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Evaluation Drinking Water in the Pediatrics and Kirkuk Educational Hospitals Within City of Kirkuk

Nadya Esmaeel Mustafa[1], Riedh Abass Abdul Jabbar [1], Mahmood K. Saleh[2]

[1] *Department of Biology, College of Science, Tikrit University, Tikrit, Iraq*

[2] *Department of Biology, College of Education for Pure Science, Tikrit University, Tikrit, Iraq*

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ABSTRACT

The study involved collecting drinking water samples from Kirkuk Teaching Hospital (A) and the Hospital of Pediatrics (B), with three sampling sites in each hospital. Sampling occurred once a month from 8:00 AM to 2:00 PM, starting from September 2022 until January 2023. The biological examination involved culturing blood agar and Mannitol salt agar to detect *Staphylococcus aureus* bacteria, but none were found. Instead, other bacteria appeared, which were not the focus of our study. These included three types: *Kocuria rosea, Kocuria rhizophila, Kocuria kristinae, Alloiococcus otitidis, and Serratia marcescens*. Physicochemical tests conducted included temperature (T), pH value (pH), electrical conductivity (EC), biochemical oxygen demand (BOD_5), and total dissolved solids (TDS). Temperature and pH levels were within the natural range recommended by the World Health Organization. However, the biochemical oxygen demand was very high in both hospitals, and total dissolved solids were within the natural range at Kirkuk Teaching Hospital (A) but were elevated at the Hospital of Pediatrics (B) in September only.

Keywords: Drinking Water, *Staphylococcus aureus*, Biochemical oxygen demand (BOD5), Total dissolved solids (TDS)

Name: Nadya Esmaeel Mustafa **E-mail:** nadiaaljoboury@gmail.com

تقييم مياه الشرب في مستشفى الأطفال وكركوك التعليمي ضمن مدينة كركوك

نادية إسماعيل مصطفى[1]، رياض عباس عبد الجبار[1]، محمود خلف صالح[2]

[1]قسم علوم الحياة، كلية العلوم، جامعة تكريت، تكريت، العراق

[2]قسم علوم الحياة، كلية التربية للعلوم الصرفة، جامعة تكريت، تكريت، العراق

الملخص

تضمنت الدراسة جمع عينات مياه الشرب من مستشفى كركوك التعليمي (A) ومستشفى الأطفال (B) وبواقع ثلاثة مواقع في كل مستشفى وبدأت عملية جمع العينات مرة واحدة في الشهر من الساعة الثامنة صباحاً الى الساعة الثانية بعد الظهر وقد بدأت هذه العملية من شهر ايلول 2022 ولغاية شهر كانون الثاني 2023. ولغرض الفحص البايولوجي حيث تم زراعتها على وسط blood agar و Manitol salt agar للبحث عن بكتريا *Staphylococcus aureus*. لكن لم يتم الحصول على بكتريا المطلوبة وبدلًا من ذلك، ظهرت بكتيريا أخرى، لم تكن محور دراستنا. وشملت هذه ثلاثة أنواع: *Kocuria rosea*، *Kocuria rhizophila*، *Kocuria kristinae*، *Alloiococcus otitidis*، و*Serratia marcescens*. اما الفحوصات الفيزيوكيميائية فقد اجريت اختبارات الحرارة (T)، الدالة الحامضية (pH)، التوصيلية الكهربائية (EC)، المتطلب الحيوي للأوكسجين (BOD_5) والمواد الصلبة الذائبة الكلية (TDS) فقد كانت الحرارة والدالة الحامضية ضمن النسبة الطبيعية لمنظمة الصحة العالمية، بينما المتطلب الحيوي للأوكسجين عالي جدًا في كلا المستشفيات والمواد الصلبة الذائبة الكلية في مستشفى كركوك التعليمي(A) ضمن النسبة الطبيعية بينما في مستشفى الاطفال (B) عالية في شهر ايلول فقط.

