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A Study of Drinking Water Properties in Some Hospitals in Baghdad City

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Abstract
One of the bigger problems in drinking water is disinfection by-products (DBPs) that come from chlorinated disinfection. This study's goal was to evaluate the drinking water in Al-Yarmouk Teaching Hospital, Ibn Sina Hospital and Ibn-Al-Nafis Hospital**.** Samples were collected between October 2018 and September 2019. Physical and chemical characteristics of the water were studied, including (temperature, hydrogen ion (pH), total dissolved solids (TDS), electrical conductivity (EC)**,** turbidity, free residual chlorine, total organic carbon (TOC), total trihalomethanes (THMs), total halo acetic acid (THAAs)). Data analysis showed the highest value of study temperature, pH**,** TDS**,** EC**,** turbidity**,** free residual chlorine and TOC **which** was 37ºC, 8.4**,**790 mg/l, 1251 µS/cm^{-1}, 15 NTU, 1.7 mg/l, and 6.7 mg/l respectively. Total trihalomethanes (THMs) results of drinking water samples from different sites showed that the highest value was 129.6 µg/l in Ibn Sina Hospital during summer while the lowest value was 41.3 µg/l in Ibn Sina Hospital in winter. The results of total halo acetic acid (THAAs) of drinking water sampled from different sites showed that the highest value of 72.9 µg/l was recorded in the sample collected from Ibn Sina Hospital during summer and the lowest THAAs water content of 40.2 µg/l was obtained in the sample collected from Ibn-Al-Nafis during winter. The results of this research were acceptable and within the range of Iraqi standards.

Keywords: Drinking, Water, Disinfection by-Products (DBPs), Hospitals, Baghdad

دراسة خواص مياه الشرب في بعض مستشفيات مدينة بغداد

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الخلاصة
واحدة من أكبر المشاكل في مياه الشرب هي المنتجات الثانوية التي تأتي من التعقيم بالكلور. تهدف هذه الدراسة إلى تقييم مياه الشرب في مستشفى اليرموك التعليمي ومستشفى ابن سينا ومستشفى ابن النفيس ودراسة محتوى نواتج التعقيم الثانوية (DBPs). تم جمع العينات في الفترة ما بين تشرين الاول 2018 وايلول 2019 اذ تمت دراسة الخصائص الفيزيائية والكيميائية ، بما في ذلك درجة الحرارة، الأس الهيدروجيني (pH)، إجمالي المواد الصلبة الذائبة (TDS)، الموصلية الكهربائية (EC)، التعكر و الكلور المتبقي الحر و الكربون العضوي الكلي (TOC)، إجمالي ثلاثي هالو الميثان(THMs)) و إجمالي حامض الخليك الهالوجيني (THAAs). أظهر تحليل البيانات أعلى قيمة لدرجة حرارة الدراسة ، درجة الحموضة ، TDS ، EC ، التعكر، الكلور المتبقي الحر و TOC فقد كانت 37 درجة مئوية ، 8.4.790 ملجم / لتر ، 1251 مايكرومتر / سم −1 ،

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15 وحدة NTU، 1.7 مجم / لتر ، و 6.7 مجم / لتر على التوالي. كما أظهرت النتائج الكلية لمياه الشرب من مواقع مختلفة أن أعلى قيمة لـ THM كانت 129.6 ميكروجرام / لتر في مستشفى ابن سينا خلال فصل الصيف بينما كانت أقل قيمة 41.3 ميكروجرام / لتر في مستشفى ابن سينا أيضاً في فصل الشتاء، وأظهرت النتائج THAAs لمياه الشرب المأخوذة من مواقع مختلفة أن أعلى قيمة سجلت 72.9 ميكروجرام / لتر في مستشفى ابن سينا في فترة الصيفوأقل تركيزمن HAA بلغ 40.2 ميكروغرام / لتر في مستشفى ابن النفيس خلال فصل الشتاء.كانت النتائج مقبولة ومتوافقة مع المواصفات القياسية العراقية.

Introduction

Healthcare-associated infections (HAIs) cause roughly 1.7 million infections and 99,000 deaths in American hospitals each year, according to the US Centers for Disease Control and Prevention. They have also recognized that hospital tap water is a source of such infections [1]. According to one study, *Pseudomonas aeruginosa* is responsible for 1400 deaths each year due to watery nosocomial pneumonia. Despite concerns about the rising occurrence of serious HAIs caused by multidrug-resistant gram-negative bacteria, the risk of these microorganisms being transmitted through water has received little attention [2].

