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Evaluation of Drinking Water Quality in Erbil City Kurdistan, Region-Iraq

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Abstract
This study is based on an analysis of drinking water characteristics in Erbil in Kurdistan. For water quality analysis Erbil is divided into four parts (Ifraz l, Ifraz ll, Ifraz lll and Bakhtari and Ainkawa wells). Several samples were collected which include three samples from source, five samples from wells, and 32 samples from houses. The physiochemical parameters of P^H, turbidity, conductivity, total hardness, and total alkalinity were analyzed. Cations potassium, calcium and sodium were also analyzed. In addition, anions chloride, nitrate and sulphate were analyzed. Further, the biological parameters of total coliform (thermo tolerant (faecal) coliform and faecal (streptococci)) were analyzed. There was no bacteria in the drinking water. All the parameters were in permissible limits. The range of pH (7.1-7.9), conductivity (282-850µ/s), turbidity (0.2-9.9mg/L), total hardness (188-407mg/L), total dissolved solids (141-360mg/L), and alkalinity was (121-378mg/L). Cations concentration range of calcium (50-102ppm), sodium (4.5-79ppm), potassium (1-5.2ppm). Anions concentration range of chloride (2.1-50ppm), sulphate (5-112ppm), nitrate 1.2-84ppm. While in ground water samples biological contamination has been found. The results indicate that the drinking water quality of Erbil is suitable.
Keywords Evaluation, drinking water, physiochemical, biological, Erbil.

1. Introduction

Since 2003 Erbil City has been undergoing massive development and expansion. It has become one of the fastest growing cities in the region. Due to increased economic activities, the immigration to the city is on a rising trend. Expansion in population, increase in economic activities, provision of recreational facilities and change in life style of the citizens are putting immense pressure on the availability and sustainability of the water resources of the city. Furthermore, partially treated city sewage (municipal and industrial) is causing pollution to the groundwater as well as surface water. It is further limiting the resource availability in desired quality.

According to the Erbil Water Directorate an estimated 530,000 m^3/day of water is being supplied to the city, almost equally from the groundwater and from the Ifraz Water Project. Groundwater levels have been on the decline day by day due to over exploitation of the aquifer. Under these circumstances, many of the drinking water wells will not be able to produce water in future in sufficient quantity. More efforts will be required to pump water, which would cause high energy and financial costs. Recharge to the groundwater is mainly through the rainfall in Erbil. Wastewater is also a substantial resource of groundwater recharge, causing deterioration to the groundwater quality.

Drinking water quality and human health are closely interrelated. Diseases like cholera, dysentery, diarrhea and typhoid are spread mainly due to microorganism present in water (Joao et al., 2010).

The high contents of nitrates, phosphates, inappropriate proportions of cations and anions also have negative health impacts. The heavy metals in drinking water are mainly carcinogenic (Elarina et al., 2014). The basic water quality parameters like electrical conductivity, total dissolved solids and dissolved oxygen mainly define the fitness of drinking water for human consumption.

Turbid water is not clear water; in turbid water there are many suspended solids of plankton and other organisms. Turbidity caused high flow rates and soil erosion etc. (Brian, 2012).

The P^H of drinking water should be less than 8. The low P^H or P^H below 4 causes eye irritation and exacerbation of skin disorders etc. Higher P^H causes hair fiber to swell and gastrointestinal irritation etc. (WHO, 2011).

Conductivity is the measurement of concentration of ionized compounds in water (Pedro et al., 2011).

Water is divided in to three categories on the basis of hardness. Most commonly hardness is expressed in mg/L of calcium carbonate in water. Soft water concentration is below 60mg/L, moderate hard water concentration is 120-180mg/L and above 180mg/L is very hard water (WHO, 2011).

Total Dissolved Solids (TDS) are dissolved solids in water and sometimes they have adverse effect on human health (Anwar et al., 2011).

Carbonates, bicarbonates and hydroxide compounds lower the acidity of water (Burton et al., 2002)

The high level of sulphate in drinking water caused diarrhea in human being (EPA, 1999).

High level of nitrate concentration has an unfavorable effect on human being (Elizabeth et al., 2013).

Sodium, Potassium and calcium are important cellular cations. They have great importance in anaesthesia (Manoj, 2012).

