hospital)			Dukan General Hospital			Psychiatric Hospital (Male)			Psychiatric Hospital (Female)		
	Total Plate Count	Total Coliform	E. Coli	Total Plate Count	Total Coliform	E. Coli	Total Plate Count	Total Coliform	E. Coli	Total Plate Count	Total Coliform	E. Coli
Main tank	550	280	30	600	10	4	580	180	60	880	50	20
Laundry	360	220	20	100	6	1	300	107	2	155	75	5
Restaurant	256	56	6	500	2	1	220	8	2	145	5	3
Lab	38	34	24	200	3	1	400	14	4	208	8	4
Sterilization room	292	142	42	440	3	1	320	110	30	400	2	1
Staff	122	78	36	78	10	2	450	30	25	280	3	1
Ward	42	22	2	6	3	1	360	3	2	440	14	4
Main faucet	290	220	20	26	14	6	250	150	50	50	5	3

The Chromogenic Coliform Agar medium is both selective and differential, enabling the enumeration of coliform and E. coli bacterial load in water based on the appearance of specific colors. Specifically, E. coli appears as blue and coliform appears as pink, while other bacteria appear as colorless or yellow, as depicted in Figure 3.

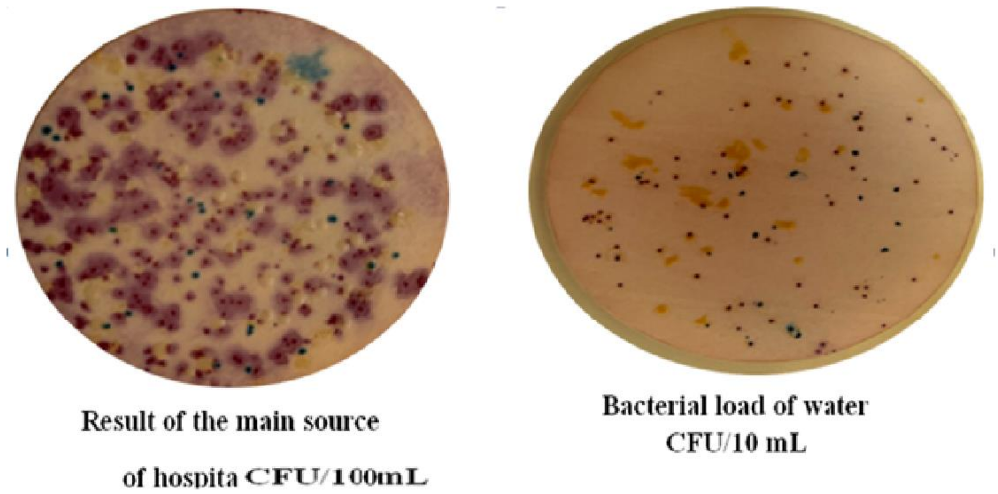


Figure 3: The colony color variations on CCA medium. *E. coli* colonies appear blue, coliform colonies appear red or pink, while other bacteria colonies appear colorless or yellow.

Discussion:

Water quality monitoring is crucial for ensuring the safety and health of the public, as well as protecting the environment. With the increasing population and industrialization, there is a growing concern about the contamination of water sources and the potential adverse effects on human and ecosystem health.