INTRODUCTION

Water contamination poses a worldwide risk to biodiversity and human health. Urbanization and industrialization have led to an increase in the usage of chemical pesticides, mining, and other human induced processes in order to enhance global food security. These actions lead to the degradation of water bodies and a rise in morbidity rates [1, 2]. Water pollution, in general, is characterized by a change in biological, physical, and chemical properties that lead to a change in the basic characteristics of water, such as color, smell, and taste, which negatively affects human health [3]. Water, in particular, is more susceptible to pollution because of its property known as the universal solvent, that is, dissolving many substances in a greater way than any liquid. It also helps dissolve agricultural and chemical fertilizers, pesticides, and various factory wastes [4]. Water pollution causes many environmental risks the most important of which is the environmental pollution of drinking water, which is caused by pathogenic organisms such as fish that humans feed on due to their exposure to biological toxins and their accumulation in their bodies. Among these diseases, such as typhoid, cholera, amoebic dysentery, and others [5]. Therefore, this current study aimed to know the quality of water in some Kirkuk hospitals by studying some physical, chemical and biological characteristics and determining the suitability of this water for drinking. and understanding the environmental factors that contribute to the relative spread of these bacteria within hospitals.

MATERIALS AND METHODS

Geographical Area

Samples were collected from Kirkuk Teaching Hospital and the Hospital of Pediatrics, with three sites in each hospital. The sampling process began once a month from 8:00 AM to 2:00 PM, starting from September 2022 until January 2023. The tests were conducted at the Kirkuk Water and Sewage

Directorate. The current study discusses the quality of drinking water at Kirkuk Teaching Hospital (Hospital A) with a latitude: about (35.4696°N) and Longitude: approximately (44.3927°E) and the Hospital of Pediatrics (Hospital B) with latitude: about (35.4682°N) and Longitude: approximately (44.3921°E). The two locations are very close to each other, as they are located in a central area of Kirkuk city, which makes moving between them easy**,** over a four-month period: September 2022, October 2022, December 2022, and January 2023**.** Figure (1) indicates the locations of the hospitals where our study took place.

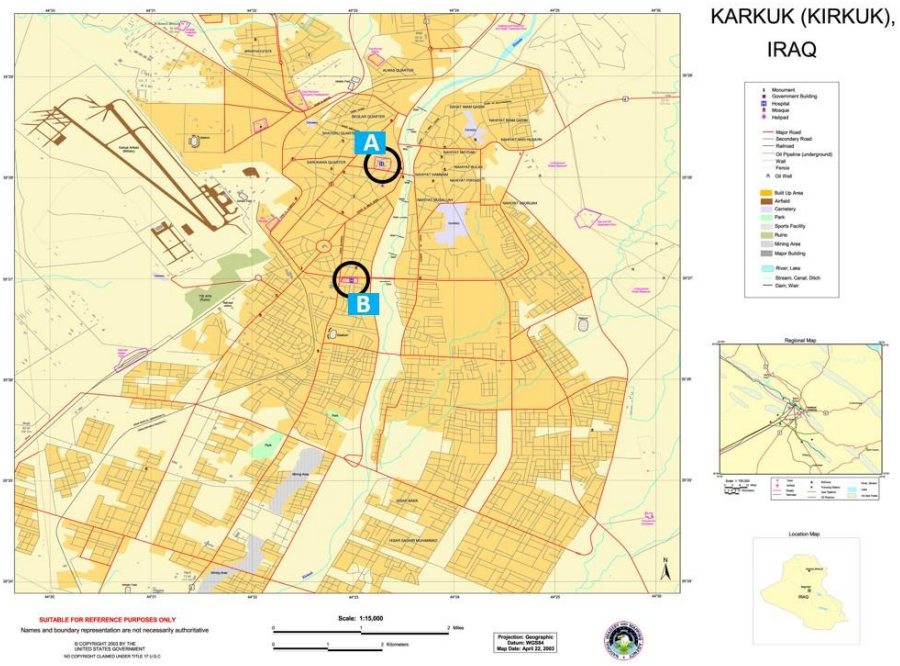

Fig. 1: The location of hospitals.

Collection of Samples

Samples were collected from water tanks and Sewage Directorate in Kirkuk. Special containers were used for collection, ensuring they were washed thoroughly with station water two or three times before filling to eliminate any air bubbles and be tightly sealed. Containers were used for sample collection for physical, chemical, and biological examinations. The samples were cultured on blood agar and Mannitol salt agar to detect *Staphylococcus aureus* (*S. aureus*) bacteria.

Culture Characteristics and Morphology

After collecting drinking water samples and culturing them on appropriate media to detect *S. aureus* bacteria, the desired bacteria did not grow after the incubation period. Therefore, diagnosis has resorted to the Vitek-2 Compact System technology was only used to ensure the isolated are not S. *aureus*.