In order to ensure safe drinking water supply to the city of Erbil with acceptable quality and quantity, it is very important to understand the status of water quality of the city from the source to the user and identify factors affecting it. The main aim of the study is to understand in depth the water quality and quantity status in the Erbil City in order to help policy makers in planning water resources management in a sustainable manner.

In order to achieve the purpose of study, comprehensive investigations will be conducted to determine the current status of water quality in City. The rate of groundwater abstraction in the current situation and anticipated for the future will be estimated. Recharging phenomena to the groundwater will be explored including fresh water stream network (if any), municipal and industrial wastewater drainage system, seepage and leakage from unserved sanitation areas and waste disposal areas. Water quality of the resource will be studied at the source, pumping and transmission system, and at the consumer end. Legal aspects of the groundwater abstraction and pollution control will also be explored and investigated. The water quality of the city will be mapped on spatial scale in order to identify the suitability of drinking water in and around the city. Water quality will be compared to the World Health Organization standards of drinking water supply.

2. Materials and Methods

2.1. Reagents

All the chemicals were purchased from Sigma (95% purity) Aldrich chemical company. The distilled water (modle 800 aquatron, bibby scientific;UK) was used for preparation of different solutions and their standards.

2.2 Samples collection

A total of 39 samples were collected in 2.5 liter sterilized bottles. Three samples were taken from source, 31 samples were taken from homes and five samples were taken from wells.

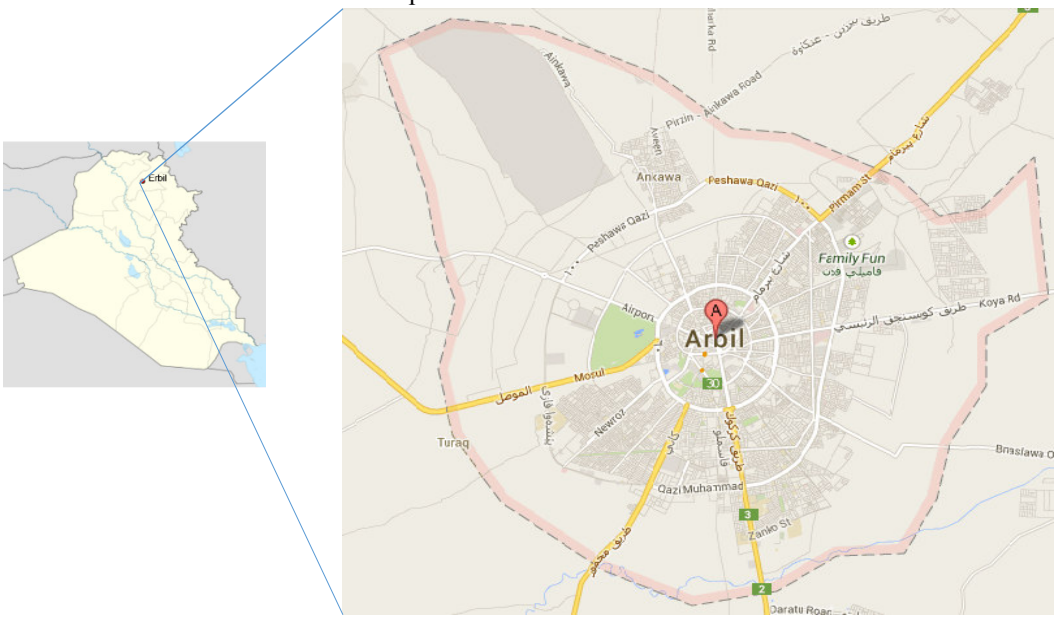

Figure 1: Location map of Erbil with administrative boundary.

2.3. Apparatus and Procedure of analysis

The pH, TDS, conductivity and turbidity of water samples were measured by using pH meter, TDS meter, conductivity meter and turbidity meter (600 modle Plaintest micro, UK). The total hardness of water samples were measured by EDTA titration method (Poonam et al., 2013).

The concentration of chloride in water samples was measured by Argentometric titration [13]. Nitrate was determined in water samples with help of UV/Visible Spectrophotometer (modle 6705 UV/Vis Jenway, UK) (Badiadka and Kenchaiah 2009).

