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Evaluation Of Ifraz Water Treatment Plants In Erbil City-Iraq

Siraj M. A. Goran
Department of Environment / College of Science
University of Salahaddin

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الخلاصة

مع زيادة الاهتمام والعناية بمحافظة اربيل المتعلقة باولوية انتاج وتزويد المياه الصالحة للشرب، تم إنشاء ثلاث محطات لمعالجة المياه فى العقود السابقة. ان تقييم ومراقبة اداء هذه المحطات ضروري من اجل فهم المشاكل والعقبات التى تواجهها. تمت مراقبة نوعية المياه شهريا من خلال قياس بعض المعايير الفيزيائية والكيميائية والبكتيرية لخمسة عشر موقعا فى المحطات الثلاث (افراز1,2و3) في محافظة اربيل ابتداء من مايس 2008 ولغاية كانون الثانى 2009, كل محطة لتصفية المياه تم تقسيمها إلى خمسة مواقع لاخذ النماذج وحسب وحدات المعاملة (التصفية). وقد كانت نتائج تحليل عينات المياه كما يأتي: تراوحت قيم العكورة بين 0.2 **إلى** 29 NTU، بينما قيمة الـ pH كانت بين 7 و8.3 ، و قيم التوصيل الكهربائي تراوحت من 340 الى 773 مايكروسيموز.سنتم$^{-1}$، اما قيم القاعدية الكلية وايون الكلوريد فقد امتدتا من 18 **الى** 92 ملغم.كاربونات الكالسيوم. ليتر$^{-1}$ ومن 8 **الى** 28 ملغم.لتر$^{-1}$على التوالي.

تراوحت العسرة الكلية للمواقع المدروسة بين 128 **و** 308 ملغم.كاربونات.الكالسيوم.ليتر$^{-1}$، وأوضحت سيادة عسرة المغنسيوم على الكالسيوم. اما بالنسبة لقيم الاوكسجين المذاب (DO) فقد تراوحت بين 3.2 إلى 11.6 ملغم.لتر$^{-1}$. التراكيز العالية من المتطلب الحيوي للاوكسجين (BOD_5) تم تسجيلها في وحدات الترسيب والماء الخام لجميع محطات تصفية المياه، بينما كانت القيم الواطئة في وحدات الخزن والترشيح لجميع محطات معالجة المياه فى الاوقات المختلفة. في حين كانت قيم النتريت لوحدات التصفية بين 0.006 **و** 2.96 مايكروغرام ذرة نايتروجين-نتريت.ليتر$^{-1}$. بصورة عامة، تركيز البوتاسيوم كانت اقل من تركيز الصوديوم. ايونات الكبريتات اظهرت قيما بين 541 **إلى** 911 ملغم.ليتر$^{-1}$. تركيز الفسفور الفعال تراوحت بين 0.15 **و** 10.5 مايكروغرام ذرة فسفور-الفوسفات.ليتر$^{-1}$. في حين كانت نتائج اختبار الجره

بين 4 و 28 ملغم.ليتر‎-1. من الناحية البكتيريولوجية فان MPN (العدد الأكثر احتمالاً) للعصويات البرازية. 100سم‎3 في المياه المعالجة أشار إلى ان المياه صالحة لغرض الشرب حسب تقارير منظمة الصحة العالمية WHO. (Jar test)

ABSTRACT

With the increasing interest and care to Erbil province related with the priority for producing and supplying of potable water, three water treatment plants (WTP) were constructed during the last decades. Water quality for physical, chemical and bacteriological parameters were monitored in 15 sampling sites of three WTPs (Ifraz 1, 2 and 3) in Erbil governorate from May 2008 to Jan. 2009 at monthly interval period, each WTPs were divided in to five sampling sites according to treatment units. Results of water sample analysis were as follow: Turbidity values ranged between 0.2 to 29NTU, while pH values ranged from 7 to 8.3, and electrical conductivity were ranged from 340 to 773 µS.cm^{-1}, total alkalinity and chloride ion were ranged from 92 to 181mg. $CaCO_3.l^{-1}$ and 8 to 28 mg.l^{-1} respectively. Total hardness for the studied sites were 128 to 308 mg.$CaCO_3.l^{-1}$, magnesium hardness is sure asses on calcium hardness. Dissolved oxygen (DO) values were ranged from 3.2 to 11.6 mg.l^{-1}. High BOD_5 values were recorded in raw water and sedimentation units in all WTPs, while the low values were recorded in filtration and storage units of all WTPs at different times. Nitrite concentrations at the major treatment units estimated to be between (0.006 to 2.96 µg at.N-NO_2.l^{-1}). Generally, potassium concentrations were lower than sodium. Sulphate concentration showed a range of 191 to 541 mg.l^{-1}. The range of reactive phosphorus was between 0.15 to 10.5 µg.at.P-PO_4.l^{-1}, and Jar test results was between 4 and 28ppm. Bacteriologically, MPN for coliform.100ml^{-1} in treated waters were safe for drinking purposes according to WHO reports.