All water for hospitals, health centres and feeding centres should be treated with chlorine or any other residual disinfectant. In situations where water is likely to be rationed by an interruption of supply, sufficient water storage should be available at the centre to ensure an uninterrupted supply at normal levels of utilization [3].

Because of both the complex nature of their drinking-water systems and the sensitivities of their occupants, hospitals, nursing care homes, other health care facilities, schools, hotels and some other large buildings are high-risk environments. Requirements similar to those outlined above for other large buildings apply, but heightened vigilance in control measure monitoring and verification is generally justified [4]. Healthcare facilities include hospitals, health centres and hospices, residential care, dental offices and dialysis units. Drinking water should be suitable for human consumption and all usual domestic purposes, including personal hygiene. However, it may not be suitable for all uses or some patients within healthcare facilities, and further processing or treatment or other safeguards may be required [5]. This study aimed to investigate the properties of the drinking water in Al-Yarmouk Teaching Hospital, Ibn Sina Hospital and Ibn-Al-Nafis hospitals and examine some water parameters.

Material and Methods

Study Area

Al-Yarmouk Teaching Hospital, , founded in 1964, is presently Iraq's second-largest hospital, after Baghdad Medical City. It is also the country's largest emergency facility, with around 700 beds at the hospital and is located on Jinub Street, Baghdad, Al-Karkh, Al-Yarmouk, Iraq [6] (Figure 1).

Ibn Sina Hospital was founded in 1964 by four Iraqi doctors and has since become one of Baghdad's premier hospitals. There are around 500 beds at the hospital [7] (Figure 1).

Ibn-Al-Nafis Hospital was opened in 1979. The site of the hospital is located on the side of the Rusafa-Karrada district-AL-Nidal neighbourhood – near the coast of Andalusia – and the other vital hospitals and in the heart of the capital Baghdad [8] (Figure 1).

Figure 1 : Showing the selected study areas within the city of Baghdad.

B-Method

Samples were collected between October 2018 and September 2019, and then physical and chemical characteristics were studied, (including temperature, hydrogen ion (pH), total dissolved solids (TDS), electrical conductivity (EC)**,** turbidity, free residual chlorine, total organic carbon (TOC), total trihalomethanes (THMs), total halo acetic acid (THAAs), and were next tested by Baghdad Government in accordance to standard methods for the examination of drinking water. The tests of TDS and pH were measured on-site at the position of sampling, while rest of the tests were done in the laboratory according to standards, wearing gloves and eye protection when collecting samples. Rinsed the bottle and cap three times with sample water and were next filled them to within one to two inches from the top. The sample was then placed into a cooler with ice for immediate delivery or shipment to the laboratory. Only steriled 125 or mL-150 plastic bottles were used [9].

Result and Discussion

Temperature

The results showed that the highest temperature was 37^{o}C in Ibn Sina Hospital through the summer, whilest the lowest temperature was 9^{o}C in Al-Yarmouk Teaching Hospital in winter. (Figure 2, Table 1)**.**