Digital burette is used to determine the concentration of sulphate in water (P.A Siskos et al., 1983)

Total alkalinity of samples was checked by using digital burette (Bibby scientific) (A.G. Dickson 1981).

Concentration metal cat ions (Sodium, Potassium, and Calcium) were determined by using a flame photometer (model PFP7 Jenway, UK). Iron concentration is determined with the help of a Flame atomic absorption spectrometer (model210/211/ Buck Scientific) (Elarina et al., 2014, Stasys, 2004).

Total coliform (Bacteria) was tested in water samples (Sherry et al., 2002).

3. Results

The City of Erbil imports an average of 85 percent of its water from the Ifraz-river. This imported water is provided by the Directorate of Erbil water, which is responsible for the overall supply of safe-water to the community. Several forces negatively impact the quality of water from the Ifraz-river and ground wells. The Ifraz-river winds through thousands of miles of unprotected watershed containing towns and farms.

Water from the wells is also subject to major contaminants such as a high concentration nitrates and pathogens. This water source also has a higher nitrate and E.coli level than the Ifraz-river water. As the pathogen (coliform, E.coli) levels increase, the potential for creating higher levels of disinfection by-products also exist which is also a water quality concern.

Erbil continually imports this treated water by Ifraz project supply containing disinfection agent. The disinfectants such as chlorine used to treat Ifraz-water can react with naturally occurring materials in the water to form unintended by-products which may pose health risks.

Water is treated at the City's three treatment plants (Ifraz I, II, III) using several processes, with each process providing additional water quality improvements. The Ifraz water treatment system consists of coagulation, flocculation, sedimentation, and sand/multi-media filtration. Combined with the conventional treatment process, advanced disinfection has been added to the treatment plants. All the water samples were colorless, odorless and tasteless.

Table 1: Physiochemical Characteristics of drinking water samples from (Ifraz l) Erbil.

No	Location	p H	Turbidity	Conductivity	Total Hardness	TDS	Alkalinity
			mg/L	µS/cm	mg/L	mg/L	mg/L
1	Ifraz(s)	7.9	0.9	441	218	264	220
2	Kuran	7.8	0.7	433	223	259	228
3	Karkar	7.4	0.3	485	226	291	230
4	Saila(a)	7.7	5.5	350	197	210	200
5	Saila(b)	7.9	2.5	420	198	252	210
6	Kurdistan1	7.1	0.4	600	317	360	330
7	Bahar	7.2	9.9	450	238	270	245
8	Kurdistan 2	7.6	0.6	350	211	210	200

In Table 1, turbidity was found to be high in Saila (a)-5.5 and Bahar-9.9 according to (WHO, 2011) both values are within permissive limits of Iraqi standards. Conductivity, Hardness and TDS values are under permissive standards. The rate of alkalinity was noticed more as Kurdistan1 > Bahar > Karkar > Kuran > Saila > Kurdistan2 and in source as well. Most of these values are not in permissive limits according to specification of Iraqi drinking water quality standards. The pH of all the water samples were between 7.1 to 7.9 which satisfy both Iraqi and WHO standards. (Standards Iraqi, WHO, 2014).

Table2: Concentration of common cations in drinking water Ifraz 1(Erbil).

No	Location	Calcium(Ca+2)	Sodium(Na+)	Potassoum(K+)
		(ppm)	(ppm)	(ppm)
1	Ifraz(s)	53	47	5.1
2	Kuran	56	47	5.2
3	Karkar	57	53	5.1
4	Saila(a)	50	45	5.1
5	Saila(b)	51	45	5
6	Kurdistan1	79	59	5.4
7	Bahar	60	63	5.3
8	Kurdistan2	53	50	5.1

In Table 2 the results of major cations are given. Most of these values are not in permissive limits according to specification of Iraqi drinking water quality standards. Calcium, Potassium and sodium values are determined to be even less than the minimum limit.

Table3: Concentration of major anions in water Ifraz1 (Erbil).

No	Location	Chloride(Cl-)	Sulphate(SO42-)	Nitrate NO3-
		mg/L	mg/L	mg/L
1	Ifraz(s)	13	32	4.5
2	Kuran	15	34	5.5
3	Karkar	22	31	30
4	Saila(a)	10	42	7
5	Saila(b))	11	47	45
6	Kurdistan1	50	29	77
7	Bahar	30	31	45
8	Kurdiatan2	15	35	9

In Table 3, the nitrate value was found to be high in Kurdistan area under the supply of Ifraz I treatment plant. Chloride and Sulphates values are determined to be even less than the minimum limit.