Keywords: Evaluation, water treatment plants, Erbil

Introduction

In most parts of the world, from long time ago when rivers, lakes, springs, and wells from which one can directly drink; most of the water are used for drinking, irrigation, and industries, not supporting habitat for natural flora and fauna, but also needs treatment to become suitable for drinking and other purposes. The quality of water in a river might be considered suitable for irrigation but not for drinking, and to determine water quality, one must first determine purposes for using the water and treated according to standards for important parameters of the water that will support and protect the designated water uses (1). Water treatment plant (WTP) is a part of urban water supply system. The principle unit processes involved in conventional water purification system includes sedimentation, filtration and chlorination (2).

Water purification originally focused on improving the aesthetic qualities of drinking water. Methods for improving taste and odor of drinking water have been recorded as early as 4000 B.C. Ancient Sanskrit and Greek writings mentioned water treatment methods such as filtration through using charcoal, exposing to sunlight, boiling, and straining. Visible cloudiness (later termed turbidity) was the reason behind the earliest water treatments. To clarify water, the Egyptians reportedly used the alum as early as 1500 B.C. During the 1700s, filtration was established as an effective means for removing particles from water. By the early 1800s, slow sand filtration was beginning to be used regularly in Europe. During the mid to late 1800s scientists studied sources and contaminants of drinking water. In 1855, epidemiologists proved that some diseases linking with the contamination of river by sewage, before the use of sands for filtration (3).

Freshwater resources around the world are decreased, demands for drinking, irrigation and industries were increased and their evaluation (physically, chemically and bacteriologically) was necessary (4).

In Iraq there are 218 urban water treatment plants (5). Construction of water treatment plants (WTPs) in Erbil city like other parts of Iraq (Nasiriyah in 2006 and Suliaymaniyah in 2009 etc.) was necessary to supply their population with clean drinking water. To evaluate WTPs in Erbil city some researchers conducted their studies on water quality for these treatment plants among them, (6) who conducted her study on old project of Ifraz, while (7) studied water quality for Ifraz treatment plants 1st and 2nd. After construction of 3rd Ifraz project at Greater Zab River in 2004, evaluation of all WTPs together was necessary to reduce the problem of water deficiency in Erbil city.

A holistic approach to drinking-water supply, risk assessment and risk management increase confidence in the safety of drinking-water. Water treatment is a process of making water suitable for its application or returning its natural state (4).

The aims of this study were to assess the quality of water resources during and after treatment within treatment plant projects; based on certain physical, chemical and bacteriological characteristics, studying the hygienic status of available drinking water and suggesting solutions and recommendations.

Description of the studied area

Three water treatment projects were selected for physico-chemical assessment and bacteriological analysis. First and third projects, locally known as Ifraz 1 and 3 are established in 1968 and 2004 respectively at Ifraz village about 32 Km north-west of Erbil city (Plate 1). While the second project known as Ifraz 2 which is located on the Erbil-Ankawa road at the right side, and established in 1982 (Plate 2). These projects collectively supply Erbil city with about 10500m3.hour of potable water. Each water treatment plant is divided into five sampling sites, raw water (River water), flash mixer (in which Alum, polymer (to increase weight of pellets), and chlorine gas were added and mixed), Sedimentation unit, filtration unit and high left (Storage unit) after second chlorination, which are ready for drinking.

