



Examination of certain aspects of the water in Kirkuk City

Azhaar A. Ali^{1}, Zubaida Kh. Elias², Rafal N. Abdallah³*

^{1,2,3}Department of Laser and Spectroscopy, Laser and Photonics Center, University of Al-Hamdaniya, Mosul, 41006, Iraq.

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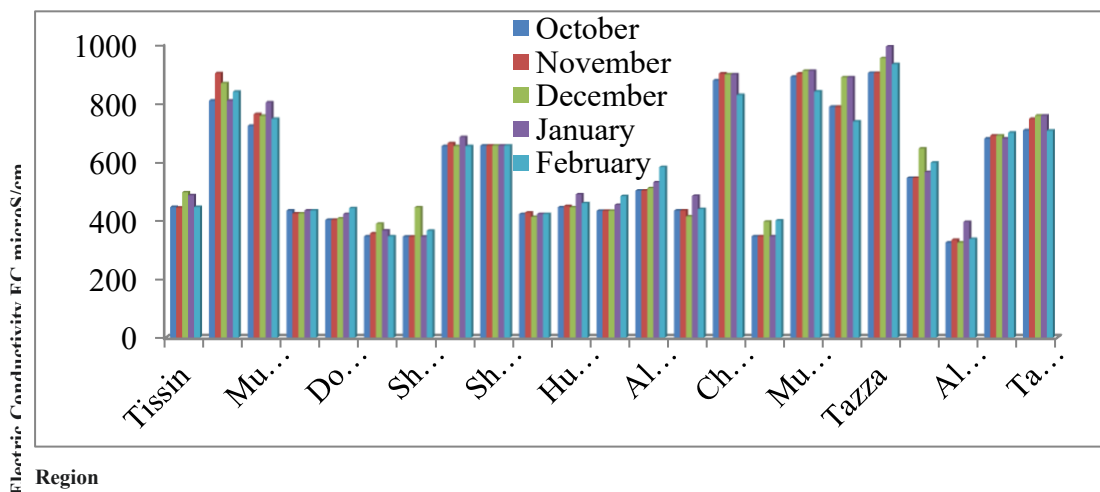
Water characteristics; temperature and pH levels; electrical conductivity; total dissolved salts; and drinking water quality in the Kirkuk Governorate

*Corresponding Author email:
 azhaar.ali14@uohamdaniya.edu.iq

ABSTRACT

The study assessed several aspects of the Kirkuk Governorate's drinking water. The acidity function, temperature, turbidity, electrical conductivity, roughness, total dissolved salts, and sodium chloride salt were among the attributes that were assessed. Studies and research have demonstrated that any increase in the levels of these aforementioned requirements causes a variety of illnesses, such as kidney and digestive irregularities and, on occasion, a number of cancerous diseases. According to the findings, the highest temperature and pH concentration was recorded in November in the Chardaghli and Quriya regions, the highest values for total dissolved salts, hardness, and electrical conductivity were recorded in December, and the highest degree of turbidity was recorded in January in the Chardaghli and Malla Abdullah regions, while the lowest levels were found in the Al-Musalla and Malla Abdullah regions. The findings also showed that the standard concentrations were higher than those set by the drinking water criteria for Iraq and the rest of the world.

Graphical Abstract



Highlights

- The study evaluated a number of the drinking water's characteristics in the Kirkuk Governorate.
- The characteristics that were evaluated included the acidity function, temperature, turbidity, electrical conductivity, roughness, total dissolved salts, and sodium chloride salt.
- previously mentioned requirements results in a number of ailments, including abnormalities of the kidney and digestive system and occasionally several malignant diseases.
- Based on the results, the regions of Chardaghli and Quriya had the greatest temperature and pH concentration in November.
- The results indicated an increase in the standard concentrations relative to those established by the drinking water criteria for Iraq and around the world. To improve the quality of water, modern methods must be used for sterilization