Table4: Biological parameters of drinking water.

No	Location	Total Coliforms	Thermo toerant (Faecal coliform)	Faecal (Streptococci)
1	Ifraz(s)	0	0	-ive
2	Kuran	0	0	-ive
3	Karkan	0	0	-ive
4	Saila(a)	0	0	-ive
5	Saila(b)	0	0	-ive
6	Kurdistan1	0	0	-ive
7	Bahar	0	0	-ive
8	Kurdistan2	0	0	-ive

In table 4, no significant biological contamination was found. Biological contaminants that may present public health risk, the WHO and Iraqi drinking water standard is set at zero because bacterium may cause adverse health effects.

Table 5: Physiochemical Characteristics of drinking water samples from (Ifraz ll) Erbil.

No	Location	ph	Turbidity (mg/L)	Conductivity µS/cm)	Total Hardness (mg/L)	TDS (mg/L)	Alkalinity (mg/L)
1	Ifrazll(s)	7.5	0.2	650	201	325	155
2	Ainkawa102	7.3	1.1	644	258	251	168
3	Ainkawa103	6.9	0.9	503	218	251	208
4	Ainkawa104	7.5	0.6	534	210	267	121
5	Kwestan(a)	7.1	0.8	618	192	309	189
6	Kwestan(b)	7.3	0.4	569	207	284	180
7	Shoresh(a)	7.2	0.4	676	260	338	216
8	Shoresh(b)	7.2	0.5	687	248	343	212
9	Tyrawa	7.2	1.1	708	266	354	212
10	Ainkaw1	7.4	0.2	550	257	275	240
11	Ainkaw2	7.5	0.3	600	201	300	230
12	Sheryani	7.5	0.1	450	277	225	200
13	Ainkawa4	6.9	0.4	450	241	225	234
14	Ainkawa5	7.5	0.6	400	208	200	200

In Table 5 all physiochemical parameters of Ifraz II samples are within permissive limit of both Iraqi and WHO standards. In samples 7,8,9,10,11 and 13 alkalinity exceeded the permissive limit according to Iraqi standards.

Table6: Concentration of common cations in drinking water Ifraz lll (Erbil).

No	Location	Calcium(Ca+2) (ppm)	Sodium(Na+) (ppm)	Potassium(K (ppm)
1	Ifrazll(s)	51	44	5.1
2	Ainkawa102	66	47	3.1
3	Ainkawa103	61	65	1.7
4	Ainkawa104	70	30	2
5	Kwestan(a)	57	39	2.8
6	Kwestan(b)	72	33	2.4
7	Shoresh(a)	65	21	1.2
8	Shoresh(b)	71	20	1.2
9	Tyrawa	78	24	1.6
10	Ainkaw1	65	61	5.2
11	Ainkaw2	51	79	6
12	Sheryani	70	56	5.1
13	Ainkawa4	61	59	5.1
14	Ainkawa5	52	50	5

In table 6 all metal cations were in permissible limits.

Table7: Concentration of major anions in water Ifrazll (Erbil).

No	Location	Chloride(Cl-) (mg/L)	Sulphate(SO42-) (mg/L)	Nitrate(NO3-) (mg/L)
1	Ifrazll(s)	51	40	4.5
2	Ainkawa102	4.3	59	3.1
3	Ainkawa103	2.1	24	1.7
4	Ainkawa104	2.1	30	2
5	Kwesten(a)	3	44	2.8
6	Kwesten(b)	3	26	2.4
7	Shoresh(a)	3	10	1.2
8	Shoresh(b)	4	5	1.2
9	Tyrawa	4	7	1.6
10	Ainkawa1	5.2	17	5.2
11	Ainkawa2	29	71	6
12	Sheryani	22	29	5.1
13	Ainkawa4	5.1	35	5.1
14	Ainkawa5	14	38	5

In table7 all anions are in permissible limits.

Table8: Biological parameters of drinking water (Ifrazll) Erbil.