Physical and Chemical Properties of Water

The physical and chemical properties of water are essential factors in evaluating the quality and suitability of water, where temperature T, pH, biological oxygen demand BOD_5, electrical conductivity EC, and total dissolved solids TDS were measured**.**

Statistical Analysis

An electronic calculator was used to implement the statistical program for statistical system (SPSS) [(6)], where it used analysis of variance (ANOVA) test. This analysis shows the presence or absence of significant differences in the variables studied**,** The Duncan test[(7)]. was also used It is a complementary test to the analysis of variance test at significance level of ($p \leq 0.05$)**,**

And Pearson correlation coefficient was also used the correlation coefficient is used to find the extent of the relationship between these studied variables at significance level of ($p \leq 0.05$) or ($p \leq 0.01$).

RESULTS AND DISCUSSION

Isolation and Identification

This part of the study aimed to isolate *S. aureus* bacteria from drinking water in the aforementioned hospitals and study their physical and chemical properties. After collecting drinking water samples and culturing them on appropriate media to detect *S. aureus* bacteria, the desired bacteria did not grow after the incubation period. Instead, other bacteria appeared, which were not the focus of our study. These included three types: *Kocuria rosea, Kocuria rhizophila, Kocuria kristinae, Alloiococcus otitidis, and Serratia marcescens*. Through research, it has been found that it is difficult to identify these genera through biochemical tests due to their similarity to other pathogenic agents such as *S. aureus*. This is the main reason for the delay in diagnosing the bacteria and determining early treatment, especially in pediatric medicine. Recent studies have shown that infections occur among immunocompromised children, especially those with renal failure [8]. Therefore, diagnosis has resorted to the Vitek-2 Compact System technology was only used to ensure the isolated are not *S.aureus*. Through analyzing various water quality standards, including temperature (T), (pH), biochemical oxygen demand (BOD_5), total dissolved solids (TDS), and electrical conductivity (EC), we can identify trends, relationships, and potential areas for improvement. The study examined and interpreted reasons for fluctuations in environmental standards and their effects on drinking water. The first test conducted was for temperature, which is considered one of the most important assessments in water sample analysis to understand its characteristics such as viscosity and density [9, 10]. The temperature at Kirkuk Teaching Hospital (A) was (25.5 ºC) in September, then decreased in October and further declined in December. It slightly increased again in January, reaching (17.8 ºC). At the Hospital of Pediatrics (B), the temperature was (24.4 ºC) in September, increased slightly in October, then decreased again in December. It rose in January and reached 16.4 degrees Celsius, as shown in Table (1).

Table 1: Monthly and spatial variations in water temperature during the study period highlight significant fluctuations that impact water quality assessment.

Coefficient	Month	Hospital	Average	Standard deviation	Error of standard Deviation	Sig
T	Sept 2022	A	25.5	0.25	0.14	N.S.
		B	24.4	0.35	0.2	
	Oct 2022	A	24.6	0.21	0.12	**
		B	25.3	0.38	0.22	
	Dec 2022	A	17.5	2.24	1.29	*
		B	14.7	1.04	0.6	
	Jan 2023	A	17.8	1.4	0.81	N.S.
		B	16.4	1.63	0.94	

Regarding electrical Conductivity value is an index used to estimate the amount of dissolved minerals in water samples [11]. the conductivity at Kirkuk Teaching Hospital (Hospital A) was 495 µS/cm in September, slightly increased in October, significantly increased in December, and continued to rise in January to 972.3 µS/cm. In the Hospital of Pediatrics (Hospital B), conductivity was 1597 µS/cm in September, decreased in October, further declined in December, and decreased to 107.7 µS/cm in January, as indicated in Table (2).

Table 2: The monthly and spatial variations in electrical conductivity values (µS/cm) during the study period.

Coefficient	Month	Hospital	Average	Standard deviation	Error of standard deviation	Sig
EC	September 2022	A	495	4.58	2.65	**
		B	1597	147.76	85.29	
	October 2022	A	714	216.88	125.22	***
		B	861.3	44.11	25.46	
	December 2022	A	880.7	285.91	165.07	N.S.
		B	110	9.17	5.29	
	January 2023	A	972.3	294.41	169.98	*
		B	107.7	6.66	3.84	

Regarding acidity (pH), it has an impact on many chemical reactions and transformations that occur in the aquatic environment [12]. At Kirkuk Teaching Hospital (A), the pH level was 6.6 in September and slightly increased in October, continuing to rise in December before stabilizing at (7.3) in January. Meanwhile, at the Hospital of Pediatrics (B), the pH level was (7.1) in September, with a slight increase in October, followed by further increases in December and January, reaching (7.8) as shown in Table (3). Meeting both WHO and Iraqi criteria, the pH concentrations are normally in the narrow range and somewhat alkaline [13].