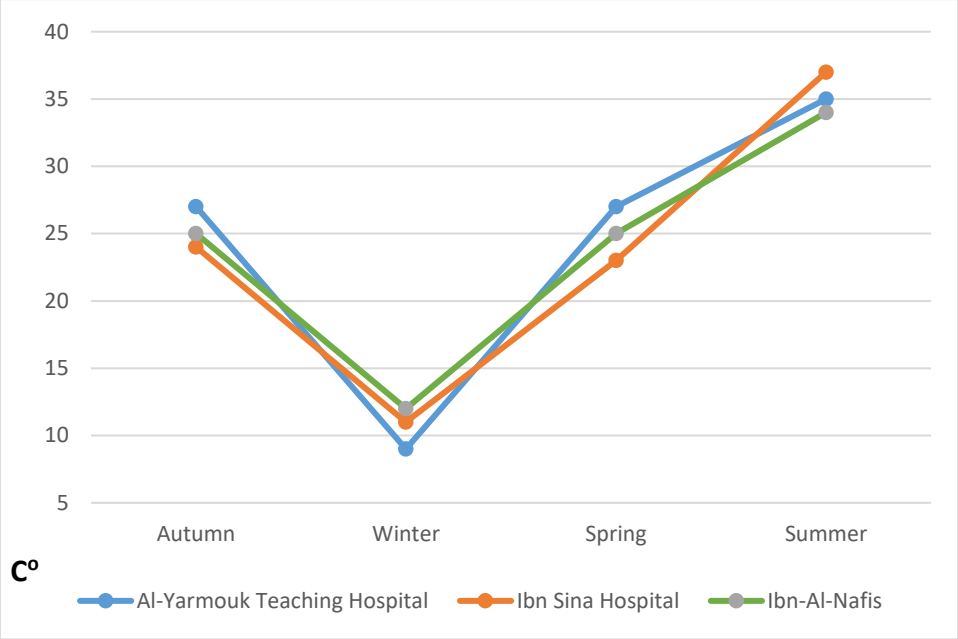

Figure 2 : Temperature values in Al-Yarmouk Teaching Hospital, Ibn Sina Hospital, and Ibn-Al-Nafis Hospital during the study period.

Table 1 : The statistical analysis between temperature, site and season.

Site / Season	Al-Yarmouk Teaching Hospital	Ibn Sina Hospital	Ibn-Al-Nafis	LSD Value
Autumn	27ºC	24 ºC	25 ºC	3.58 NS
Winter	9 ºC	11 ºC	12 ºC	3.07 NS
Spring	27 ºC	23 ºC	25 ºC	3.98 *
Summer	35 ºC	37 ºC	34 ºC	3.14 NS
LSD value	6.02 *	6.55 *	5.83 *	---

* ($P \leq 0.05$).
NS= Non-significant

The main reason for the lower values measured during the winter months and higher values in the summer months is linked directly to air temperature [10]. This variation reflects the alteration in the values of the natural organic matter by affecting the metabolic and analytical processes, gases solubility as carbon, oxygen in addition to chlorine. All these readings give a clear image of the effect of temperature on all ecosystems [11].

Hydrogen ion (pH)

The obtained results showed that the highest value read was 8.4 in winter in Ibn Sina Hospital while the lowest value recorded was 6.4 in Ibn-Al-Nafis Hospital in July (Figure 3**,** Table 2**).**

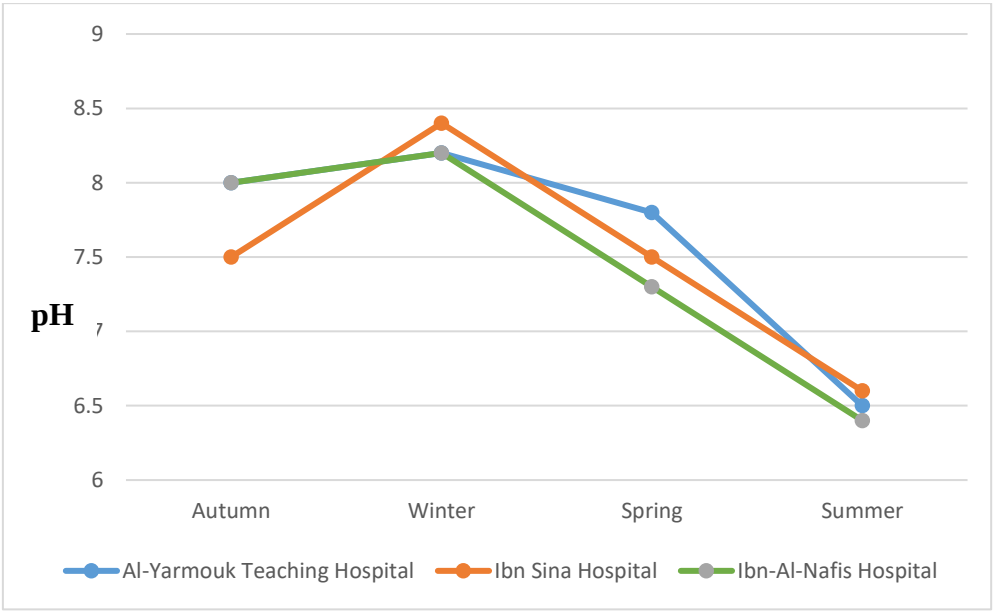

Figure 3 : pH values in Al-Yarmouk Teaching Hospital, Ibn Sina Hospital, and Ibn-Al Nafis Hospital during the study period.