No	Location	Total Coliforms	Thermo toerant (Faecal coliform)	Faecal (Stretococci)
1	Ifraz ll (s)	0	0	-ive
2	Ainkawa 102	0	0	-ive
3	Ainkawa 103	0	0	-ive
4	Ainkawa 104	0	0	-ive
5	Kwestan(a)	0	0	-ive
6	Kwestan(b)	0	0	-ive
7	Shoresh(a)	0	0	-ive
8	Shoresh(b)	0	0	-ive
9	Tyrawa	0	0	-ive
10	Ainkawa1	0	0	-ive
11	Ainkawa2	0	0	-ive
12	Sheryani	0	0	-ive
13	Ainkawa4	0	0	-ive
14	Ainkawa5	0	0	-ive

In table 8, no significant biological contamination was found. Biological contaminants that may present public health risk, the WHO and Iraqi drinking water standard is set at zero because bacterium may cause adverse health effects.

Table9: Physiochemical Characteristics of drinking water samples from (Ifraz lll) Erbil.

No	Location	pH	Turbidity (mg/L)	Conductivity (µS/cm)	Total Hardness (mg/L)	TDS (mg/L)	Alkalinity (mg/L)
1	Iflll(source)	7.4	0.2	400	240	200	181
2	IF3001	7.5	0.7	386	192	193	116
3	IF3R004	7.3	2.9	648	248	324	171
4	IF3lS005	7.7	0.8	324	208	162	160
5	IF3MU006	7.7	0.4	304	196	152	150
6	IF3MU007	7.6	0.4	309	220	154	152
7	IF3lS008	7.8	0.7	330	224	165	158
8	IF3RU009	7.6	0.6	286	220	143	160
9	IF3RU010	7.9	0.6	282	188	141	154
10	Siydwan	7.5	0.4	850	407	425	378
11	Minthakawa	7.7	1.8	400	228	200	191
12	Khanakaw	7.9	0.9	475	235	237	200

Table 9 analyzes samples having turbidity, conductivity, total hardness and TDS parameters and all are found to be under permissive limits and no significant difference has been identified compared to Iraqi and WHO standards. Alkalinity was found to be high in the Siydwan water sample.

Table10: Concentration of common cations in drinking water Ifrazlll (Erbil).

No	Location	Calcium(Ca+2) (ppm)	Sodium(Na+) (ppm)	Potassium(K+) (ppm)
1	Ifrazlll(source)	60	4.7	1
2	IF3001	68	8.3	1.7
3	IF3R004	99	13	1.1
4	IF3IS005	68	13	1.2
5	IF3MU006	64	14	1.3
6	IF3MU007	86	11	1.3
7	IF3IS008	67	14.1	1.2
8	IF3RU009	63	16	1.3
9	IF3RU009	73	11	1.3
10	Siydwan	102	10	1.1
11	Minthakaw	57	4.5	1
12	Khanakaw	59	8.9	1.3

In table 10 all major cations are in permissible limits.

Table11: Concentration of major anions in water Ifrazlll (Erbil).

No	Location	Chlooride(Cl-) (mg/L)	Sulphate(SO4-2) (mg/L)	Nitrate(NO3-1) (mg/L)
1	Ifrazlll(source)	12	42	6
2	IF3001	3.4	27	35
3	IF3R004	5	38	2.6
4	IF3IS005	3	12	32
5	IF3MU006	3.9	63	35.5
6	IF3MU007	3	29	32.2
7	IF3IS008	3.7	61	37.5
8	IF3RU009	2.6	74	29
9	IF3RU010	1.5	112	14
10	Siydwan	49	44	84
11	Minthakawa	13	45	7
12	Khanakaw	15	41	20

In table 11, the concentration of nitrate was found to be high in the Siydwan water sample, while the rest of the samples are under tolerant limits assessed under national and international standards.

Table12: Biological parameters of drinking water Ifraz lll (Erbil).

No	Location	Total Coliforms	Thermotolerant (Faecal coliform)	Faecal (Streptococci)
1	Ifrazlll(source)	0	0	-ive
2	IF3001	0	0	-ive
3	IF3R004	0	0	-ive
4	IF3IS005	0	0	-ive
5	IF3MU006	0	0	-ive
6	IF3MU007	0	0	-ive
7	IF3IS008	0	0	-ive
8	IF3RU009	0	0	-ive
9	IFRU010	0	0	-ive
10	Siydwan	0	0	-ive
11	Minthakawa	0	0	-ive
12	Khanakaw	0	0	-ive

In Table 12, the Ifraz III supply didn't show any biological contamination in selected samples.