Table 3: The monthly and spatial variations in pH levels during the study period.

Coefficient	Month	Hospital	Average	Standard deviation	Error of standard deviation	Sig
PH	September 2022	A	6.6	0.10	0.06	N.S
		B	7.1	0.15	0.09	
	October 2022	A	6.8	0.06	0.03	**
		B	7.5	0.15	0.09	
	December 2022	A	7.2	0.51	0.30	**
		B	7.3	0.12	0.07	
	January 2023	A	7.3	0.45	0.26	N.S.
		B	7.7	0.12	0.07	

Regarding the Biological Oxygen Demand (BOD_5), which measures the amount of oxygen consumed by living organisms during the breakdown of organic matter under specific temperature and atmospheric conditions over a specified period, this test is essential for assessing drinking water quality [14].
In Kirkuk Teaching Hospital (A), the BOD level was (10 mg/L) in September and October, increased in December, and then decreased again in January to (13.3 mg/L). In the Hospital of Pediatrics (B), the BOD_5 levels were consistently (10 mg/L) in September, October, and December, but varied between (10-30 mg/L) in January, as shown in Table (4).

Table 4: Monthly and spatial variations in biochemical oxygen demand (BOD_5) (mg/L) during the study.

Coefficient	Month	Hospital	Average	Standard deviation	Error of standard Deviation	Sig.
BOD_5	September 2022	A	10.0	0.00	0.00	N.S.
		B	10.0	0.00	0.00	
	October 2022	A	10.0	0.00	0.00	N.S.
		B	10.0	0.00	0.00	
	December 2022	A	20.0	5.77	3.33	**
		B	10.0	0.00	0.00	
	January 2023	A	13.3	5.77	3.33	*
		B	20.0	10.00	5.77	

Total Dissolved Solids (TDS) are solid materials dissolved in water in either ionized or non-ionized states, excluding suspended matter or gases dissolved in the solution. These tests are crucial as they serve as important indicators of water quality suitable for drinking, washing, and other uses [15]. At Kirkuk Teaching Hospital (A), TDS levels were (372.7 mg/L) in September, decreased in October, increased again in December, and further rose to 386.3 mg/L in January. Meanwhile, at the Hospital of Pediatrics (B), TDS levels were (706.7 mg/L) in September, decreased in October, decreased further in December, and continued to decrease in January to (42.3 mg/L), as shown in Table (5). According to the WHO classification our result was less than the limitation [13].

Table 5: Monthly and spatial variations in total dissolved solids (mg/L) during the study period.

Coefficient	Month	Hospital	Average	Standard deviation	Error of standard deviation	Sig.
TDS	September 2022	A	372.7	137.63	79.47	**
		B	706.7	37.86	21.86	
	October 2022	A	328.7	100.13	57.81	*
		B	398.7	21.03	12.14	
	December 2022	A	351.3	124.60	71.94	N.S.
		B	41.7	1.53	0.88	
	January 2023	A	386.3	113.61	65.59	*
		B	42.3	0.58	0.33	

A statistical analysis was conducted to determine the nature of relationships among the five factors, as presented in Table (6).

Table 6: Relationship between variables.

Parameter	T	Ph	BOD	TDS	EC
T	1.000	-0.243	-0.482	0.435	0.402
Ph	-0.243	1.000	0.691	-0.402	-0.412
BOD	-0.482	0.691	1.000	-0.364	-0.372
TDS	0.435	-0.402	-0.364	1.000	0.999
EC	0.402	-0.412	-0.372	0.999	1.000

DISCUSSIONS

When studying Table (1), it is evident that temperatures in both hospitals are significantly influenced by seasonal variations. Lower temperatures during winter months reduce microbial activity, which can enhance water quality. Despite similar seasonal trends, there are slight differences in temperatures between the hospitals. This could be due to variations in water sources or storage practices. Identifying these differences can aid in improving water treatment processes. The temperatures in both hospitals were within the normal and expected range for drinking water according to environmental standards [16]. consistent with findings by [17-20]. While these results were less than those reached by in [21, 22]. While it was higher than what he achieved [23-25]. Table (2) showed a difference in the results between the two hospitals, as the Hospital of Pediatrics B experienced higher EC levels in September 2023, but improved significantly in the following months. This difference could be due to differences in water sources or the effectiveness of treatment processes.