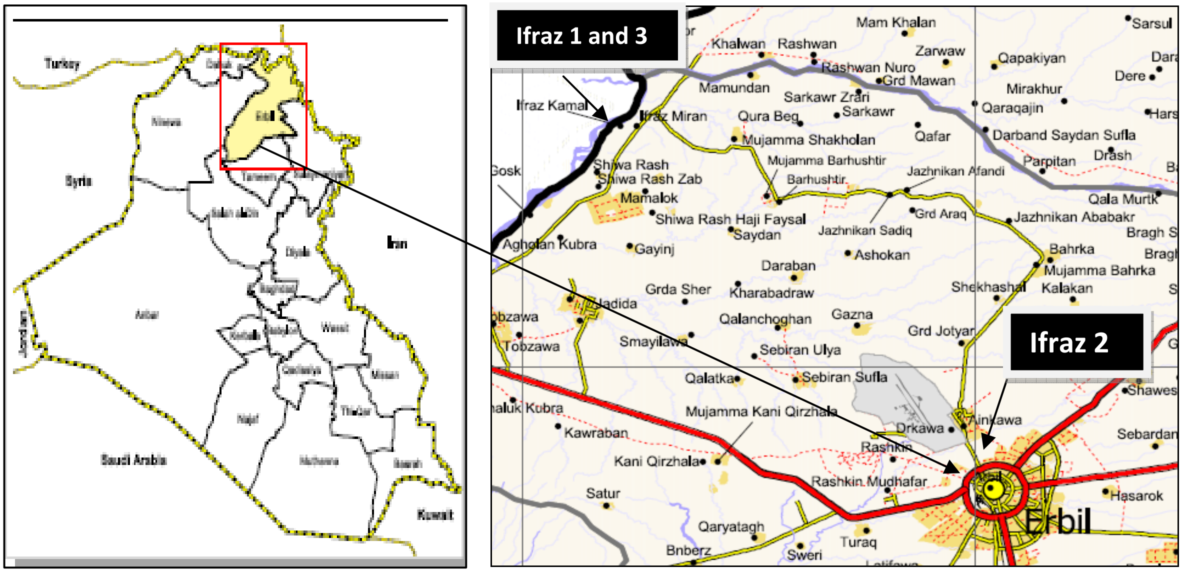

Figure (1): A- Iraq Map **B- Erbil Map with studied stations.**

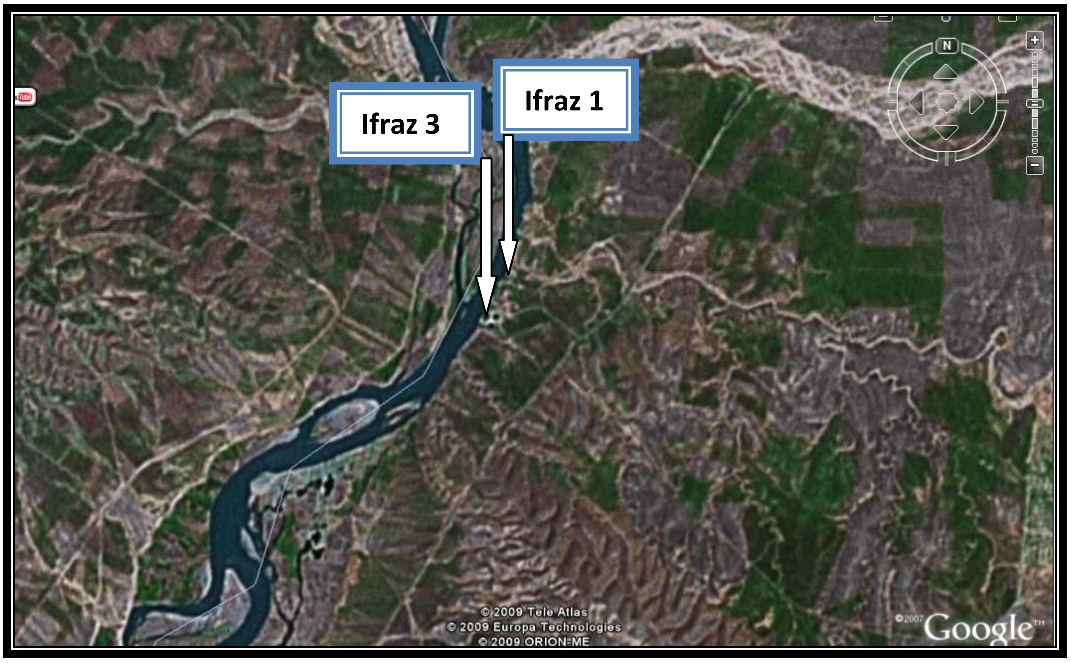

Plate (1): Satellite image of Ifraz 1 and 3 at Greater Zab River

Plate (2): Satellite image of Ifraz 2 in Erbil city near Ankawa sub district

Methodology

Water samples from fifteen sites located at water treatment projects were collected monthly` for physical, chemical and bacteriological analysis from May 2008 to the January 2009. Each site was visited on nine occasions during the period of the study. On the other hand, each water treatment project (Ifraz 1, 2 and 3) is divided into 5 sampling sites (Raw water, flash mixer, sedimentation, filtration and Storage tank). Water samples were collected in polyethylene bottle and following standard methods described by (8 and 9) for water analysis All water samples analyzed within first 4-6 hours. Alkalinity, chloride, total and calcium hardness were measured by titration method, while magnesium hardness measured by calculation. EC and pH were measured using (pH-EC-TDS meter, HI 9812, Hanna instrument). Nitrite and phosphate were determined according to the (9). Sulfate was determined by turbidimetric method and Jar test conducted for raw water according to (8). Sodium and potassium cations measured using Flame Emission Photometer technique. Turbidity was measured using Turbidimeter (HF scientific, inc. model BRF- 15 CE). Dissolved oxygen measured by azide modification of Winkler method, BOD_5 and Most probable number (MPN) determined according to (8). Statistical analysis RCBD design Duncans multiple range tests were used to evaluate differences between sampling sites and sampling dates at ($P<0.05$) in addition to mean and standard error (SE) to find significant differences between sites or dates.

Results and Discussion

Turbidity measurements were used for aesthetic purposes and removal of undesirable particles by water treatment processes (The turbidity in water of WTPs must be less than or equal to 1 NTU in at least 95% of the measurements taken each month, but in potable water usually less than 5NTU). Turbidity values at Ifraz water treatment plant (IWTP) units ranging from (0.2 to 29 NTU). The minimum value recorded at (St.5) of Ifraz 1 during June, 2008, whereas, maximum value recorded in (St.1) during Dec. 2008. Turbidity results of the present study in Ifraz 3 agreed with (6 and 10). While results in Ifraz 1 and 2 agreed with (7) (Table 1).