1. INTRODUCTION

Drinking water is directly linked to the spread of disease. The World Health Organization reports that diarrhea kills over 25 million people annually, with children under the age of five accounting for approximately one-third of these deaths. They attribute this to waterborne pathogens. Studies and statistics in the United States of America show that contaminated drinking water is the cause of 59% of diseases. Polluted drinking water sources are the cause of over 80% of infections and over 33% of fatalities in underdeveloped nations, according to United Nations Programs (UNEP) statistics from 1999. However, Ministry of Health reports from Iraq indicate that throughout the 1990s of the previous century, there was a noticeable increase in waterborne infections (WHO, 2017; Kheder, et al., 2023; Kheder, 2023). Water pollution has been the cause of approximately 90,000 child deaths in Iraq in 2001 alone, and the number and variety of these deaths is continually rising due to the country's poor drinking water quality. According to environmental data reports for 2005, over 136,000 out of the 920,000 instances of diarrhea that were for patients visiting and staying in hospitals and health facilities for those under five years of age in Iraq were cases of diarrhea. It posed a significant difficulty in many parts of the world, particularly Iraq, as it was limited to the Nineveh Governorate and because there was insufficient potable water from purification plants (Karamanis, et al., 2007). Any material or substance that is physical, chemical, biological, or radioactive in water is considered a "contaminant" under the Safe Drinking Water Act. Thus, anything other than water molecules is included in the exceedingly broad definition of "contaminant" given by the law. It is reasonable to assume that some contaminants will be present in drinking water, even only in trace amounts. While some toxins in drinking water may be safe to consume at certain amounts, others may not be (Marcussen & Holm, 2013). Contaminants alone do not always mean that drinking the water is dangerous for your health. adherence to drinking water regulations and non-adherence to their physical and chemical characteristics. Physical, chemical, and biological parameters are the three elements of water quality parameters that are used to gauge the quality of the water. Color, taste, odor, temperature, turbidity, solids, and electrical conductivity are some examples of the physical properties. Conversely, chemical parameters can include dissolved oxygen, hardness, pH, acidity, alkalinity, and chlorine (Semerjian, 2011). In general, pollution is defined as the introduction of materials or energy into the environment, either directly or indirectly, with the intention of harming ecosystems or living things (Rittmann & McCarty, 2001). According to the World Health Organization, it is any direct or indirect physical or chemical

alteration in the quality of water that affects its properties and renders it unsafe for living things to consume (Guzzellam et al., 2006). When water is considered potable, it indicates that it is appropriate for home and human usage. Numerous international agencies backed this and saw the opposite of this approach, making the water contaminated, in order to protect consumers' health (Pal et al., 2018). Physical, chemical, and biological pollutants are the several categories into which the pollutants of the aquatic environment fall. Thermal pollution is one of the physical sources of water pollution because it raises the temperature of the water and alters its pH. It also increases the solubility of materials in and related to radioactive contamination. Physical pollutants are substances that change the color and taste of water. Thermal pollution is the result of the disposal of cooling water from electric power plants and factory waste (Kassir et al., 2015). More than 200 radionuclides have been identified as coming from either natural or human activity sources, and consuming more of them than is permitted could result in the development of malignant disorders (Baird & Cann, 2005). Chemical pollutants are produced by industrial and agricultural processes that are conducted near water. This leads to the build-up of numerous pollutants, many of which enter riverbeds untreated and then find their way into groundwater, endangering both the environment and human health. It is among the most common contaminants in water (Boyd & Claude, 2000; Sharma et al., 2012; Manoj & Padhy, 2014; Food Standards Agency, 2003; Manhan, 2004).

The objective of this study is to assess the physical and chemical properties of drinking water in various Kirkuk Governorate regions in order to determine whether it is safe for human consumption. This is because drinking water pollution is a major contributor to a number of diseases that affect people.

2. MATERIALS AND METHODS

2.1. Collection of the Sample

In order to evaluate the physical specifications of the drinking water for HMTCK Water, twenty-three samples were collected over the course of five months in the Kirkuk Governorate from various residential areas, including Tissin, Quriya, Musalla, Almas, Domez, Raheem awa, Shoreja, Baghdad Road, Shoraw, Panja Ali, Huzayran 1, Daquq, Al-Wasity, Hay Al-Askaray, Chardaghli, Asra and Mafqudeen, Mulla Abdullah Yaychee, Tazza, Arafaa, Alkorneesh, Health and Medical Technical College. Tanki Water is home to Health and Medical Technical College. At Al Karunji Company, drinking water samples were examined using several instruments (pH meter, spectrophotometer, turbidity meter, and salinity meter) in order to produce water and juices.

