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Evaluation of Some Chemical Properties and Heavy Metals Excreted from Tikrit Teaching Hospital in Saladin Governorate/ Iraq

Mustafa A. H. AL-Jubori[1]*, Mazin N. Fadhel al Sanjari[1], Abid Ahmad Erdeni[2]
[1]College of Environmental Sciences, University of Mosul, Mosul, Iraq
[2]College of Education for Women, University of Tikrit, Tikrit, Iraq

[*]**Corresponding Author: mustafa.22evp5@student.uomosul.edu.iq**

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ABSTRACT

Various chemical properties and some heavy elements of wastewater discharged from Tikrit Teaching Hospital were studied during the period of October to December 2023. Some chemical properties were measured, such as pH, total hardness, calcium and magnesium hardness in addition to biological and chemical requirements. Compared to the Iraqi water standards, considering the biological and chemical requirements, an increase was recorded in most values of oxygen, pH and some heavy elements such as lead, cadmium, copper, and iron. For the total hardness and the hardness of calcium, magnesium, and chloride, they were within the Iraqi water standards. These results show that hospitals are the main source of excreta that must be taken into consideration before any action strategy to assess environmental and health threats. The quantity and type of toxins and liquid excreta produced from hospital operations pose a danger to living organisms in general, particularly humans. In many developing countries, liquid waste from hospitals is often disposed directly into the environment, such as by discharging it into rivers without treatment.

INTRODUCTION

Wastewater is one of the most dangerous pollutants to the aquatic environment. The World Health Organization defines health pollution as resulting from the activities of health care centers, hospitals, medical centers, and drug stores **(Kwekereza *et al.*, 2019)**. Liquid medical waste contains pharmaceutical products and materials, organic and inorganic chemicals, and toxic substances **(Liu *et al.*, 2023)**. It also includes pathogenic bacteria that may develop resistance to antibiotics **(Khan *et al.*, 2023; Ramírez-Coronel *et al.*, 2023)**.

In recent decades, wastes and pollutants released into hospital wastewater have increased as a result of advances in the diversification of medical services and goods and the increase in the number of patients, as well as the, sometimes, lack of proper management of waste treatment and disposal **(Amoi *et al.*, 2015)**. Pollution occurs when pollutants are discharged into rivers, such as physical, chemical, and biological pollutants resulting from industrial, sanitary, or domestic wastewater, and the presence of these chemicals has an impact on the vitality of living organisms **(Saleh *et al.*, 2018)**. Water pollution is one of the most serious threats to the health of all living organisms including humans. Moreover, polluted water may contain heavy metals, dangerous and toxic compounds, and disease-causing organisms, making it unfit for drinking **(Hassa, 2023)**.

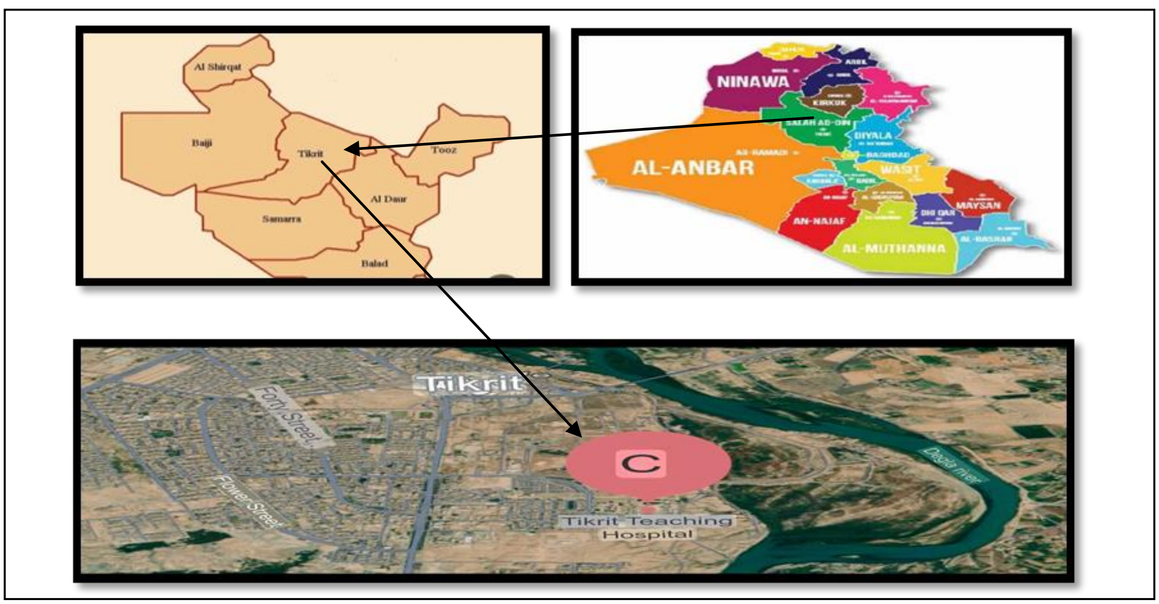
If the waste was not medically treated (physical chemical and biological) before release, it could seriously pollute lakes and other water bodies and contaminate the water upon reaching the riverbed. Additionally, water quality is also affected by the presence of heavy metals **(Twinsch, 2009)**.

The current study aimed to evaluate the chemical properties and some heavy elements in wastewater coming out of some health units in Tikrit Teaching Hospital, Iraq.

MATERIALS AND METHODS

Description of the study area

The study was conducted at the University of Mosul, College of Environmental Sciences, and Tikrit University, College of Education for Girls/Iraq. The study samples were collected from Tikrit Teaching Hospital, which is located in the city of Tikrit, the center of Salah al-Din Governorate, north of Baghdad, and which was established in 1988 with a capacity of 480 beds at coordinates N43. 7206496; E34. 5730969, which is one of the major hospitals in the governorate, as shown in picture (1).



Picture 1. City of Tikrit, with Tikrit General Teaching Hospital showing sampling stations

Samples collection

The process of collecting samples of wastewater discharged from the health departments and lobbies of Tikrit General Teaching Hospital began for the purpose of evaluating its quality.

Four sites were chosen to collect samples from the hospital. The first site was tap water (liquefaction water) inside Tikrit General Hospital and was considered a control treatment. As for the site, the second is the Lobbies basin; the third location represents the consultation basin; and the fourth location is the general complex, which includes all hospital departments for a period of three months (October, November, and December) for the year 2023. Twice a month, samples were collected between 8 a.m. and 9 a.m. at a depth of 10 to 25cm below the surface water in the collection basins. Samples were taken using opaque 1-liter polyethylene bottles and stored at a temperature of 4°C **(APHA, 2005)**. Some chemical tests and some heavy metals were conducted in the graduate studies laboratory/Department of Biology Sciences/College of Education for Girls/Tikrit University and the laboratories of the College of Engineering, Chemical Department, and Environment Department.

Chemical tests

The pH values

The pH value was estimated using a Lovibond pH meter-type device.

Total hardness concentration

The total hardness concentration was estimated according to the method of **APHA (2003)**.