Higher turbidity values were observed in raw water of WTPs (Figure 2) which may be due to sewage water effluents of neighbor village and erosion effects of rainfall. The maximum value of turbidity in raw water of Ifraz 1 was in Dec. 2008 because of dusty storm and dust falls. The turbidity of raw water increased toward winter season due to the soil run off by rain fall, which accepted with results obtained by (6, 11 and 12). The minimum values of turbidity were found in storage tanks due to the remove of undesirable particles in treatment processes (sedimentation and filtration) of IWTPs (13). These results agreed with results of (6 and 7).

pH values of the major treated units were ranging from (7.0 to 8.4) which are the optimum pH values of drinking water and they are within normal range of drinking water 6.5-8.5 (8 and 14). The lowest values were recorded at flash mixer and sedimentation units of Ifraz 1 during Dec. 2008. While the highest values were measured in filtration unite of Ifraz 1 and raw water of Ifraz 2 during June and May 2008 respectively (Table 2).

In the results of current study, slight decrease in pH values observed from St. 1 toward St. 5 in WTPs which may be due to the salts of Aluminum (Al_2SO_4), which are used today as coagulant for reacting in water with chemicals, macromolecules and particles then precipitate them, which intern reduce the pH of water. In addition, removal of algae from water during treatment, and chlorination has a role in this process (15 and 16). However, these values were come in accordance with results obtained by (6 and 7) on WTPs of Erbil and (16) on Ivedik WTP in Turkia.

The EC value is an indicator of the amount of dissolved salts in the water (17). Results showed that EC values in raw water increased in dry season because of evaporation, while in wet season their values decreased because of dilution by rainfall (11 and 17) and controversy with results of (6 and 18).

The EC values in raw water of WTPs were ranging from minimum of 351 $\mu s.cm^{-1}$ and maximum of 773 $\mu s.cm^{-1}$ during Dec. and Aug. 2008 respectively (Figure 3), while in treated water units the EC values varied between the maximum value of (757 $\mu s.cm^{-1}$) recorded at the (St. 2) of Ifraz 1 during the Aug. 2008, and the minimum value of 340 $\mu s.cm^{-1}$ measured in Ifraz 2 at (St. 5) during Dec. 2008 (Table 3). Values of EC in 56% of sites increased about 14 $\mu s.cm^{-1}$ as average during treatment at flash mixer of WTPs because of adding alum and polymer, while in 96% of sedimentation tanks about 10$\mu s.cm^{-1}$ of EC reduced due to the precipitation of soil particles in the form of pellets after binding with coagulants (coagulation and flocculation), while in storage units, EC values were increased because of second chlorination and this accepted with results of (6 and 7).