2.2. Evaluation of pH and Temperatures

Using a pH meter, the pH function and temperatures were determined for 23 samples of drinking water as well as for the months of October through February of the following year. The Al-Karunji laboratory conducted these tests in order to produce drinking water. The figures are displayed in Table 1, 2.

2.3. Evaluation of Total Dissolved Salts, Electric Conductivity & Hardness

Using an EC & T.D.S meter, total dissolved salts and electric conductivity were assessed for 23 drinking water samples and for the months of October to February in Kirkuk. In order to produce drinking water, these experiments were conducted in the laboratories of Al-Karunji. The values are displayed in Table 3-5 and Figures 1, 2.

2.4. Evaluation of Turbidity and (Na⁺, Cl⁻)

Using turbidity meters, the turbidity of 23 drinking water samples was determined for Kirkuk, as well as for the months of October through February in the subsequent year. The purpose of these tests was to produce drinking water in the laboratories of Al-Karunji. The values are shown in Table 6, and Figure 3. Collected drinking water samples from 23 different regions in Kirkuk over a 5-month period (October to February) and assess the NaCl salt content using an EC meter and TDS. These experiments were conducted in the Al-Karunji laboratories in order to produce drinking water. The values are shown in Tables 7, 8. Turbidity in drinking water can be a sign of infections, high bacterial counts, or particles that can shield dangerous organisms from disinfection procedures. Water treatment facilities therefore keep a close eye on turbidity levels to make sure the water does not go above safe limits (Léziart et al., 2019).

3. RESULTS AND DISCUSSION

3.1. pH and Temperatures

The Tables 1, 2 below show the value of the pH and Temperatures Factors.

Table 1: pH for the study period

Region	pH Where the reference for pH=6.5-8.5				
	October	November	December	January	February
Tissin	6.9	7	7.1	7.3	7.3
Quriya	9.1	9.3	9.4	9.5	9.4
Mussala	8.8	8.7	8.8	8.9	8.8
Almas	7.3	7.5	7.6	7.5	7.5
Domez	7.5	7.6	7.4	7.3	7.2
Raheem awa	7.9	7.9	7.7	7.6	7.6
Shoreja	8	7.9	7.6	7.7	7.5
Baghdad road	6.8	6.9	6.8	6.7	6.7
Shoraw	7.9	8	8.1	8	8.2
Panja ali	7.8	7.9	7.8	7.9	7.8
Huzayran I	6.9	7.1	7.3	7.2	6.6
Daquq	6.5	6.6	6.5	6.6	7.6
Al wasty	7.6	7.7	7.7	7.6	8.3
Hay Al-Askaray	7.9	8	8.1	8.3	8.2
Chardaghli	9.8	9.9	9.8	9.7	9.5
Asra and Mafqudeen	7.7	7.8	7.6	7.5	8.2
Mula Abdullah	8.8	8.9	8.8	8.7	9
Yaychee	8.7	8.7	8.9	9	9.6
Tazza	9.3	9.4	9.5	9.6	7.2
Arafaa	6.9	7	7.1	7.2	7.4
Alkorneesh	7.6	7.7	7.6	7.4	7.8
D.W. for HMTCK	7.8	7.7	7.6	7.8	7.9

Region	pH Where the reference for pH=6.5-8.5				
	October	November	December	January	February
Tank for HMTCK	7.4	7.5	7.7	7.9	7.6

To put it simply, pH is a measurement of how basic or acidic a solution is. Seven is the neutral pH of water. It can be defined more scientifically as the amount of hydrogen ions in a liquid. A high pH denotes a lower hydrogen concentration, whereas a low pH denotes a higher hydrogen concentration. The scale goes from 14 (very basic) to 0 (highly acidic) (Jahnen-Dechent & Ketteler, 2012). A high pH for the following regions (Quriya, Mussala, Chardaghli, Mula Abdullah, Yaychee, Tazza) during the five months is normal. Water should normally have a pH range of 6.5 to 8.5. The water in question is deemed unsafe for human consumption and requires sterilization due to its differing acidity function value from both international and Iraqi requirements. Additionally, it is contaminated with numerous hazardous substances (Fitzgerald, 2000).