One of the important parameters in checking the quality of tap water in any region is water PH. According to the guidelines of the World Health Organization, the permissible range of pH for drinking purposes is 6.5 to 8.5 [25]. The results of the water pH variable investigation showed that the mean pH of the studied water samples was 7.35, which is within the permissible range of drinking water. This finding is consistent with the study of Ghalib et al (2017) [26]. One of the important parameters that determine the quality of water is the electrical conductivity (EC) of water. The National Standards Institute of the country has set the limit of electrical conductivity of drinking water as 1000 micro-siemens/cm [27]. The minimum and maximum electrical conductivity in the main sources of the water distribution network of hospitals were 284 and 706, respectively, and the mean was 376.46 siemens/cm. According to the national standard, drinking water is within the standard range in terms of electrical conductivity. Electrical conductivity of more than 1500 micro-siemens/cm causes corrosion of iron structures and pipes of urban water distribution network [28].TDS of total dissolved solids (mg/L): includes inorganic salts and a small number of organic substances (Ca^{+2}, Mg^{+2}, K^{+}, Na^{+}, HCO_3^{-1}, Cl^{-}, SO_4^{-2}) [29,30]. In this study, the minimum and maximum TDS levels of water samples were 184 and 476, respectively, and the mean was 314.08 mg/L. The current results were consistent with the mean determined in Iraq [31,32]. Total Hardness (mg/L) is used to describe the effect of dissolved calcium and magnesium, evaluating solubility in drinking, domestic and industrial water. It is accompanied by the presence of (HCO_3^{-1}, SO_4^{-2}, Cl^{-1}, and NO_3^{-1} of Ca and Mg) [33].

Water quality can be evaluated by measuring the content of chloride, which includes Ca^{+2}, Mg^{+2} salt, and K^{+} anion. High levels of chloride may indicate contamination from domestic sewage and industrial waste [34]. Sulfates, particularly magnesium and sodium sulfates, can cause diarrhea in humans when present in high concentrations in drinking water. Calcium sulfate, on the other hand, causes permanent water hardness. The source of sulfate in water can either be natural or from liquid waste from industries [35]. Elevated chloride concentrations in surface waters can have a more significant impact on water quality. Chronic chloride concentrations exceeding 250 mg/L are harmful to freshwater life and not suitable for human consumption [36]. Water with chloride levels exceeding 250 mg/L may have a distinct salty taste and may contain harmful impurities from road salt, posing potential health risks to humans [37]

Furthermore, it should be noted that higher concentrations of chlorides can reduce the antibacterial effectiveness of disinfectants [38]. The study evaluated the microbial quality of tap water in terms of chloride concentration and its effect on bacterial reduction. The results demonstrated a decrease in the number of bacteria with increasing chloride concentration. The mean chloride concentration in the current study was found to be 14.62 mg/liter, which is significantly lower than the WHO recommended limit of 250mg/L. Therefore, it can be inferred that the quality of tap water in terms of chloride content is within normal limits. Excessive chloride levels can lead to corrosion and taste issues, as well as negatively impacting water quality. Studies by Mahdii et al. (2016) and Naji et al. (2011) support these findings [27, 31]. Chloride concentration in excess of 250 mg/L can also cause detectable taste in water [39]. The mean concentration of Ca and Mg ions were also at an acceptable and safe level. The results were consistent with other studies in Iraq, Baghdad, and Erbil [27,32, 40, 41].

The microbial quality of the water samples was assessed by measuring the total coliform bacteria (TC) present. All over the world, total coliforms are used as a reliable microbial index to determine the microbial quality of water and to determine laws and standards for different models of water and wastewater use. Most of the laws and standards have been established with a strong reliance on coliform bacteria as a suitable tool for determining the microbiological health of water and wastewater [33,42]. Coliforms are a group of microorganisms that reside in the intestines of humans, warm-blooded, and cold-blooded animals in significant quantities, where they assist in food digestion. TC indicates the presence of pathogens that can cause many waterborne diseases [43,44].

The detection of coliform bacteria in water is an indication that the water may be contaminated with fecal matter from animals or humans. As a result, the presence of harmful pathogens that can cause numerous diseases transmitted through water is possible. Based on the study findings, it was observed that the microbiological quality of all the samples of the main sources of water supplying the hospitals were contaminated. A high concentration of total fecal coliform bacteria and fecal coliforms in water is a sign of water contamination with human or animal feces [45, 46]. *E. coli* is the best type of coliform bacteria, which is an indicator of fecal contamination caused by human or animal sewage. The presence of this bacterium in water is more indicative of fecal contamination because it is present in large numbers in faces and generally does not exist anywhere else in nature[47].