Calcium hardness concentration

Calcium hardness was estimated according to the method of **APHA (2003)**.

Magnesium hardness concentration

Magnesium hardness was estimated according to the method of **APHA (2005)**.

Chloride concentration:

The chloride ion was estimated using the method stated in **APHA (2005)**.

Concentration of the biochemical oxygen demand

It was estimated using the LOVIBONDOXiDirect device.

Concentration of the chemical oxygen demand

It was estimated according to the method of **APHA (1997)**.

Heavy metals

The estimation of lead, cadmium, copper, and iron was evaluated according to the guidelines of **APHA (2002)**.

RESULTS

Table 1. The results of chemical tests for wastewater discharged from Tikrit General Teaching Hospital

Sample time / Sample location	October		November		December		the averae	
	First sample 10/1	The second sample 10/15	The Third sample 11/1	Fourth sample 11/15	Fifth sample 12/1	Sixth sample 12 / 15		
Tap water	7.39	7.1	6.06	6.6	6.85	6.7	6.7	pH
Atrium basin	6.83	6.2	5.9	5.35	6.04	6.13	6.7	
Consulting Basin	7.72	8.3	8.63	8.19	8.29	8.29	8.2	
General complex basin	7	7.51	7.07	7.36	7.68	7.8	7.4	
Tap water	138	230	230	257.6	243.8	276	229.2	T.H. (mg/l) as $CaC0_3$
Atrium basin	920	276	230	441.6	349.6	349.6	427.8	
Consulting basin	575	276	276	340.4	322	368	359.5	
General complex basin	805	368	184	552	368	386.4	443.9	
Tap water	52	34.4	51	53.32	34.4	63.64	48.12	Ca. H (mg/l) as $CaC0_3$
Atrium basin	129	60.2	51	82.56	70.52	70.52	77.3	
Consulting basin	55.9	173.6	47.3	56.76	84.28	75.68	82.2	
General complex basin	172	103.2	68.8	79.12	87.72	79.12	98.3	
Tap water	2	35	25.1	30.32	38.5	28.52	26.57	Mg. H. (mg/l) as $CaC0_3$
Atrium basin	146	30	25.1	57.38	42.28	42.28	57.17	
Consulting basin	106	38	38.49	48.42	27.15	43.62	50.2	
General complex basin	102	26	20.92	86.42	36.28	46.01	52.93	
Tap water	27.64	25.94	20.00	26.69	68.00	37.60	34.31	Cl^- (mg/l)
Atrium basin	378.82	234.06	178.00	210.93	260.00	169.20	238.5	
Consulting basin	60.16	31.02	36.00	472.16	100.00	178.60	146.32	
General	435.22	232.18	100.00	211.59	319.00	182.70	246.8	

complex basin								
								BOD5 (mg/l)
Tap water	0	0	0	0	7	8	2.5	
Atrium basin	337	352	326	544	393	459	401.8	
Consulting basin	290	248	441	385	256	146	300.3	
General complex basin	372	240	217	443	381	141	299	

Tap water	0	0	0	0	25	23	8	COD (mg/l)
Atrium basin	705	746	986	848	978	508	795.2	
Consulting basin	610	390	860	432	438	428	526.3	
General complex basin	560	772	400	622	636	406	566	

Table 2. Test results for some heavy elements of wastewater discharged from Tikrit General Teaching Hospital

Sample time / Sample location	October		November		December		the averae	
	First sample 10/1	The second sample 10/15	The Third sample 11/1	Fourth sample 11/15	Fifth sample 12/1	Sixth sample 12 / 15		
Tap water	0.36	0.43	0.45	0.55	0.57	0.61	0.5	Fe (mg/l)
Atrium basin	2.54	3.96	2.63	3.10	2.91	2.94	3.01	
Consulting basin	0.70	2.49	1.03	1.14	1.40	1.49	1.38	
General complex basin	1.95	3.41	2.47	1.85	3.08	3.93	2.78	
								Pb (mg/l)
Tap water	0.071	0.083	0.044	0.067	0.099	0.069	0.07	
Atrium basin	2.27	1.94	2.39	1.98	1.41	1.65	1.94	

Consulting basin	**0.58**	**0.83**	**1.14**	**0.73**	**0.91**	**0.39**	**0.76**	
General complex basin	**1.25**	**1.66**	**1.19**	**0.97**	**0.88**	**1.06**	**1.17**	
								Cd (mg/l)
Tap water	**0.006**	**0.007**	**0.008**	**0.009**	**0.003**	**0.005**	**0.006**	
Atrium basin	**0.71**	**0.80**	**0.97**	**0.85**	**0.67**	**0.85**	**0.81**	
Consulting basin	**0.17**	**0.39**	**0.15**	**0.19**	**0.13**	**0.05**	**0.18**	
General complex basin	**0.58**	**0.90**	**0.86**	**0.65**	**0.45**	**0.64**	**0.68**	
								Cu (mg/l)
Tap water	**0.08**	**0.11**	**0.09**	**0.11**	**0.12**	**0.11**	**0.07**	
Atrium basin	**0.50**	**0.94**	**0.63**	**0.60**	**0.85**	**0.70**	**0.71**	
Consulting basin	**0.08**	**0.47**	**0.11**	**0.13**	**0.12**	**0.10**	**0.17**	
General complex basin	**0.43**	**1.03**	**0.58**	**0.48**	**0.84**	**0.65**	**0.65**	

Table 3. Classification of rivers in terms of pollution

Classification of river	BOD_5 (mg/l)
very clean	1
clean	2
Fairly clean	3
Questionable cleanliness	5
Bad	More than 10

Table 4. Iraqi standard specifications for water

Property	Iraqi standard specifications for water
pH	**6.5_8.5**
T.H. (mg/l) as $CaC0_3$	**100_500**
Ca. H (mg/l) as $CaC0_3$	**75_200**
Mg. H. (mg/l) as $CaC0_3$	**50_150**
Cl^- (mg/l)	**250**
Fe (mg/l)	**0.3**
Pb (mg/l)	**0.05**
Cd (mg/l)	**0.005**
Cu (mg/l)	**0.05**

DISCUSSION

Chemical properties

The pH values

The results in Fig. (1) show that the pH values of the water supplied by the departments and health units of Tikrit General Teaching Hospital ranged between weakly acidic and weakly basic, as the average values were 6.7, 6.7, 8.2, 7.4, respectively, for both tap water (the liquefaction) entering the hospital, which represents the control factor, the hall basin, the Istishari basin, and the general complex basin into which the hospital departments flow. The highest pH value recorded was in the Istishari basin (8.2), while the lowest was in the liquefaction water entering the hospital (6.7). These results fall within the standard value range of 6.5 to 8.5, as per the Iraqi standards for water sources **(Dunia Frontier Consultants, 2013)**. As shown in Table (4), the highest pH value was 8.63 in the advisory basin for November, recorded in the third sample on November 15, while the lowest value was 5.35 in the halls basin for the same month, recorded in the fourth sample on November 15. The increase in pH values in certain periods can be attributed to the use of cleaning materials with basic properties, which may not be well-balanced during manufacturing and are widely available in Iraqi markets. The decrease in pH values is due to the presence of CO2 gas, nitrite, chlorides, and sulfates, which have acidic effects **(Mustafa, 2000)**. The current results are similar to those obtained in the study of **Al-Enzi's (2016)**, who reported that the pH values of wastewater at Al-Sadr Teaching Hospital did not fall below 7. The pH levels ranged between 7.38 and 7.5, which is within the safe limits set by the World Health Organization (WHO), ranging from 6.5 to 9.5 **(WHO, 2011)**. These levels are also within the Iraqi standard limits for the year 2009, which range from 6.5 to 8.5.