Table 2. Temperature for the study period

Region	Temperature Where the reference for Temperature =20°C - 45°C				
	October	November	December	January	February
Tissin	18	19	18	19	19
Quriya	21	23	21	21	24
Mussala	21	22	23	21	23
Almas	19	17	16	15	15
Domez	18	20	21	19	19
Raheem awa	18	19	18	17	17
Shoreja	19	19	22	17	17
Baghdad road	18	19	18	16	18
Shoraw	18	19	17	18	18
Panja ali	18	17	19	17	17
Huzayran 1	19	20	20	20	19
Daquq	20	19	20	19	19
Al wasty	20	19	18	19	20
Hay Al-Askaray	20	20	23	20	19
Chardaghli	20	19	19	19	19
Asra and Mafqudeen	19	18	20	19	23
Mula Abdullah	21	21	21	23	22
Yaychee	21	23	22	22	23
Tazza	20	19	18	17	18
Arafaa	18	17	19	18	19
Alkorneesh	20	20	20	19	19
D.W. for HMTCK	20	19	20	19	23
Tank for HMTCK	21	22	22	23	22

3.2. Total Dissolved Salts, Electric Conductivity EC and Hardness

The values of these factors are displayed in the Tables and Figures below.

Table 3. Total Dissolved Salts in the study period

Region	Total Dissolved Salts Where normal range of Total Dissolved Salts =1000 mg/l				
	October	November	December	January	February
Tissin	677	679	679	687	699
Quriya	503	603	515	503	508
Mussala	1003	1014	1099	1063	1063
Almas	678	678	666	698	678
Domez	601	601	601	621	606
Raheem awa	455	465	477	455	455
Shoreja	443	443	445	443	483
Baghdad road	324	364	324	384	364
Shoraw	213	219	213	213	266
Panja ali	434	454	406	434	434
Huzayran I	654	654	700	684	658
Daquq	655	655	655	675	685
Al wasty	589	599	589	599	595
Hay Al-Askaray	433	433	353	433	483
Chardaghli	987	989	997	987	987
Asra and Mafqudeen	431	431	436	431	451
Mula Abdullah	1123	1155	1203	1123	1123
Yaychee	989	989	980	989	950
Tazza	456	456	458	466	455
Arafaa	345	345	398	366	396
Alkorneesh	564	564	564	564	564
D.W. for HMTCK	499	499	501	501	509
Tank for HMTCK	205	512	582	509	485

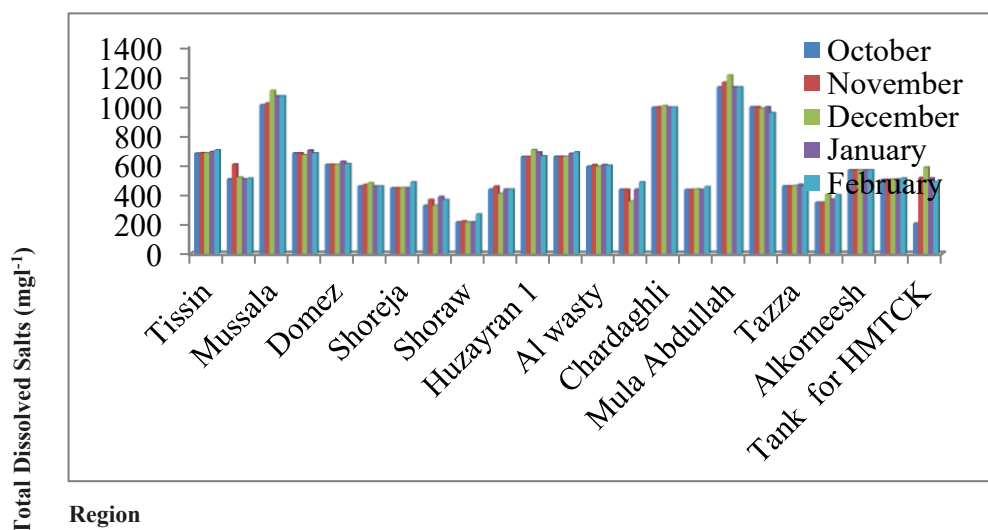


Figure 1: Show the relationship between Total Dissolved Salts for 23 regions of Kirkuk for the study period.