The minimum value of alkalinity in the studied WTPs was 92 mg. $CaCO_3.l^{-1}$ recorded in Ifraz 1 at filtration unit in May. 2008, while the maximum value was 181 mg $CaCO_3.l^{-1}$ observed in raw water of old Ifraz during Aug. 2008 (Table 4). Generally, the alkalinity levels in sites of raw water ranged between 100-190 mg $CaCO_3.l^{-1}$ that is similar with results obtained by (7 and 18). These results were within the permissible levels of WHO (4). Alkalinity in Northern part of Iraq is due to the presence of bicarbonates and carbonate (19).

As stated by (20), the variation in alkalinity may be related to various factors, among them dissolved Carbon dioxide (CO_2) concentration, rainfall and runoff the catchment basin, microorganisms activity, and hydrolysis of bicarbonate ions. Total alkalinity values reduced in flash mixer of all WTPs by the effects of coagulant, sedimentation which intern minimize pH values and then alkalinity , k and this accepted with (6 and 7) results.

The lowest value of total hardness (TH) recorded was (116 mg.$CaCO_3.l^{-1}$) at (St. 3) of Ifraz 2 in June 2008, while the highest value was (308 mg.$CaCO_3.l^{-1}$) recorded at (St. 4) of Ifraz 2 in Dec. 2008 (Table 5). In 70% of sites about 19 mg.$CaCO_3.l^{-1}$ of Ca hardness increased, while in 30% of sites only 1.25 mg.$CaCO_3.l^{-1}$ was decreased as average. In 66% of WTPs about 30 mg.$CaCO_3.l^{-1}$ of Mg hardness was decreased, while in other sites, Mg hardness was increased about 27 mg.$CaCO_3.l^{-1}$ as average. Total hardness values in raw water of present study come in accordance with results mentioned by (7 and 18) and ranged between 146 and 284 mg.$CaCO_3.l^{-1}$ (Figure 4). High concentrations of hardness observed in wet season because of erosion effects of rainfall (21). The quality of water in this survey is classified as moderately hard to hard water (8).

The principle water hardness cause ions are Ca^{+2} and Mg^{+2}, which originated from the sedimentary rocks like limestone and chalk (4). The calcium hardness concentrations for the studied sites were ranged from the maximum value of (220 mg $CaCO_3.l^{-1}$) at (St.3) of new Ifraz project during

Dec.2008, to the minimum value of (32 mg $CaCO_3.l^{-1}$) in (St. 2) of old Ifraz project during Aug. 2008 (Table 6). High values of total hardness in old Ifraz project at Nov. 2008 may be related to the waste water effluents of neighbor village in to the River at that time (11).

The lowest value of magnesium hardness was (42 mg $CaCO_3.l^{-1}$) noted at (St.3) of Ifraz 2 during June 2008, while the highest value was (228 mg $CaCO_3.l^{-1}$) recorded at St.1 of new Ifraz project during Aug. 2008 (Table 7). The dominancy of magnesium hardness on calcium recorded in different sites during the present study, which may be related with geological formation of the catchments area (21).

The dissolved oxygen (DO) concentration in water depends on the physical, chemical, and biochemical activities in the water body, and its levels provides a good indication of water quality (22). Dissolved oxygen values were ranging from 3.2 to 10.9 $mg.l^{-1}$ for row water, while in storage tank ranged from 4.4 to 12 $mg.l^{-1}$. Similar results were obtained by (6 and 7).

Variations in DO concentrations were observed throughout the entire sampling periods among sampling sites of WTPs, with low concentrations in dry season and high values in wet season that closely related with the temperature, dissolved salts, partial pressure of gasses, inputs of organic matters, climatic factors, light transparency and phytoplankton contents (23). During treatment process, water was aerated and DO values were increased, as obtained by (7 and 16). On the raw water of Greater Zab River showed lower DO values than that of treatment units due to aeration in treatment units. Similar to results obtained by (6).