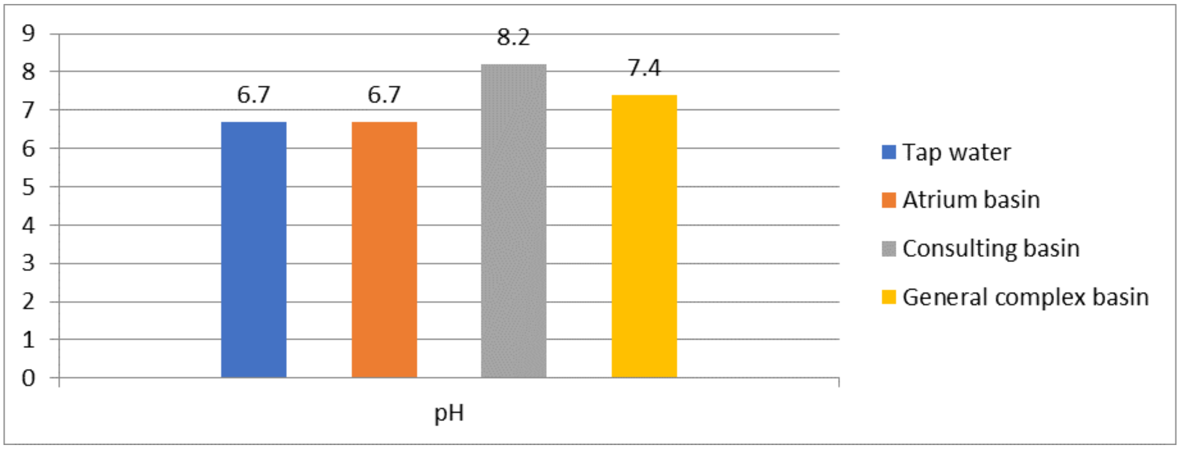


Fig. 1. Average (pH) values for the sites during the study period

Total hardness (T.H.)

The results presented in Fig. (2) show that the total hardness values of the water discharged from the health departments and units of Tikrit General Teaching Hospital ranged from 229.2 to 443.9mg/ l. The measurements were taken from tap water (liquefaction water) entering the hospital, which served as the control, the hall basin, the consultation basin, and the general complex basin, where all hospital departments drain. The highest value was observed in the general complex basin (427.8mg/ l), and the lowest was in the liquefaction water entering the hospital (229.2mg/ l). These values are within the standard range of 100 to 500mg/ l, as per the Iraqi standards for water sources **(Dunia Frontier Consultants, 2013)**. According to Table (4), the highest total hardness recorded was 920mg/ l in the hall basin for October, with the first sample taken on October 1, and the lowest value was 138mg/ l in the inlet liquefaction water (tap water) for the hospital, also for October. The results align with the standard and international specifications **(EPA, 2002; WHO, 2004)**. These results classify water hardness between 250–500mg/ l as ranging from hard to very hard **(Todd, 1980)**. The high total hardness indicates the presence of many calcium and magnesium ions and alkaline metals **(Al-Shamaa *et al.*, 2012)**. The elevated total hardness in some study basins can be attributed to chemicals released into the water from operating rooms, surgical operations, laboratories, and other medical activities **(Dedeh, 2018)**. This study's findings are consistent with those of **Farag (2015)** and **Abd-Al Satar (2021)**, who also reported an increased hardness in Iraqi water, particularly at the wastewater site of the Medical City.

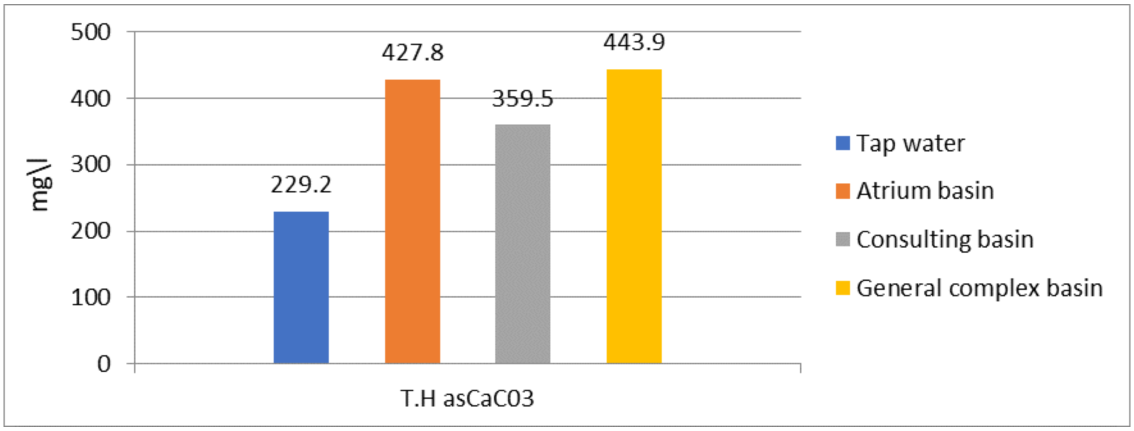


Fig. 2. Averages of total hardness values for the sites during the study period

Calcium hardness (Ca H.)

The results recorded in Fig. (3) indicate that the calcium hardness values of the water discharged from the health departments and units of Tikrit General Teaching Hospital ranged between 48.12 and 98.3mg/ l. These measurements were taken from tap water (liquefaction water) entering the hospital, which served as the control, as well as from the hall basin, the consultation basin, and the general complex basin, into which all hospital departments discharge their wastewater. The highest value was observed in the general complex basin at 98.3mg/ l, while the lowest value was recorded in the wastewater entering the hospital at 48.12mg/ l. These values fall within the standard range of 75 to 200mg/ l, as per the Iraqi standards for water sources **(Dunia Frontier Consultants, 2013)**, as shown in Table (4). Additionally, Table (1) indicates that the highest value of calcium hardness was 173.6mg/ l, recorded in the consultation basin for the month of October, with the second sample taken on October 15. The lowest value was 34.4mg/ l, recorded in the liquefaction water entering the hospital for the same month, with the second sample also taken on October 15. Calcium levels above 50mg/ l can cause problems, as excess calcium can lead to the formation of carbonate deposits, which can negatively affect water quality **(Bhateria & Jain, 2016)**.