Table 2 : The statistical analysis between the pH, site and season.

pH				
Site / Season	Al-Yarmouk Teaching Hospital	Ibn Sina Hospital	Ibn-Al-Nafis	LSD Value
Autumn	8	7.5	8	0.569 NS
Winter	8.2	8.4	8.2	0.308 NS
Spring	7.8	7.5	7.3	0.422 NS
Summer	6.5	6.6	6.4	0.493 NS
LSD value	0.881 *	0.746 *	0.784 *	---

* ($P \leq 0.05$).
NS= Non-significant

The lowest and highest pH values obtained did not exceed the permissible limits both for Iraqi drinking water [12] and WHO standards for drinking water [13] which range from 6.5 to 8.5.

Total Dissolved Solids (TDS)

The maximum recorded concentration was 790 mg/l in the Ibn Sina Hospital during winter, while the minimum concentration recorded was 378 mg/l in Ibn Sina Hospital during summer (Figure 4, Table 3).

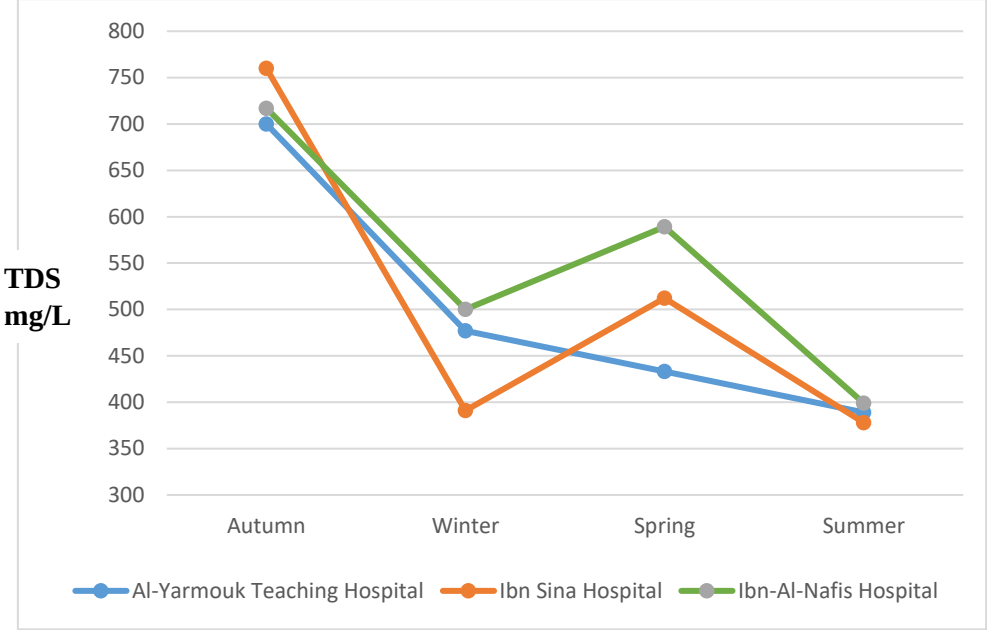

Figure 4 : TDS values in Al-Yarmouk Teaching Hospital, Ibn Sina Hospital, and Ibn-Al-Nafis Hospital during the study period.

Table 3 : The statistical analyses between TDS, site and season.

TDS				
Site	Al-Yarmouk Teaching Hospital	Ibn Sina Hospital	Ibn-Al-Nafis	LSD Value
Autumn	700	760	717	72.38 NS
Winter	477	391	500	93.57 *
Spring	433	512	589	114.67 *
Summer	389	378	399	66.84 NS
LSD value	102.47 *	97.55 *	97.26 *	---

* ($P \leq 0.05$).
NS= Non-significant

The cracks and breaks of drinking water pipelines may increase TDS content particularly when there is no pressure in the pipelines and using a house water pump. The minimum and maximum TDS values recorded in the present study, were found to be within the permissible limits of Iraqi [12] and WHO [13] standards for drinking water which was 1000 mg/l.

Electrical Conductivity (EC)

The obtained results of EC of drinking water samples showed that the maximum value of 1251 $\mu S/cm^{-1}$ was found in Al-Yarmouk Teaching Hospital in winter and the minimum value of 784 $\mu S/cm^{-1}$ was recorded in summer in Ibn Sina Hospital (Figure 5, Table 4).