The World Health Organization (WHO) has established guidelines for safe drinking water that includes limits for microbial contamination. According to WHO guidelines, drinking water should not contain more than 0 colony-forming units (CFU) of fecal coliform bacteria or *Escherichia coli* per 100 ml of water [48].

Based on the results of the microbial contamination of the four hospitals, it can be seen that all the water sample have higher level of microbial contamination compared to WHO guidelines. All hospitals have high levels of total coliforms and E. coli, indicating a potential risk for fecal contamination in their water sources.

The Aerobic Heterotrophic plate count (HPC) is a commonly used technique for microbiological testing and safety management of drinking water. It has been utilized in this field for a considerable period, dating back to the late 1800s. Its original purpose was to evaluate the efficacy of water treatment systems, such as disinfection and filtration, and indirectly measure water safety. However, with the introduction of fecal indicators like coliforms and enterococci during the 20th century, HPC's use as a safety gauge declined. Nonetheless, numerous countries still integrate HPC measurements and limits into their water regulations and guidelines [49].

The CDC has set a standard for potable water that requires the total Heterotrophic plate count to be below 500 CFU/ml. Elevated Heterotrophic plate counts can be an indication of the presence of harmful bacteria in the potable water, such as Legionella, Pseudomonas, and Mycobacteria, which can pose a risk to public health. These bacteria can cause infections and illnesses, particularly in immunocompromised patients [50].

The results of this study showed that the Heterotrophic plate count levels in the water tank of the four hospitals were more than 500 CFU/mL, indicating a general decrease in water quality and potential risks to public health. These results suggest that the water systems in the four hospitals may contain harmful bacteria that can pose a risk to patients and staff. Therefore, it is crucial for hospitals to implement appropriate remediation measures and conduct regular monitoring of the Heterotrophic plate counts to ensure the safety of potable water, in accordance with the CDC standard. The remediation measures may include implementing a comprehensive water management plan, such as regular disinfection and maintenance of the distribution system. To further minimize the risk of waterborne infections, hospitals should consider installing filtration systems near the point of use.

In general, the goal of water quality testing in a hospital setting is to ensure that the water is safe for use by patients, staff, and visitors. This result of this study indicates a high number of bacteria in the water tank than the water collected from the faucets in different location of the hospital. One possibility is that the water tank is not properly cleaned and maintained, which could lead to the accumulation of bacterial growth and contamination. This could be due to a lack of regular cleaning and maintenance procedures, or inadequate disinfection of the water tank. Another possibility is that the bacteria are being introduced into the water tank through external sources, such as through leaks or breaks in the water supply system. This could allow bacteria to enter the tank and proliferate, leading to high levels of contamination. Some of these reasons include: location of the faucet which can impact the quantity of bacteria found in the water. For example, a faucet located closer to the water tank may have a higher bacterial load as compared to a faucet located further away. Also, faucets that are used less frequently may have a higher bacterial load as the water in the pipes may remain stagnant for longer periods, allowing bacteria to grow. In addition, the condition of the pipes carrying the water from the tank to the faucet can also impact the quantity of bacteria found in the water. Old or corroded pipes may have a higher bacterial load as compared to newer, well-maintained pipes

Therefore, it is important to conduct regular testing of the water quality in different areas of the hospital to monitor for any changes or trends in the bacterial load, and identify any potential issues or areas for improvement in the water treatment and distribution systems.

Conclusion

Based on the findings of the survey, it can be concluded that the physical and chemical parameters of the main reservoirs in city hospitals do not pose any health risks. However, the bacterial analysis conducted during the study revealed the existence of coliform and *E. coli* bacteria in the hospitals' main water supply. Coliform bacteria are often associated with human and animal waste contamination in water, which could potentially harm human health. The study suggests that the contamination may be due to various reasons, such as outdated urban plumbing projects or improper filtration and rainfall processes. To prevent such contamination, special attention should be given to the chlorination process during water disinfection. Therefore, it is crucial to implement proper measures to ensure the safety of the hospital water supply and prevent the spread of waterborne diseases.

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Conflicts of Interest: The authors state that they do not have any conflicts of interest.

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