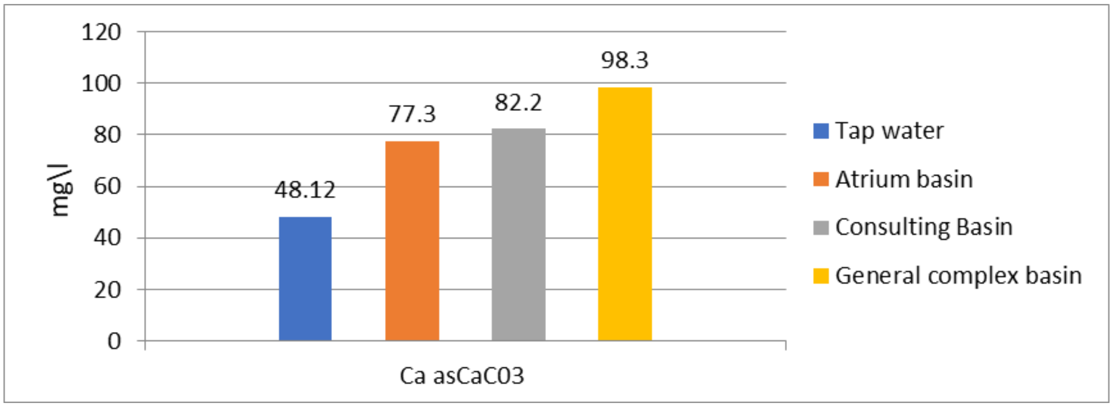


Fig. 3. Average (calcium hardness) values for the sites during the study period

Magnesium hardness (Mg H.)

The results presented in Fig. (4) indicate that the magnesium hardness values of the water discharged from the health departments and units of Tikrit General Teaching Hospital ranged between 26.57 and 57.17mg/ l. These measurements were taken from various sources, including tap water (liquefaction water) entering the hospital, which served as the control, as well as from the hall basin, the advisory basin, and the general complex basin into which all hospital departments drain. The highest value was recorded in the hall basin at 57.17mg/ l, while the lowest value was found in the tap water entering the hospital at 26.57mg/ l. These results fall within the standard values range of 50 to 150mg/ l, as per Iraqi standards for water sources **(Dunia Frontier Consultants, 2013)**, as shown in Table (4). Furthermore, Table (1) indicates that the highest value for magnesium hardness was 146.2mg/ l in the consultation basin for the month of October, with the first sample taken on October 1. The lowest value was 2mg/ l in the tap water (liquefaction water) entering the hospital for the same month, also recorded on October the 1^{st}. Magnesium contributes to increasing water hardness, which is primarily caused by an increase in positive ions such as magnesium and calcium, as well as some heavy elements like zinc and iron **(WHO, 2004)**.

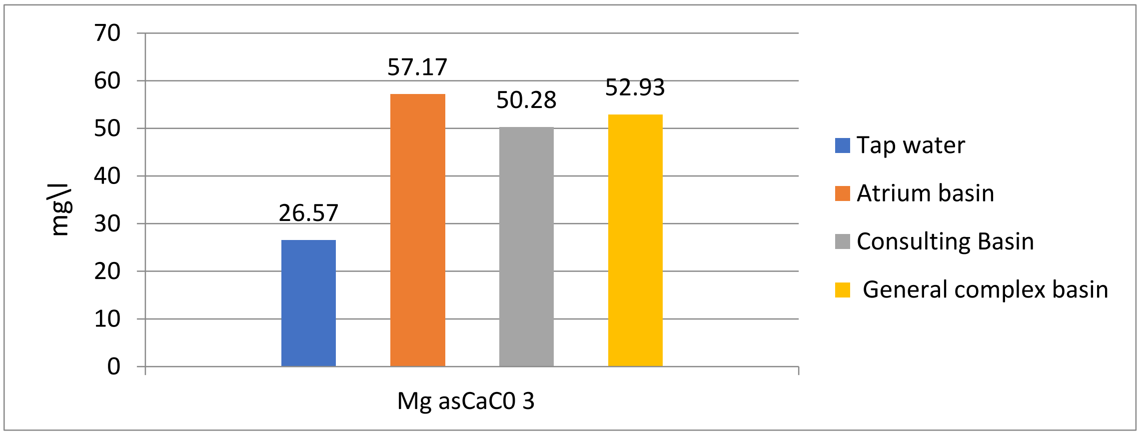


Fig. 4. Average (magnesium hardness) values for the sites during the study period

Chloride (Cl-)

The results, as shown in Fig. (5), indicate that the chloride values of the water discharged from the health departments and units of Tikrit General Teaching Hospital ranged between 34.31 and 246.8mg/ l. These measurements were taken from various sources, including tap water (liquefaction water) entering the hospital, which served as the control, as well as from the hall basin, the consultation basin, and the general complex basin into which all hospital departments discharge their wastewater. Most results exceeded the World Health Organization's limits, except for the tap water entering the hospital, which ranged between 45 and 250mg/ l, and was within the limits of the **Iraqi standard specifications (2009)** of 200mg/ l. The highest value was recorded in the general complex basin at 246.8mg/ l, while the lowest was in the tap water entering the hospital at 34.31mg/ l. Chloride is a negative ion that is widely distributed in nature due to its association with positive ions, forming salts such as sodium and magnesium chloride **(Hynes, 1974)**. Additionally, Table (1) shows that the highest chloride value was 472.16mg/ l in the consultation basin for November, with the fourth sample taken on November 15, and the lowest was 20mg/ l in the tap water entering the hospital for November, with the third sample taken on November 1. Chloride concentrations exceeding 1000mg/ l are considered toxic and can adversely affect human health and the aquatic environment **(WHO, 1996)**. These findings are consistent with those recorded in the study of **Edan and Sharqi (2020)**, which examined the physicochemical and bacteriological characteristics of the Euphrates River water and found average chloride values ranging from 92 to 588mg/ l due to wastewater discharged from the Ramadi Teaching

Hospital.