Table 4. The Electric Conductivity for the study period

Region	Electric Conductivity EC				
	Where normal range of EC =1000 microS/cm				
	October	November	December	January	February
Tissin	445	443	495	485	445
Quriya	807	900	866	807	837
Mussala	721	761	755	801	745
Almas	433	423	423	433	433
Domez	401	401	406	421	441
Raheem awa	345	355	388	365	345
Shoreja	344	344	444	344	364
Baghdad road	652	662	652	683	652
Shoraw	654	654	654	654	654
Panja ali	421	426	411	421	421
Huzayran 1	444	448	444	488	458
Daquq	432	432	432	452	482
Al wasty	501	501	509	529	581
Hay Al-Askaray	433	433	413	483	438
Chardaghli	876	899	896	896	826
Asra and Mafqudeen	345	345	395	345	399
Mula Abdullah	888	899	908	908	838
Yaychee	786	786	886	886	736
Tazza	901	901	951	991	931
Arafaa	544	544	644	564	596
Alkorneesh	324	333	324	394	336
D.W. for HMTCK	678	688	688	678	698
Tank for HMTCK	706	745	756	756	705

Table 5. The Hardness for the study period

Region	Hardness				
	Where normal range of Hardness =500 mg/L				
	October	November	December	January	February
Tissin	456	436	465	456	486
Quriya	344	354	342	344	364
Mussala	602	612	615	608	635
Almas	322	322	333	326	322
Domez	334	334	338	334	384
Raheem awa	201	211	205	221	211
Shoreja	189	189	175	209	206
Baghdad road	267	287	256	247	267
Shoraw	322	322	422	323	355

Region	Hardness				
	Where normal range of Hardness =500 mg/L				
	October	November	December	January	February
Panja ali	466	422	466	466	499
Huzayran 1	234	284	234	222	284
Daquq	433	433	433	438	433
Al wasty	217	217	217	217	217
Hay Al-Askaray	270	279	275	233	290
Chardaghli	489	489	499	459	499
Asra and Mafqudeen	237	237	237	237	255
Mula Abdullah	505	515	525	505	505
Yaychee	498	489	493	478	489
Tazza	344	344	344	384	355
Arafaa	266	266	312	226	285
Alkorneesh	321	355	361	361	322
D.W. for HMTCK	245	245	245	249	345
Tank for HMTCK	321	345	311	391	331