Table13: Physiochemical Characteristics of drinking water samples from (Ifraz lll) Erbil.

No	Location	ph	Turbidity (mg/L)	Conductivity (µS/cm)	Total Hardness mg/L	TDS mg/L	Alkalinity mg/L
1	Bhaktiari well3	7.5	0.3	505	230.8	252.5	203.2
2	Bhaktiari well4	7.3	0.5	541	250	270.5	144
3	Ainkawa well29	7.3	0.4	573	238	286.5	210
4	Ainkawa well33	7.4	0.4	499	224	249.5	204
5	Well(Nawroz)	7.8	1.2	500	230	250	203
6	Bhatiari house3	7.3	0.6	543	250	271.5	232

In Table 13, all the physiochemical parameters are under permissible limits.

Table 14: Concentration of common cations in drinking water of Bakhtiari and Ainkawa (Erbil).

No	Location	Calcium(Ca+2) (ppm)	Sodium(Na+) (ppm)	Potassium(K+) (ppm)
1	Bakhtiari well3	69	26.6	1.5
2	Bakhiari well4	84	18.2	1.1
3	Ainkawa well29	65	41.8	2.3
4	Ainkawa well33	66.5	26.8	1.7
5	Well(Nawroz)	58	14.6	1.4
6	Bakhtari house 3	76.3	18.4	1.1

In Table 14, all cations are under permissible limits.

Table15: Concentration of major anions in water of Bakhtiari and Ainkawa (Erbil).

No	Location	Chloride(Cl-) (mg/L)	Sulphate(SO4-2) (mg/L)	Nitrate(NO3-1) (mg/L)
1	Bakhtiari well3	2.16	17.75	17
2	Bhahhtari well4	2.6	13.75	20.8
3	Ainkawa well29	2.16	32	12.5
4	Ainkawa well33	2.16	41.75	15
5	Well(Nawroz)	23	43	19.5
6	Bhahhtari house3	2.16	12	21.5

In Table 15, for the sample from the Ainkawa well 33, the concentration of nitrate was found to be 41.75 mg/L which is relatively high then other wells.

Table16. Biological parameters of drinking water Bakhtiari and Ainkawa (Erbil).

No	Location	Total Coliforms	Faecal (Streptococci)
1	Bakhtiari well 3	2.2/100ml	+ive
2	Bakhtiari well 4	16/100ml	+ive
3	Ainkawa well29	5.1/100ml	+ive
4	Ainkawa well33	9.2/100ml	+ive
5	Well(Nawroz)	0	-ive
6	Bakhtiari house 3	0	+ive

In Table 16, the first four samples have coliform bacteria, they indicate possible fecal contamination, which can carry disease-causing viruses and other organisms.

Iron

The concentration of iron is less then 1ppm in all drinking water samples. The permissible limit for drinking water is 0.3-1ppm [17].

4. Discussion

Table17: Correlation Table (Ifraz-I) Erbil

	Turbidity	*Conductivity*	*Total Hardness*	*TDS*	*Alkalinity*	*Total cations*	*Total anions*
Turbidity	1.00						
Conductivity	-0.24	1.00					
Total Hardness	-0.16	0.90	1.00				
TDS	-0.23	1.00	0.90	1.00			
Alkalinity	-0.11	0.93	0.99	0.93	1.00		
Total cations	0.10	0.83	0.94	0.83	0.93	1.00	
Total anions	0.11	0.79	0.79	0.79	0.84	0.82	1.00

In Ifraz-I, the correlation studies (Table 17) shows that the conductivity has a strong correlation with total hardness, TDS, alkanity, total cations and anions. A similar trend is also observed with total hardness to TDS, alkalinity, total cations, and anions. Similarly, strong correlation is observed in the case of TDS with alkalinity and total cations/anions. Whereas, the turbidity is negatively correlated with conductivity, hardness, TDS and alkalinity.

Table18: Correlation Table (Ifraz-ll) Erbil.