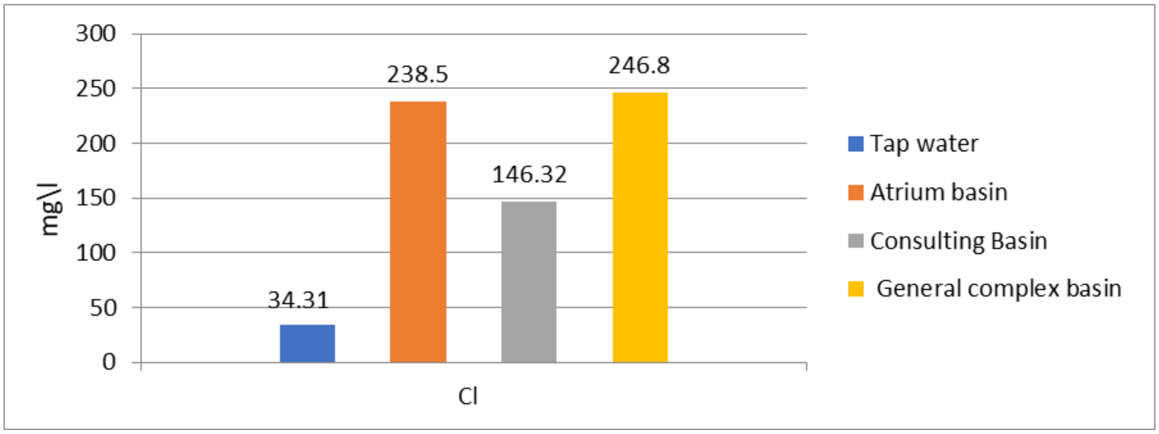


Fig. 5. Average (chloride values) for the sites during the study period

Biological oxygen demand (BOD5)

The results, depicted in Fig. (6), reveal that the BOD5 values of the water discharged from the health departments and units of Tikrit General Teaching Hospital ranged from 2.5 to 401.8mg/ l. This range includes measurements from tap water (liquefaction water) entering the hospital, which served as the control, as well as from the hall basin, the consultation basin, and the general complex basin into which all hospital wastewater is discharged. The highest BOD5 value was recorded in the hall basin at 401.8mg/ l, while the lowest was in the tap water entering the hospital at 2.5mg/ l. According to Table (3), the hall basin, the consultation basin, and the general complex basin are classified as having very poor water quality due to high BOD5 values, while the tap water entering the hospital is classified as having good water quality. High BOD5 concentrations in some of the study sites are attributed to elevated water temperatures that accelerate the decomposition of organic materials, thus increasing the demand for biological oxygen **(Warqa'a & Al-Azzawi, 2016)**. Additionally, pollutants from various hospital departments contribute to these high levels. Table (1) shows that the highest BOD5 value was 544mg/ l in the hall basin for November, with the fourth sample taken on November 15, while the lowest value was 8mg/ l in the tap water entering the hospital for December, with the sixth sample taken on December 15. These concentrations are significantly higher compared to those reported by **El-kanater (2011)** in Australia and align with the findings of **Sadia *et al.* (2023)**, indicating that the discharge standards are exceeded as per World Health Organization guidelines.

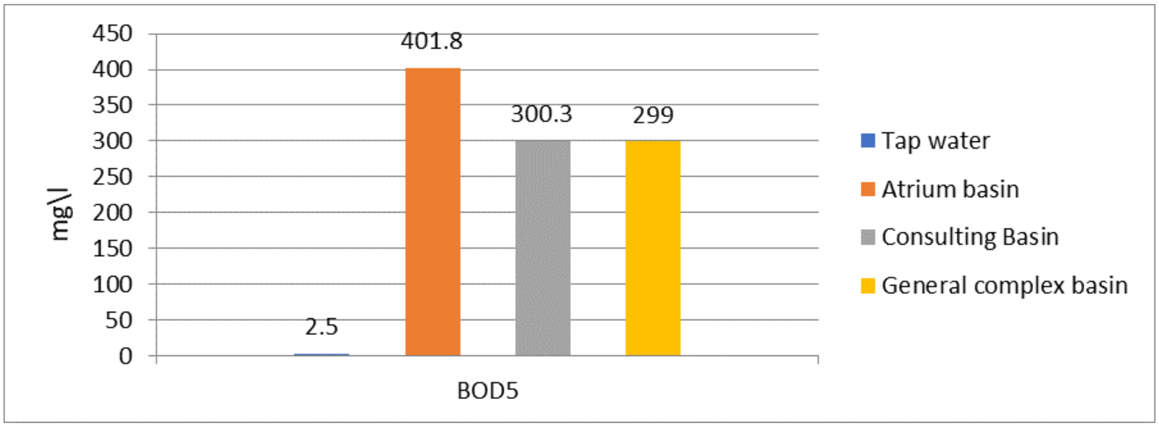


Fig. 6. Average (BOD_5) values for the sites during the study period

Chemical oxygen demand (COD)

The results presented in Fig. (7) indicate that the COD (Chemical Oxygen Demand) values for the water discharged from the health departments and units of Tikrit General Teaching Hospital ranged from 8 to 795.2mg/ l. These measurements include both the tap water (liquefaction water) entering the hospital, which served as a control, and the water from various basins: the hall basin, the consultation basin, and the general complex basin, where all hospital wastewater is discharged. The highest COD value, recorded in the hall basin, was 795.2mg/ l, while the lowest was found in the tap water entering the hospital, at 8mg/ l. Table (1) further illustrates that the highest COD value was 986mg/ l in the hall basin for October, with the third sample taken on November 1, and the lowest value was 25mg/ l in the tap water entering the hospital for December, with the sixth sample taken on December 15. These findings reflect a significant increase in COD values, indicating a high presence of oxidizable organic matter in the polluted water. Elevated COD levels reduce dissolved oxygen (DO), which can result in anaerobic conditions detrimental to aquatic life **(Bader *et al.*, 2022)**. The results align with those of **Nyiransabimana *et al.* (2023)**, showing that COD levels exceed the permissible values recommended by the World Health Organization.

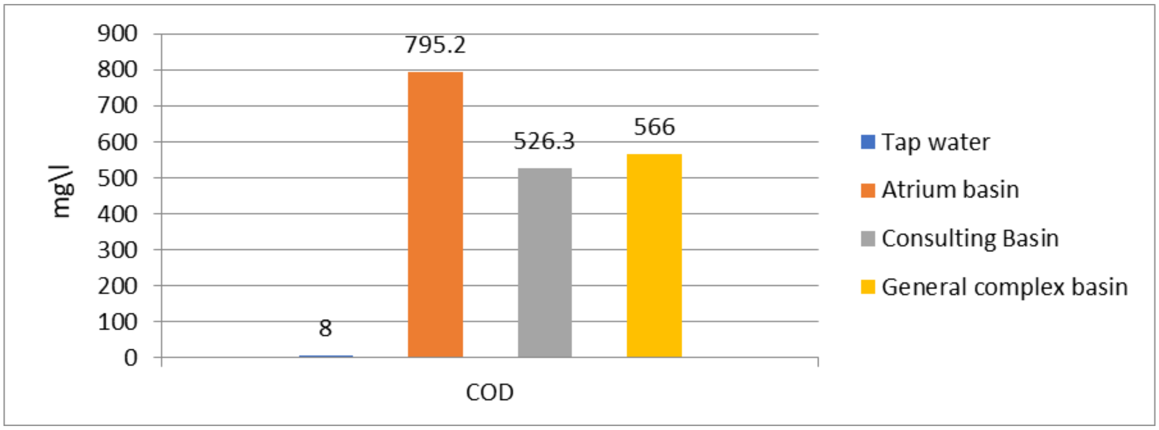


Fig. 7. Average (COD) values for the sites during the study period

Heavy metals

Iron (Fe)