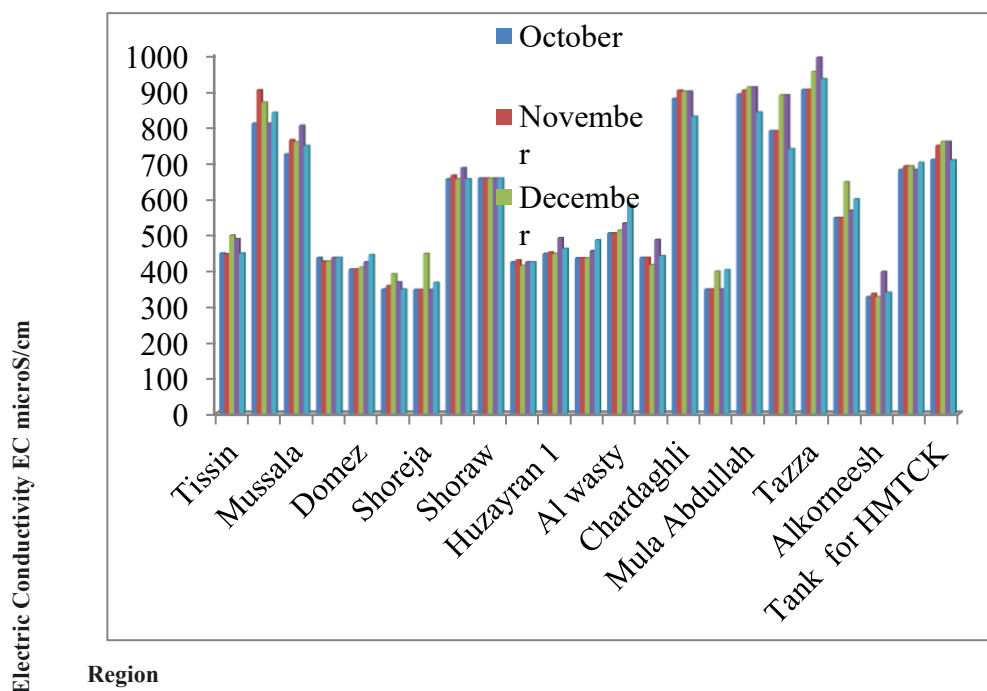


Figure 2. Show the relationship between Electric Conductivity for 23 regions of Kirkuk for the study period

All of the dissolved solids in a water solution are equal to the entire amount of dissolved salts in the water. The weight of the solids that remain after the water sample evaporates is used to calculate it. The ion concentrations in the water are also added to compute it. However, in the case of water containing 100–500 mg/L of dissolved salts, the overall concentrations of ions are less than the weight of the remaining

solids by roughly 10–20 mg/L. In nature, the concentrations vary from 10 mg/l in snow and rainwater to over 300,000 mg in seawater. It is well recognized throughout the world that water used for agriculture should have less than 3000 mg of dissolved salts per liter, while water acceptable for residential and commercial usage must have less than 1000 mg. In fresh drinking water with a total dissolved salt content of less than 1000 mg/L (Jurkic & Capanec, 2013). As we all know, the larger the proportion of dissolved salts in the water, the higher the electrical conductivity (also known as electrical current conductivity), which quantifies the percentage of total dissolved salts in the water (Ammonia, 1986). Either natural processes, like the characteristics of water and groundwater, or materials that dissolve and fall from the sky, or industrial processes, like the outflow of sewage or industrial effluent into natural water bodies, are to blame for the rise in salts (Montenegro, 2011). For the five months, we see that the following regions—Mussala, Chardaghli, and Mula Abdullah—have high levels of total dissolved salt. This denotes the potential for pollutants to be present. This falls within the typical reference range (TDS<1000 mg/l). For the five months that it was visible, the normal Electrical Conductivity value for every region was within the usual reference range (EC<1000 mg/L). a high Hardness range for the next five months in the following areas: Mula Abdullah and Mussala This indicates that there may be pollutants present, although they should fall within the typical reference range (hardness < 500 mg/L). Salt has been used as a preservative for a long time because of its antibacterial qualities. Certain bacteria can be successfully killed by salt by having their water content drawn out. Water exits a bacterium through a process called osmosis in order to maintain an equilibrium between the concentrations of salt on each side of the cell membrane. However, in contrast to other kinds of bacteria, they like growing in the presence of NaCl (Health Canada, 1996).

3.3. Turbidity, Na⁺ and Cl⁻

The values of these factors are displayed in the Tables and Figures below.

Table 6. Turbidity for the study period

Region	Turbidity				
	Where reference for Turbidity =5 NTU				
	October	November	December	January	February
Tissin	4.2	4.2	4.5	4.3	4.0
Quriya	6.3	6.4	6	6.5	6.5
Mussala	5.5	5.4	5.6	5.9	5.9
Almas	5	4.9	5	4.8	4.8
Domez	4.8	4.9	4.8	4.7	4.9
Raheem awa	4.8	4.7	4.9	4.9	5
Shoreja	5.7	5.5	5.8	5.8	6.1
Baghdad road	4.33	4.2	4.1	4.1	4.5
Shoraw	6	5.9	6	6.1	6.2
Panja ali	5.9	5.8	5.7	5.9	5.8
Huzayran 1	5.1	5.2	5.3	5.4	5.2