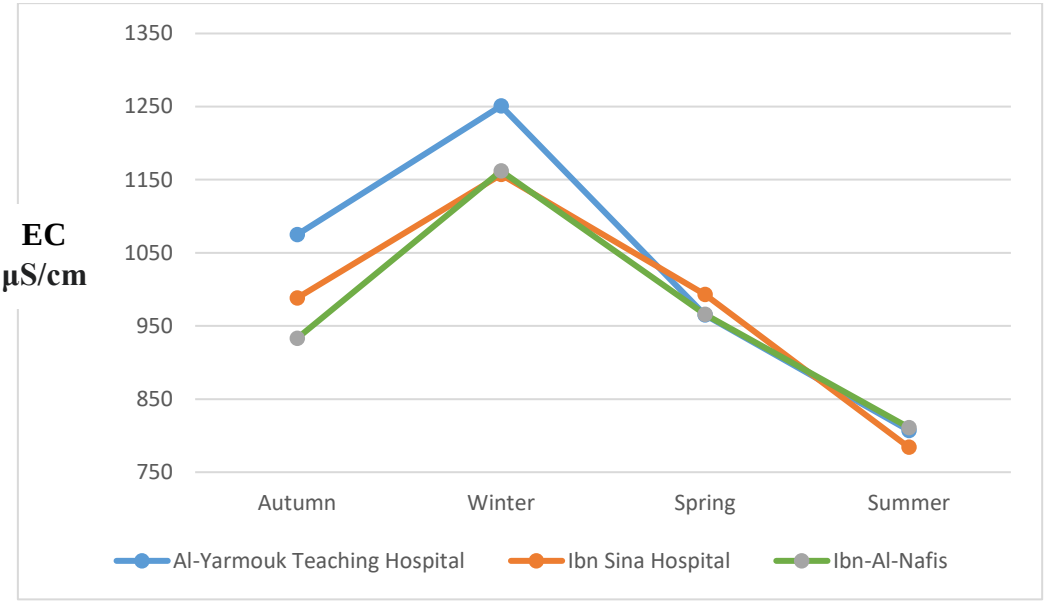

Figure 4 : EC values in Al-Yarmouk Teaching Hospital, Ibn Sina Hospital, and Ibn-Al-Nafis Hospital during the study period.

Table 4 : The statical analysis between EC, site and season.

EC				
Site	Al-Yarmouk Teaching Hospital	Ibn Sina Hospital	Ibn-Al-Nafis	LSD Value
Autumn	1075	988	933	112.63 *
Winter	1251	1157	1162	92.17 *
Spring	965	993	966	76.83 NS
Summer	807	784	811	69.23 NS
LSD value	94.38 *	88.51 *	96.04 *	---

* ($P \leq 0.05$).
NS= Non-significant

Pure water is not a good conductor of electric current but rather a good insulator. An increase in ion concentration enhances the electrical conductivity of water. Generally, the amount of dissolved solids in water determines the electrical conductivity. Electrical conductivity (EC) measures the ionic process of a solution that enables it to transmit current that increases (EC) through the winter because of the increase in the salts that come from the ground near the river [14].

The values obtained did not exceed the permissible limits for Iraqi [12] and WHO standards for drinking water [13] which was 2000 µS/cm.

Turbidity

This study found that the drinking water sample of Ibn Sina Hospital had the highest value of 15 NTU during spring. Whereas, the sample from Ibn-Al-Nafis gave the lowest value of 4.5 NTU during winter (Figure 6, Table 5).