	Turbidity	*Conductivity*	*Total Hardness*	*TDS*	*Alkalinity*	*Total cations*	*Total anions*
Turbidity	1.00						
Conductivity	0.29	1.00					
Total Hardness	0.02	0.14	1.00				
TDS	0.09	0.92	0.04	1.00			
Alkalinity	-0.19	-0.08	0.37	0.02	1.00		
Total cations	-0.22	-0.54	0.11	-0.57	0.41	1.00	
Total anions	-0.28	-0.15	-0.45	-0.23	-0.17	0.39	1.00

In Ifraz-ll the correlation studies (Table 18) shows that the conductivity has strong correlation with total hardness, alkalinity, cation and anions,total hardness has correlation with TDS, alkalinity, total cations but not with anions, turbidity is negatively correlated with total cations and anions.

Table19: Correlation Table (Ifraz-III) Erbil

	Turbidity	*Conductivity*	*Total Hardness*	*TDS*	*Alkalinity*	*T.cations*	*T.anions*
Turbidity	1						
Conductivity	0.326393	1					
Total Hardness	-0.02321	0.889408742	1				
TDS	0.326648	0.999997422	0.889389434	1			
Alkalinity	-0.08298	0.832171364	0.970386099	0.8321237	1		
Total cations	0.253214	0.610191306	0.54697281	0.6101212	0.434729	1	
Total anions	-0.43085	0.35308918	0.589035238	0.3534894	0.660046	0.331272	1

In Ifraz-lll the correlation studies (table 19) show that conductivity has a correlation with total hardness, alkalinity, TDS, total cations and anions. Where total hardness has correlation with TDS, alkalinity, total cations and anions. Similar correlation is observed in the case of TDS with alkalinity, cations and anions.

Table20: Correlation Table (Bakhtiari and Ainkawa) Erbil.

	Turbidity	*Conductivity*	*Total Hardness*	*TDS*	*Alkalinity*	*T.cations*	*T.anions*
Turbidity	1						
Conductivity	-0.29657	1					
Total Hardness	-0.06809	0.68275643	1				
TDS	-0.29657	1	0.68275643	1			
Alkalinity	0.073426	-0.017175902	-0.246667184	-0.0171759	1		
Total cations	-0.85968	0.721277209	0.408650738	0.7212772	-0.20139	1	
Total anions	0.8002	-0.504466555	-0.602986018	-0.5044666	0.115092	-0.80943	1

In Bakhtiari and Ainkawa, the correlation studies (table 20) show conductivity has correlation with total hardness, TDS and total cations but not with alkalinity and total anions. Where total hardness has correlation with TDS and total cations but not with alkalinity and total anions.

Conclusion

On the whole, the drinking water quality of Erbil is in acceptable limits by considering selective parameters (pH, total hardness, conductivity, turbidity, cations, anions, total hardness and bacteria) while in ground water samples major biological contamination has been identified.The range of pH (7.1-7.9), conductivity (282-850µ/s), turbidity (0.2-9.9mg/L), total hardness (188-407mg/L), total dissolved solids (141-360mg/L), and alkalinity was (121-378mg/L). Cations concentration range of calcium (50-102ppm), sodium (4.5-79ppm), potassium (1-5.2ppm). Anions concentration range of chloride (2.1-50ppm), sulphate (5-112ppm), nitrate 1.2-84ppm. In Ifraz 1 in two places (Saila and Bahar) the turbidity was found high acoording to WHO standards but permissible limits according to Iraqi standards. Alkalinity was high in all samples including source. Only in Kuran it in permissible limit. According to specification of Iraqi drinking water and WHO the concentration of anions and cations were determined to be less than minimum limit. No biological contamination was found in in water samples rest of all the parameters were under permissible limits.

In Ifraz II some water samples (Shoresh, Tyrwa, Ainkwa, Sheryani, Ainkwa) alkalinity values exceeded the permissible limit according to Iraqi standards. No biological contaminations was found.

In Ifraz III only in Siydwan alkalinity and nitrate was found to be high and the rest of parameters were in permissible limits.

In ground water samples only in Ainkawa well 33 the concentration of nitrate was found to be high .While in ground water samples biological contamination has been found. The results indicate that the drinking water quality of Erbil is suitable.

Correlation between water quality parameters showed if there is good relationship between different parameters, the measurement of different parameters can be used for predicting another parameter like acidity and TDS.

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