Region	Turbidity				
	Where reference for Turbidity =5 NTU				
	October	November	December	January	February
Daquq	3.65	3.7	3.5	3.2	3.9
Al wasty	3.65	3.8	3.6	3.7	4
Hay Al-Askaray	4.76	4.6	4.5	4.5	4.9
Chardaghli	5.87	5.9	6	6.3	6.4
Asra and Mafqudeen	4	4.1	4	4.3	4.1
Mula Abdullah	6.3	6.4	6.5	6.3	6
Yaychee	5.77	5.8	5.9	5.8	5.8
Tazza	5.32	5.4	5.5	5.6	5.6
Arafaa	4.1	4.2	4.1	4.2	4
Alkorneesh	4.8	4.9	4.8	4.7	4.9
D.W. for HMTCK	5.3	5.4	5.5	5.9	5.7
Tank for HMTCK	5.88	5.9	6	6.8	5.9

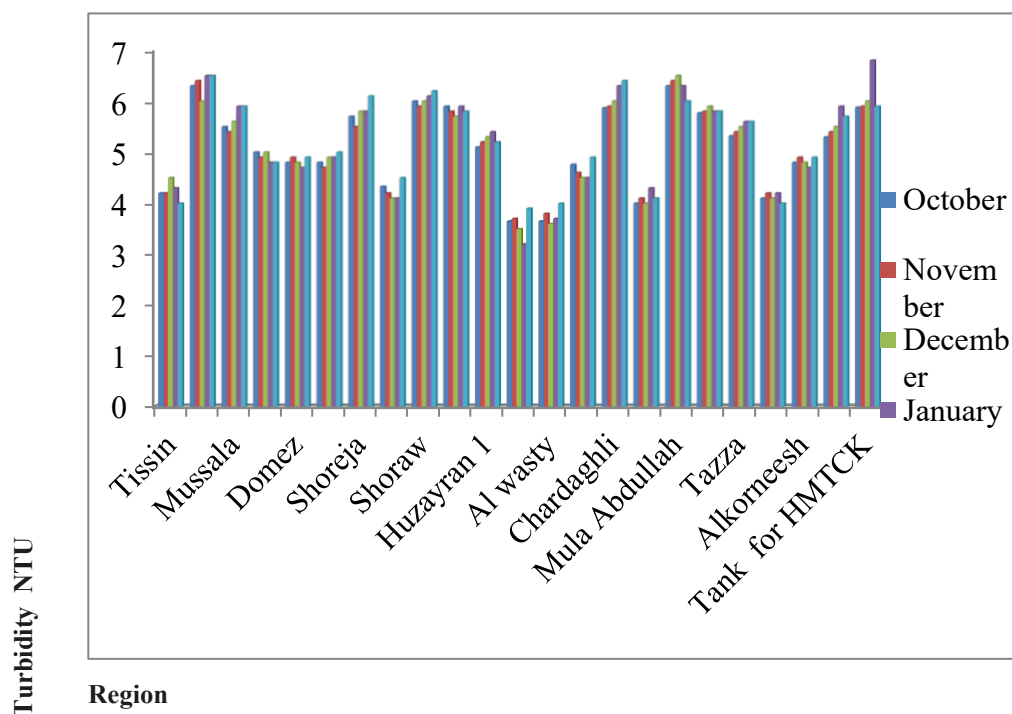


Figure 3. Show the relationship between Turbidity for 23 regions of Kirkuk for the study period

Table 7. Na⁺ for the study period

Region	Na ⁺ Where Reference for Na ⁺ =200 mg/L				
	October	November	December	January	February
Tissin	170	171	168	166	163
Quriya	230	229	228	230	229
Mussala	210	212	210	215	213
Almas	154	155	154	154	154
Domez	155	150	155	158	159
Raheem awa	176	177	175	177	176
Shoreja	164	165	160	169	167
Baghdad road	150	149	145	145	140
Shoraw	202	200	200	198	195
Panja ali	133	130	125	120	121
Huzayran l	156	155	155	150	150
Daquq	187	188	185	182	180
Al wasty	201	200	200	200	199
Hay Al-Askaray	123	122	120	122	129
Chardaghli	234	232	232	230	234
Asra and Mafqudeen	189	188	180	188	187
Mula Abdullah	250	245	244	245	248
Yaychee	301	300	333	338	340
Tazza	231	230	233	235	240
Arafaa	133	132	130	133	139
Alkorneesh	123	120	125	125	123
D.W. for HMTCK	176	175	177	178	172
Tank for HMTCK	189	185	185	184	185