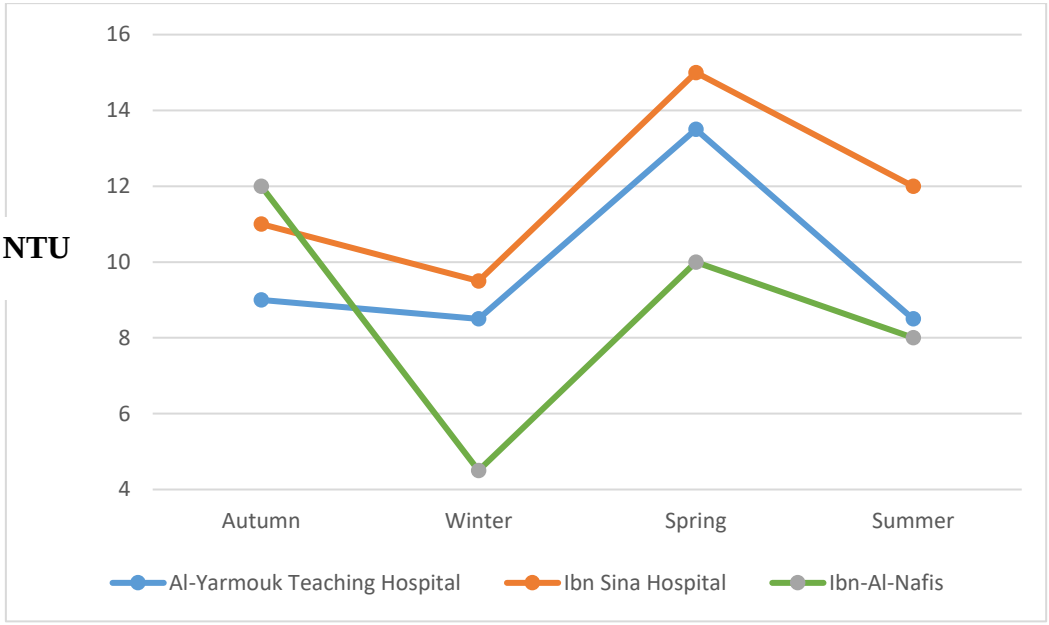

Figure 6 : Turbidity values in Al-Yarmouk Teaching Hospital, Ibn Sina Hospital, and Ibn-Al-Nafis Hospital during the study period.

Table 5 : The statistical analysis between turbidity, site and season.

Site	Al-Yarmouk Teaching Hospital	Ibn Sina Hospital	Ibn-Al-Nafis	LSD Value
Autumn	9	11	12	3.18 NS
Winter	8.5	9.5	4.5	4.02 *
Spring	13.5	15	10	4.17 *
Summer	8.5	12	8	3.87 *
LSD value	4.58 *	3.66 *	3.06 *	---

* ($P \leq 0.05$).
NS= Non-significant

The operation method, fitness of maintenance processes, age of the plant and the amount of article alum added have a great influence on turbidity values in water [15].

The turbidity values recorded in the present study were higher than the permissible level recommended by the Iraqi [12] and WHO standards [13] for drinking water for all seasons which was 0 -5 NTU.

Free Residual Chlorine

Examined drinking water samples had various contents of free residual chlorine. The maximum value of 1.7 mg/l was recorded in Ibn Sina Hospital during the summer while the minimum value of 0.4 mg/l was detected in the water sample of Ibn-Al-Nafis during the summer (Figure 7, Table 6).

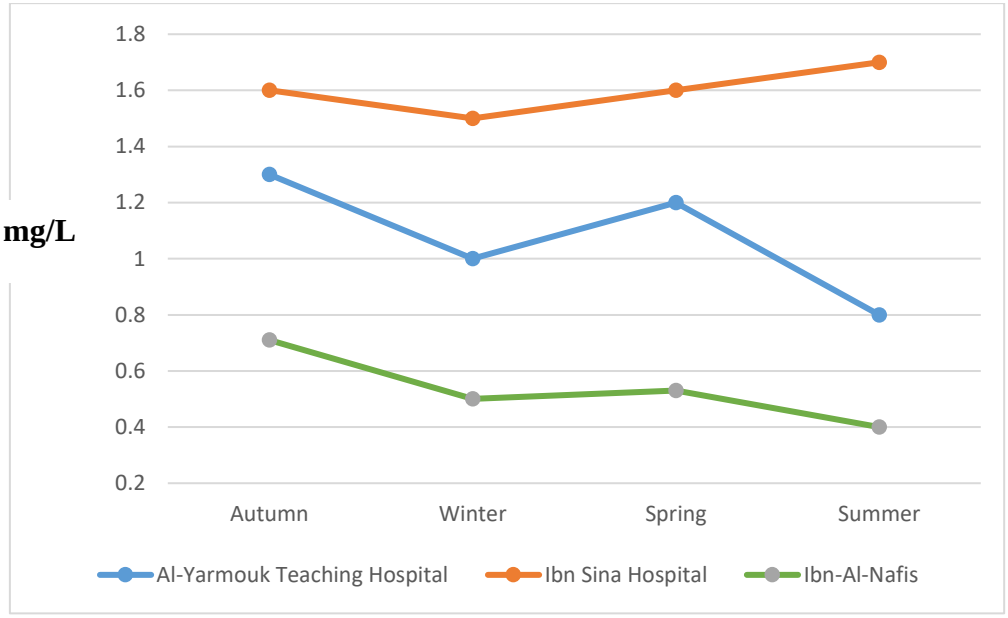

Figure 7 : Free Residual Chlorine values in Al-Yarmouk Teaching Hospital, Ibn Sina Hospital, and Ibn-Al-Nafis Hospital during the study period.