High EC levels could indicate high concentrations of dissolved ions, which can affect the taste and quality of water. They are also related to TDS levels, so both parameters should be managed in conjunction. The electrical conductivity values in both hospitals were within the normal and expected range for drinking water according to the World Health Organization standards, reflecting an appropriate concentration of dissolved ions [16]. The results of this study were close to the results of the study reached by [19]. While these results were less than those reached by [20, 21, 26]. While it was higher than what he achieved [18, 27]. In Table (3), the data reveals that Hospital B tends to have more alkaline water compared to Hospital A. This difference could stem from variations in water sources or treatment processes. The pH values in both hospitals were within the normal and expected range for drinking water according to World Health Organization standards [16]. These results closely align with those reported by [27, 28]. which were lower than those reported by [17, 19, 21, 23]. While it was higher than what he achieved [17]. In Table (4), the data reveals differences between the hospitals, where Hospital B showed significantly higher variability in BOD_5 levels in January 2023 compared to Hospital A. This necessitates a detailed study of water sources and treatment processes at each hospital to ensure water quality preservation. The BOD_5 values in both hospitals were much higher than the acceptable standard set by the World Health Organization[16]. indicating organic pollution that requires treatment. These results were higher than those reported by [19]. and also higher than those reported by [17]. when studying some water stations in Salah al-Din, with values ranging from (0.2 to 2.3 mg/L). High BOD_5 levels indicate significant amounts of biodegradable organic matter, which can deplete dissolved oxygen in water. This can lead to undesirable anaerobic conditions affecting water quality and consumer health [29]. In Table (5), the data shows differences between the hospitals indicating that Hospital B had higher TDS levels in September 2022, but there was a significant improvement in subsequent months. This difference could be attributed to variations in water sources or the effectiveness of treatment processes. The TDS values in Hospital A remained within acceptable limits according to the World Health Organization standards for most of the times, whereas Hospital B exceeded the acceptable limit only in September 2022 [16]. These results were similar to what each of them reached by [19, 28]. and also higher than those reported by [18, 23, 27, 30]. which were lower than those reported by [21, 31]. High TDS levels can lead to an unacceptable taste of water and diminish its drinkability, potentially indicating contamination by dissolved solids or minerals [16]. In Table (6) a statistical analysis was conducted to examine relationships between five factors. There was a negative correlation between temperature (T) and pH. As temperature increases, pH decreases, making the water more acidic. This might require water treatment adjustments. Conversely, there was a positive correlation between temperature and TDS. Increasing temperature leads to increased dissolved solids, likely due to higher chemical activity at elevated temperatures. Furthermore, a positive relationship between T and EC is evident, which can be explained by the fact that an increase in temperature increases the movement of ions in water, thereby increasing EC. On the other hand, statistical analysis showed a negative relationship between pH and EC, indicating an inverse relationship between them. This may suggest that water with higher acidity (lower pH) may contain higher concentrations of ions, thereby increasing EC. However, according to the table, the relationship between pH and TDS is inverse, meaning that water with higher acidity may contain higher levels of dissolved solids, thereby increasing TDS. However, the results showed a strong positive relationship between TDS and EC, indicating that any change in TDS will directly and similarly affect

EC, emphasizing the importance of monitoring both indicators together to ensure water quality. Controlling TDS levels will also enable us to control EC levels, and vice versa. Either variable can be used as an indicator of the other. However, BOD_5 did not show a strong correlation with the other parameters due to its stable values in most months, except for some occasional increases. This highlights the importance of promptly addressing specific pollution events.

CONCLUSION

Based on the physical and chemical tests conducted on drinking water, the temperature and pH were within the normal range according to World Health Organization standards. However, the biological oxygen demand (BOD_5) was very high in both hospitals. Total dissolved solids (TDS) were within normal limits at Kirkuk Teaching Hospital, while they were high at the Hospital of Pediatrics in September only.

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