Table 8. Cl⁻¹ for the study period

Region	Cl-1 Where Reference for Cl-1 =250 mg/L				
	October	November	December	January	February
Tissin	155	155	155	157	155
Quriya	261	260	265	268	269
Mussala	248	249	255	259	257
Almas	155	155	160	166	166
Domez	203	202	210	211	216
Raheem awa	189	188	185	184	189
Shoreja	179	180	180	189	185

Region	CI-1				
	Where Reference for CI-1 =250 mg/L				
	October	November	December	January	February
Baghdad road	206	205	209	209	209
Shoraw	200	200	201	211	217
Panja ali	144	145	140	144	145
Huzayran 1	198	199	201	216	250
Daquq	155	155	155	159	154
Al wasty	203	203	208	208	230
Hay Al-Askaray	167	167	170	178	177
Chardaghli	268	267	270	277	277
Asra and Mafqudeen	134	133	135	133	130
Mula Abdullah	276	275	280	288	288
Yaychee	303	300	310	313	311
Tazza	256	255	260	259	260
Arafaa	198	197	200	215	220
Alkorneesh	131	130	140	142	144
D.W. for HMTCK	164	163	165	172	169
Tank for HMTCK	188	185	188	183	188

Turbidity in drinking water can be a sign of infections, high bacterial counts, or particles that can shield dangerous organisms from disinfection procedures. Water treatment facilities thus keep a close eye on turbidity levels to make sure the water does not go above safe limits. Quriya, Mussala, Chardaghli, Mula Abdullah, Yaychee, Tazza, Shoreja, Shoraw, Panja ali, Huzayran 1, D.W for HMTCK, Tank for HMTCK) had a high total turbidity value during the course of the five months. This indicates that a conflict may arise. It should be within the typical range (turbidity less than five NTU). For the five months, there was a high total value of Na⁺ in the following regions: Quriya, Mussala, Shoraw, Al Wasty, Chardaghli, Mula Abdullah, Yaychee, Tazza. This denotes the potential for conflict to exist. It ought to fall within the typical reference range (Total Na⁺ < 200 mg/L). For the five months, we observe a high Total CI-1 for the following regions: Quriya, Mussala, Chardaghli, Mula Abdullah, Yaychee, and Tazza. This denotes the potential for conflict to exist. It ought to fall within the typical reference range (Total CI-1 < 250 mg/L).

4. CONCLUSIONS

An increase in the governorate of Kirkuk's drinking water's acidity. This results in the water being invalid and contaminating it with bacteria and other impurities. It is most effective when there is high levels of sodium chloride in the water. The symptoms include intense diarrhea that lasts longer than an hour, thirst, muscle soreness, general weakness, and emaciation. A number of variables, including sewage and industrial waste water, raise the likelihood of bacterial growth. The present investigation has revealed the existence of sulfate ions in numerous regions inside the Kirkuk governorate, with their concentration beyond the allowable threshold. Many parts of the Kirkuk Governorate have drinking water that is contaminated with substances that are bad for people's health and can lead to a variety of illnesses,

including cancer. The fact that drinking water in many parts of the Kirkuk governorate has high levels of turbidity is one of the crucial issues that needs to be taken seriously. germs are carriers in turbidity, muck, and silt, and these elements aid in the propagation of the germs. Water undergoes three different sorts of treatments, including sedimentation, filtration, and sterilizing, in order to remove the many impurities, it contains and make it appropriate for human usage and other multiple applications.

5. DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflicts of interest.

6. FUNDING INFORMATION

The authors declare no funding of this study.

7. AUTHOR CONTRIBUTION

All authors have contributed equally, they reviewed, and agreed to their individual contributions ahead of this time.

8. DATA AVAILABILITY STATEMENT

The datasets generated during the current study are not publicly available as the study is ongoing; however, they are available from the corresponding author upon reasonable request.

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