Table 6 : The statistical analysis between free residual chlorine site and season.

Site	Al-Yarmouk Teaching Hospital	Ibn Sina Hospital	Ibn-Al-Nafis	LSD Value
Autumn	1.3	1.6	0.71	0.452 *
Winter	1	1.5	0.5	0.479 *
Spring	1.2	1.6	0.53	0.467 *
Summer	0.8	1.7	0.4	0.502 *
LSD value	0.367 *	0.297 NS	0.300 *	---

* ($P \leq 0.05$).
NS=Non-significant

The results indicated high levels of free residual chlorine in drinking water during summer despite the high temperatures, which directly affected the chlorine concentration causing volatilization. The reason is that most of the water treatment plants add high doses of chlorine to the water in summer [16].

These results agreed with the Iraqi [12] and WHO standards for drinking water [13] which were 2-5 mg/l (Cl_2 dose) and 0.3mg/l (residual chlorine).

Total Trihalomethanes (THMs)

The results of drinking water samples from different sites showed that the highest value of THMs was 129.6 µg/l in Ibn Sina Hospital during summer while the lowest value was 41.3 µg/l in Ibn Sina Hospital also in winter (Figure 9, Table 8).

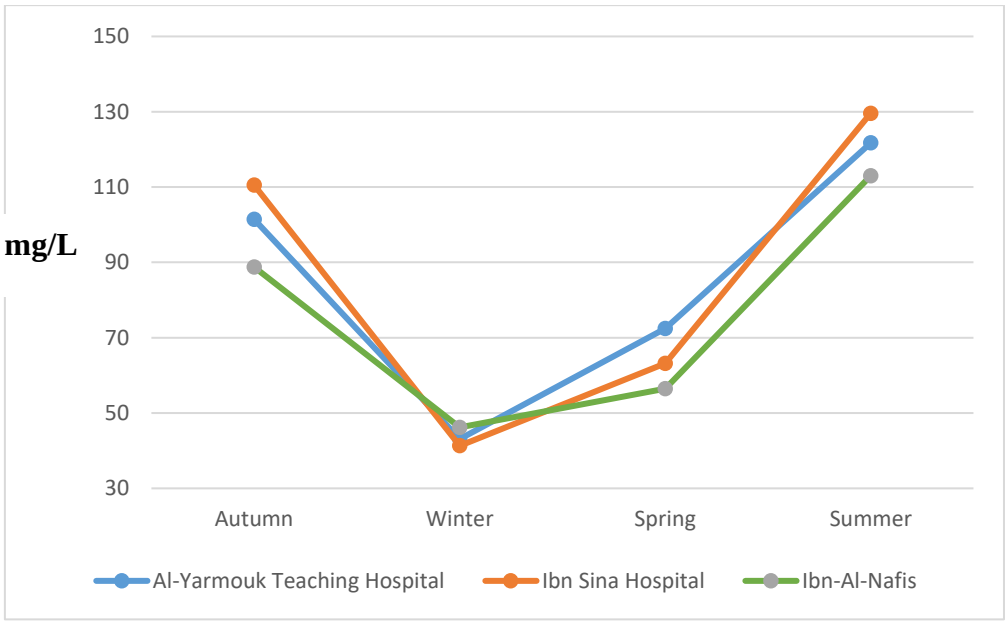

Figure 9 : THMs values in Al-Yarmouk Teaching Hospital, Ibn Sina Hospital, and Ibn-Al-Nafis Hospital during the study period.

Table 8 : The statistical analysis between THM, site and season.

Site	Al-Yarmouk Teaching Hospital	Ibn Sina Hospital	Ibn-Al-Nafis	LSD Value
Autumn	101.4	110.5	88.8	13.68 NS
Winter	43.1	41.3	46.2	8.42 NS
Spring	72.4	63.2	56.5	14.58 *
Summer	121.7	129.6	113	12.95 *
LSD value	18.42 *	25.79 *	19.33 *	---

* ($P \leq 0.05$).
NS= Non-significant

THM levels were found to be 2.4 times greater in the summer than in the winter, according to the research. This was because increasing the water temperature increased the reaction rate between NOM and added chlorine, as well as an increase in THM formation during the summer was due to raw water quality (mostly due to high TOC concentrations during the summer season) and treatment plant operational conditions (such as increasing chlorine dose) [17]. Also, this study observed that the THMs concentration increased along with the distribution systems of most water plants more than THMs concentration measured immediately after disinfection and became stable in the middle and extremities of the distribution system which may be related to treated water before consumption which can spend an extensive amount of time within the distribution system leading to longer free chlorine contact time. Also THMs were chemically stable where their concentrations increased with time as excess chlorine reacted with organic precursors [18].