The results depicted in Fig. (8) show that the iron concentrations in the water discharged from the health departments and units of Tikrit General Teaching Hospital ranged from 0.5 to 3.01mg/ l. These measurements include tap water (liquefaction water) entering the hospital, serving as a control, and the water from various basins: the hall basin, the consultation basin, and the general complex basin, where all hospital wastewater is directed. The highest iron concentration was found in the hall basin at 3.01mg/ l, while the lowest was in the tap water entering the hospital at 0.5mg/ l. According to the Iraqi standard for water sources **(Dunia Frontier Consultants, 2013)**, the permissible iron concentration limit is 0.3mg/ l. As shown in Table (4), all measured locations exceeded this standard, with the highest value recorded as 3.96mg/ l in the hall basin for October, and the lowest value as 0.36mg/ l in the tap water entering the hospital for October. These results are consistent with **Abd-Al Satar (2021)**, indicating that iron concentrations exceed the permissible limits set by the Iraqi standards. Compared to previous studies, the current results are lower than those reported by **Salafu *et al.* (2022)**, who found iron concentrations ranging from 12.79 to 13.11ppm. However, they are higher compared to the study by **Hamdan and Abood (2019)**, which reported an iron concentration of 0.02ppm in wastewater from Ali Hospital.

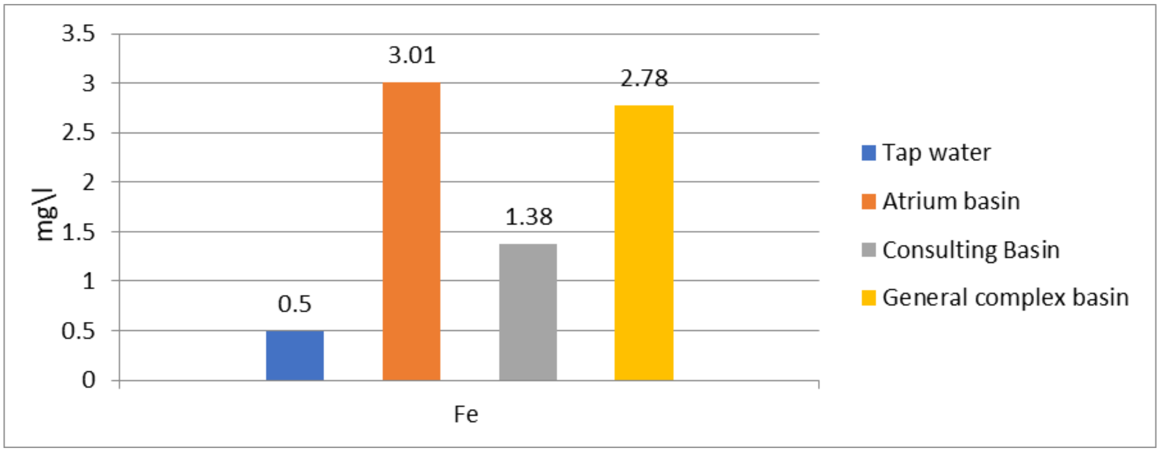


Fig. 8. Average (ion metal) values for the sites during the study period

Lead (Pb)

The results presented in Fig. (9) reveal that lead concentrations in the water discharged from the health departments and units of Tikrit General Teaching Hospital ranged from 0.07 to 1.94mg/ l. This includes measurements from both tap water (liquefaction water) entering the hospital, which serves as a control, and various basins: the hall basin, the consultation basin, and the general complex basin, into which all hospital wastewater flows. The highest lead concentration was found in the hall basin at 1.94mg/ l, while the lowest was in the tap water entering the hospital at 0.07mg/ l. All measured values exceeded the Iraqi standard for water sources, which sets the permissible limit for lead at 0.05mg/ l **(Dunia Frontier Consultants, 2013)**. Tables (2, 4) further show that the highest recorded lead concentration was 2.39mg/ l in the hall basin for November, and the lowest was 0.044mg/ l in the tap water entering the hospital for November. The elevated lead levels can be attributed to the proximity of hospitals and factories to the river basin, where untreated medical liquid waste and pollutants are discharged directly into the water. Such pollutants, including heavy metals like lead, can lead to severe health issues such as encephalopathy, anemia, reduced iron formation, and cardiovascular diseases **(Chen *et al.*, 2016)**. These findings align with the observations of **Carr *et al.* (2008)** and indicate levels significantly above environmental safety thresholds.

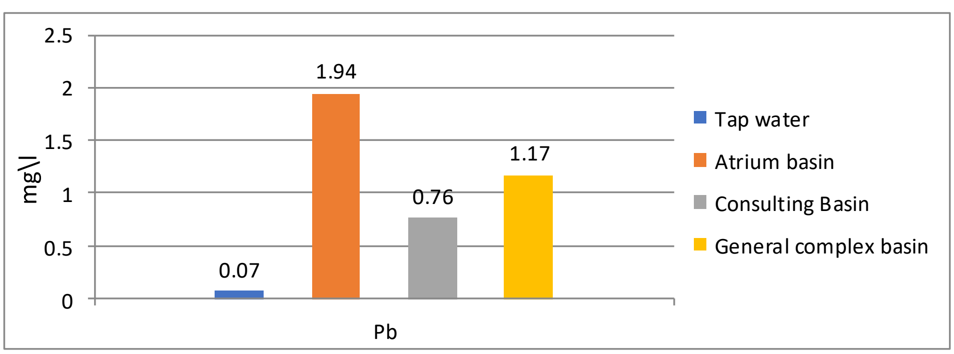


Fig. 9. Average (lead metals) values for sites during the study period

Cadmium (Cd)

The results depicted in Fig. (10) show that cadmium concentrations in the water discharged from the health departments and units of Tikrit General Teaching Hospital ranged from 0.006 to 0.81mg/ l. These measurements include both tap water (liquefaction water) entering the hospital, which serves as a control, and various basins: the hall basin, the consultation basin, and the general complex basin, where all hospital wastewater flows. The highest recorded cadmium concentration was 0.81mg/ l in the hall basin, while the lowest was 0.06mg/ l in the wastewater entering the hospital. All measured cadmium values exceeded the Iraqi standard limit of 0.005mg/ l for water sources **(Dunia Frontier Consultants, 2013)**. As shown in Table (4), these results indicate that cadmium concentrations in the wastewater are significantly high, aligning with findings from **Salih *et al.* (2018)**. Table (2) further highlights that the highest cadmium concentration was 0.97mg/ l in the hall basin for November, and the lowest was 0.003mg/ l in the tap water entering the hospital for December. Elevated cadmium levels in the water are attributed to the discharge of untreated liquid waste from hospitals and factories, as well as the use of fertilizers and pesticides. Additionally, plastic water pipes may contribute to cadmium leakage into the water **(Otchere, 2003; Sarvestani & Agassi, 2019)**. This study's findings are consistent with those of **Hussein (2018)** and **Salih *et al.* (2018)**, who reported high cadmium concentrations in wastewater exceeding the environmental safety limits.

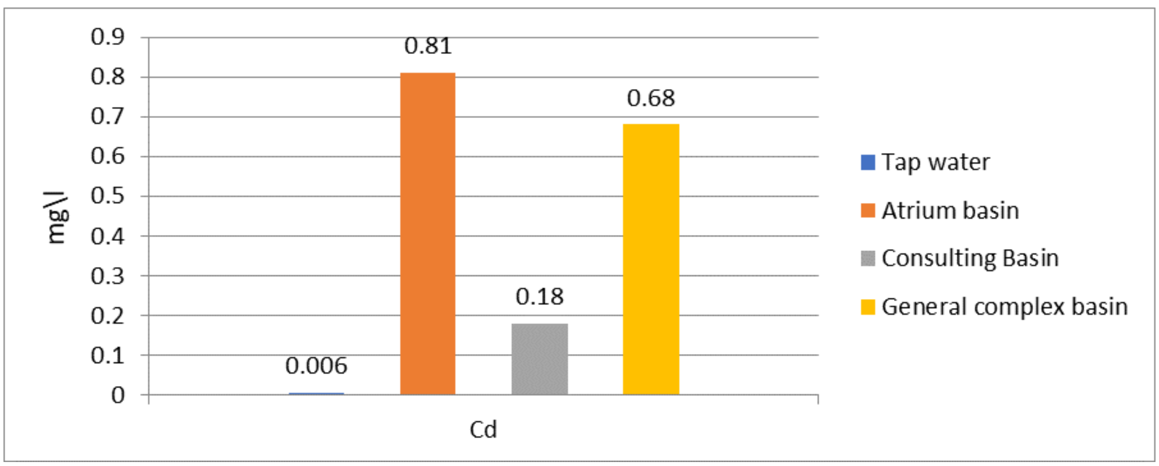


Fig. 10. Average values of (cadmium metals) for the sites during the study period

Copper (Cu)

The results depicted in Fig. (11) show that copper concentrations in the water discharged from the health departments and units of Tikrit General Teaching Hospital ranged between 0.07 and 0.71mg/ l. This includes both tap water (liquefaction water) entering the hospital, which serves as a control, and the water from various basins: the halls basin, the consultation basin, and the general complex basin where all hospital wastewater is directed. The highest copper concentration was 0.71mg/ l in the halls basin, while the lowest was 0.07mg/ l in the sewage water entering the hospital. All measured copper values exceeded the standard limit of 0.05mg/ l set by the Iraqi standards for water sources **(Dunia Frontier Consultants, 2013)**, except for the tap water entering the hospital. Table (4) shows that the highest copper concentration was

0.94mg/ l in the halls basin for October, and the lowest was 0.08mg/ l in the tap water entering the hospital for the same month. Copper is a heavy metal that poses risks to both human health and aquatic environments. The presence of heavy metals in wastewater from hospitals can result from excreta, detergents, and equipment used in medical settings **(Terms & Joss, 2006)**. The findings of this study coincide with those of **Hamdan and Abood (2019)**, who observed elevated copper levels in hospital wastewater in Malaysia, where the concentration reached 1.03ppm.

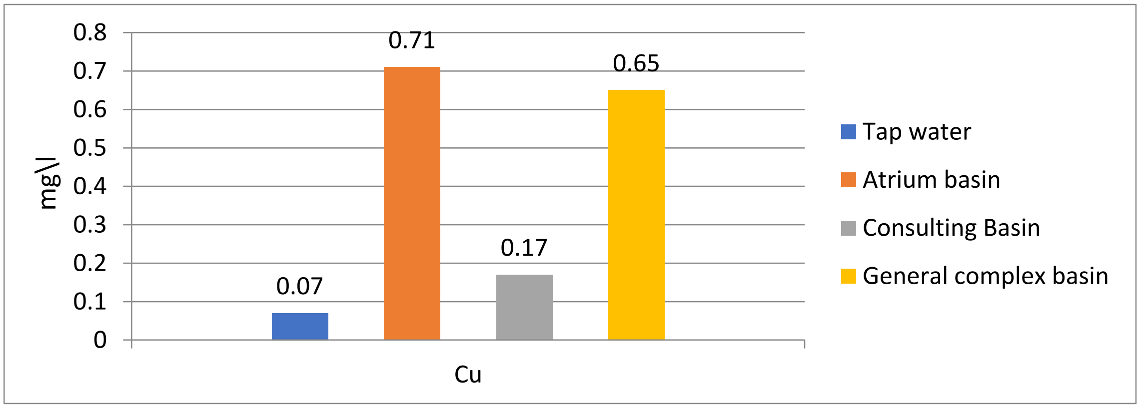


Fig. 11. Modifiers (copper metals) values for the sites during the study period

CONCLUSION

The study revealed a significant variation in pollutant concentrations across different hospital departments, with the Lobbies basin and the general complex basin identified as the most polluted areas. Significant differences were noted in the chemical factors and heavy metals across various locations, including the liquefaction water entering the hospital, the hall basin, the advisory basin, and the general complex basin. Elevated levels of certain heavy metals such as lead (Pb), cadmium (Cd), iron (Fe), and copper (Cu) were detected in the hospital wastewater, exceeding environmentally permissible limits. Among the studied units, the hall basin was found to be the most contaminated concerning those elements.

REFERENCES

Abd Al Satar, N. H. and Sachit, D. E. (2021). Assessment of Hospital Wastewater Quality and Management in Bab-Al Muadham Region at Baghdad. J. Engineering and Sustainable Development. 25(3):44-50.

Abd Al Satar, N.H. (2021). Assessment of Medical City Complex Wastewater Quality through Water Quality. Thesis, Mustansiriayah University College of Engineering, pp114.

Adia, S. P.; Gnamba, C. Q. M.; Kambiré, O.; Konan, K. M.; Berté, M.; Koffi, K. S. and Ouattara, L. (2023). Principal component analysis of physico-chemical parameters of wastewater from the University Hospital Center of Treichville in Côte d'Ivoire. J. Materials and Environmental Science. 14(7):826-837.

AK Al-Hiyaly, S.; Ma'alah, W. N. and N AL-Azzawi, M. (2016). Evaluating the effects of medical city wastewater on water quality of Tigris River. J. Engineering and Technology. 34(3B):405-417.

Akin, B. S. (2016). Contaminant properties of hospital clinical laboratory wastewater: a physiochemical and microbiological assessment. J. Environmental Protection. 7(5): 635-10.4236

Al-Enazi, M. S. (2016). Evaluation of wastewater discharge from Al-Sadr teaching hospital and its impact on the Al-Khorah channel and Shatt Al-Arab River in Basra City-Iraq. Evaluation. 6(12):55-65.

Al-Shamaa, I. and Ali, B. (2012). Estimation of groundwater recharge in Badra-Jassan Basin using annual water surplus method. J. Science. 53(1):107-112.

American Public Health Association. (1926). Standard methods for the examination of water and wastewater (Vol. 6). American Public Health Association.