When the observed TTHM values were compared to regulatory standards, none of the samples from the distribution systems exceeded the permissible limits for Iraqi drinking water regulations (150 g/l). In the summer and autumn, however, numerous tests exceeded the USEPA's allowed levels (80 g/l) [19].

Total Halo Acetic Acid (THAAs)

The results of THAAs in drinking water sampled from different sites showed that the highest value of 72.9 µg/l was recorded in water sample collected from Ibn Sina Hospital during summer and the lowest THAAs water content of 40.2 µg/l was obtained in sample from Ibn-Al-Nafis during winter (Figure 10, Table 9).

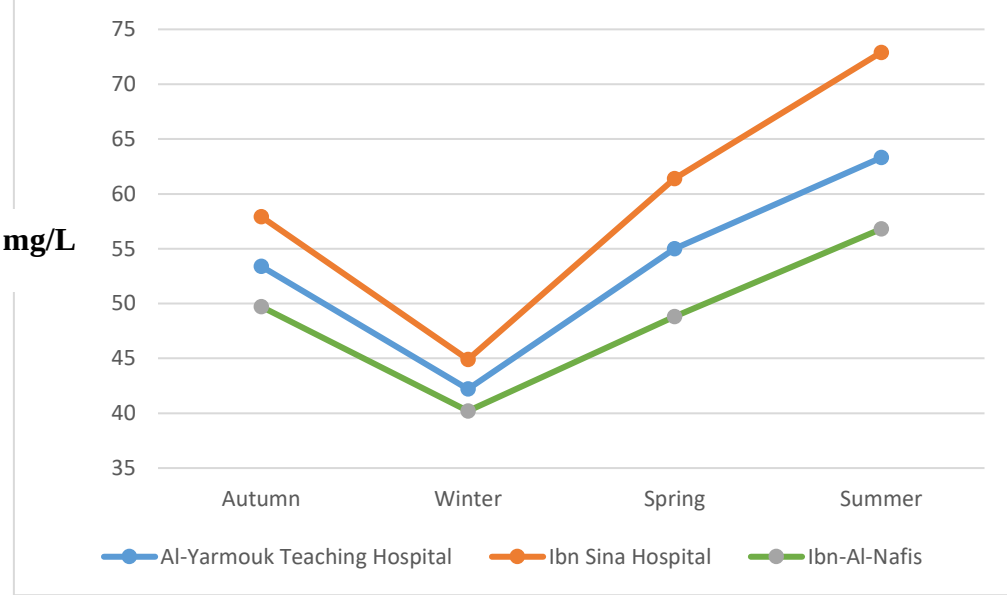

Figure 10 : THAAs values in Al-Yarmouk Teaching Hospital, Ibn Sina Hospital, and Ibn-Al-Nafis Hospital during the study period.

Table 9 : The statistical analysis between THAAs, site and season.

Site	Al-Yarmouk Teaching Hospital	Ibn Sina Hospital	Ibn-Al-Nafis	LSD Value
Autumn	53.4	57.9	49.7	6.89 *
Winter	42.2	44.9	40.2	5.31 NS
Spring	55	61.4	48.8	6.92 *
Summer	63.3	72.9	56.8	8.44 *
LSD value	7.02 *	8.66 *	8.31 *	---

* ($P \leq 0.05$).
NS= Non-significant

The THAAs concentrations during summer were higher about 1.5 times than those of winter possibly because the water temperature was higher enough in summer that promoted the formation reactions of HAAs. In addition to more DBPs, precursors could be present as higher organic content was also observed during summer [20].

Conversely, when comparing the obtained values of total HAA with USEPA regulatory standards, many water samples exceeded the regulated limits which are 60 µg/l.

Conclusion:

Although the drinking water tests were mostly acceptable, the existence of trihalomethane and haloacetic acid is an indicator of danger to human health. Therefore, the presence of drinking water purification plants has become necessary to supply hospitals with drinking water.

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