Amouei, A.; Asgharnia, H.; Fallah, H.; Faraji, H.; Barari, R. and Naghipour, D. (2015). Characteristics of effluent wastewater in hospitals of Babol University of Medical Sciences, Babol, Iran. Health Scope. 4(2): e23222

APHA (American Public Health Association) (2003). Standard method for the examination of waste and wastewater. 20th ed. American Public Health Association. Washington. Cunningham, W. P.; Cunningham.

APHA. (1997). 5220 Chemical Oxygen Demand (COD) 5220 B. 5220 D. Open Reflux Method, 14–19.

APHA. (2002). Standard Methods for the Examination of Water and Wastewater.

APHA. (2005). Standard methods for the examination of water and wastewater. American Public Health Association (APHA): Washington, DC, USA, 21.

Bader, S. M.; Cooney, J. P.; Pellegrini, M. and Doerflinger, M. (2022). Programmed cell death: the pathways to severe COVID-19. J. Biochemical. 479(5):609-628.

Bhateria, R. and Jain, D. (2016). Water quality assessment of lake water: A review. Sustainable Water Resources Management. 2(2):161-173.

Boyles, W. (1997). Chemical oxygen demand. Technical information series, Booklet. (9):2-24.

Carr, C. (2008). On edge: Performance at the end of the twentieth century, Wesleyan University Press.

Chen, Y.; Guan, J.; Hu, H.; Gao, H. and Zhang, L. (2016). Infrared spectroscopic study on structural change and interfacial interaction in rubber composites filled with silica–kaolin hybrid fillers. J. Applied Spectroscopy. 83(3):490-496.

Dedeh, I. R. S. (2018). Effectively of phytoremediation in liquid waste treatment BHAKTI WIRA TAMTAMA hospital in Semarang. Magister Environmental Health Master's Program, Faculty of Public Health, Diponegoro University. J. Advanced Research in Science, J. Engineering and Technology. ISSN: 2350-0328.

Dunia Frontier Consultants (DFC). (2013). Water and Sewage Sectors in Iraq: Sector Report - February 2013. A report for Japan Cooperation Center for the Middle East (JCCME).Washington DC, Dubai, Kampala. Available online: http://www.meti.go.jp/meti_lib/report/2013fy/E002 792.pdf.

Edan, A. I. and Sharqi, M. M. (2020). A study of some physico-chemical and bacterial properties of wastewater for Ramadi Teaching Hospital and its impact on the Euphrates River. J. Forensic Medicine & Toxicology. 14(4):2319.

El-kanater, Q. (2011). Assessment of aquatic environmental for wastewater management quality in the hospitals: a case study. J. Basic and Applied Sciences. 5(7):474-782.

Farag A. EL M. (2015). Evaluation of Wastewater Discharge from Hospitals in the Northeastern Part of Libya. Engineering, Benghazi University, Libya.

Gupta, T. and Paul, M. (2013). The seasonal variation in ionic composition of pond water of Lumding, Assam, India. Current World Environment. 8(1):127-131.

Hamdan, D. A. and Abood, M. M. (2019). THE EFFECTS OF HOSPITAL EFFLUENT DISCHARGES ON THE QUALITY OF WATER. J. RESEARCH (IUKLRJ).7(1):1809

Hassan, N. E. (2023). An investigation of heavy metals concentration in rainwater and their effects on human health in Kurdistan Region, Iraq. GSC Advanced Research and Reviews. 17(2):229-239.

Hynes, H. B. N. (1960). The biology of polluted waters. Liverpool: Liverpool University Press. pp.202

Kawatra, B. L. and Bakhetia, P. (2008). Consumption of heavy metal and minerals by adult women through food in sewage and tube-well irrigated area around Ludhiana city (Punjab, India). J. Human Ecology. 23(4):351-354.

Khan, R. A.; Khan, N. A.; Morabet, R. E.; Alsubih, M.; Khan, A. R.; Khan, S.; Mubashir, M.; Balakrishnan, D. and Khoo, K. S. (2023). Comparison of constructed wetland performance coupled with aeration and tubesettler for pharmaceutical compound removal from hospital wastewater. Environmental Research. 216(1):114437.

Kumar, P.; Yadav, S.; & Yadav, A. (2024). Radioactive waste minimization and management. In Green Chemistry Approaches to Environmental Sustainability (pp. 165-184). Elsevier.

Kwikiriza, S.; Stewart, A. G.; Mutahunga, B.; Dobson, A. E. and Wilkinson, E. (2019). A whole systems approach to hospital waste management in rural Uganda. Frontiers in public health. 7:136.

Liu, A.; Zhao, Y.; Cai, Y.; Kang, P.; Huang, Y.; Li, M. and Yang, A. (2023). Towards effective, sustainable solution for hospital wastewater treatment to cope with the post-pandemic era. J. Environmental Research and Public Health. 20(4):2854.

Mustafa, M. H. (2000). Tigris river water quality within Mosul area. Raf. J. Sci. 11(4):26-32.

Ramírez-Coronel, A. A., Mohammadi, M. J., Majdi, H. S., Zabibah, R. S., Taherian, M., Prasetio, D. B., ... & Sarkohaki, S. (2023). Hospital wastewater treatment methods and its impact on human health and environments. Reviews on Environmental Health. (0) :

Salem, D. A.D.; Hassan, M. H.; **Issa, A. R. and Ali, F. A.** (2008). A Study of 60 Some Determinants of Pollution in the Wastewater of Hospitals in Najaf (Arabic). 215–232.

Salifu, O. C.; **Idemudia, I. B.**; **Imarhiagbe, E. E. and Ekhaise, F. O.** (2022). Evaluation of wastewater from a public healthcare facility in Benin City, Nigeria: A case study of its physicochemical and bacteriological qualities and the occurrence of extended-spectrum beta-lactamase bacterial isolates. J. of Health, Safety, and Environment. 3(2):46–60.

Salih, A. L. M.; Al-Qaraghul, S. A.; & Idan, R. M. (2018). Geochemical study of the Tigris river sediments in the surrounding area of Baghdad medical city. J. GEOMATE. 15(52):192-198.

Tchobanoglus, G.; Burton, F. and Stensel, H. D. (2003). Wastewater engineering: treatment and reuse. J. American Water Works Association. 95(5):201.

Ternes, T. and Joss, A. Eds. (2007). Human pharmaceuticals, hormones and fragrances. IWA publishing.

Todd, D. K. and Mays, L. W. (2004). Groundwater hydrology. John Wiley & Sons.

Twinch, E. (2009). Medical Waste. J. General Practice. 59:451.

US-EPA (United States Environmental Protection Agency). (2002). Ground water and drinking water standards: National primary drinking water regulation 816-F: 02-03.

Vincent, M. and Rosine, U. (2023). Impact of hospital wastewater on the rivers' quality: Case of Byumba hospital. J. International. 7(1):1-8.

Water, 21st Edition, edited by Eaton, A.D.; A.D L.S. Clescer, E.W. Rice, and A.E. Greenb Erg, American Water Work Association, and Water Environment.

WHO (World Health Organization). (2004). Guidelines for Drinking Water Quality, vol. 1. World Health Organization, Geneva, Switzerland, pp. 221-223.