Generally, biochemical oxygen demand (BOD_5) values for non seeded samples were ranging between (0.1 $mg.l^{-1}$) at (St. 5) for each of WTPs, and the highest value was (5.4 $mg.l^{-1}$) observed in (St.4) at old Ifraz project in Nov. 2008 (Table 9), this may be due to low filtration efficiency of old Ifraz project and low chlorination of water during treatment. The chlorine gas action for killing of microorganisms will complete after one hour (24) in spite, some organisms remain in water and consume small amount of oxygen during incubation period, which may supported by fecal coliform results in most sites of WTPs which contain less than 2.2 MPN.100ml. This means that some bacteria still exist in water, even after chlorination and consume dissolved oxygen during incubation, or by chemical oxidation. Results of present study agreed with (6 and 7). On the other hand, Greater Zab River sites showed higher BOD_5 values than treatment units, due to the chlorination and filtration.

Nitrite concentrations at the major treatment units located between (0.006 to 2.96 μg at. $N\text{-}NO_2.\ l^{-1}$). The lowest level was measured at storage unit of Ifraz 2 during June 2008, while the highest level was recorded for sedimentation unit of the Ifraz 2 during June 2008 (Table 10). These results were come in accordance with results obtained by (6). The low Nitrite values in present study related to aeration of water during processes and converted to NO_3 (25).

Sodium salts are generally highly soluble in water and are leached from the terrestrial environment to the ground and surface water. Most water supplies contain less than 20 mg of sodium per liter, but in some countries, the levels can exceed 250 mg.l-1 (4). During the present investigation, fluctuations in Sodium concentration were noticed (Table 11). The dusty storm in Aug. 2008 was behind the high levels of Sodium in water samples particularly in raw water of grater Zab River (Figure 5). While during rainfall season sodium levels reduced by dilution of water as stated by (26). After treatment processes, sodium concentrations increased, because sodium ions are available in alternate forms (ex. Organic compound), and degraded after treatment processes and oxidized by aeration to form soluble sodium (27).

Potassium cation K^+ occurs in water as a result of mineral dissolution, from decomposing plant material, and from agricultural runoff (8). Generally, K^+ concentrations were lower than the sodium levels during the entire sampling periods may possibly related to soil formation of Erbil province (7). Potassium concentrations in WTPs were ranged between the minimum value (0.2 $mg.l^{-1}$) measured in raw water of Ifraz 3, and the maximum value (4.9 $mg.l^{-1}$) recorded in filtration unit during May 2008 of Ifraz 2 (Table 12). These results agreed with the results obtained by (7), who stated that potassium values were high in dry season and low in wet season.

Chlorides (Cl^-) occur in natural water, causes a salty taste when combined with sodium and forming sodium chloride (20). However, Cl^- range were 8 to 28 mg. l^{-1} observed at filtration unit of Ifraz 3 during June 2008 and flash mixer in Ifraz 2 and 3 during Oct. and Sept. 2008 (Table 13). The high levels of chlorides in flash mixer and storage units for all WTPs may come from the disinfection of water by chlorine gas which produces hypochlorous and hydrochloric acid which in turn increase Cl^- ions in water or the effect of other ions in water which interfere with the results of (25).

Sulphate is an abundant ion on the earth's crust and its concentration in water range from few milligrams to several thousand milligrams per liter (22). Sulphate concentration relatively was within the permissible and desirable standards given for natural waters.

Sulphate concentrations showed a range of 191 to 541 $mg.l^{-1}$. The lowest value was noticed in (St.4) of Ifraz 2 during Jun. 2008, due to sedimentation, filtration processes and the distance between raw water of Greater-Zab and Ifraz 2, which minimize their values. The higher level was measured at (St.1) of Ifraz 1 during Aug. 2008 (Table 14) because of dusty storm weather (Figure 6). These results agreed with the results obtained by (6). Clear seasonal fluctuations in Sulphate concentration were observed throughout entire sampling periods and increased with electrical conductivity values (25). Sulphate values in flash mixer of WTPs are lower than values in raw water, due to the binding of Alum with suspended particles in water (naturally SO_4 exists in earth crust) that clumped together via the processes of coagulation and settled faster before sedimentation process, thereby minimizing sulphate concentrations in flash mixer of WTPs during the periods of study (27).

Phosphorus is commonly found in soil, rocks, and plants. It is an essential nutrient for plants growth and important contaminants of surface water, even when low (25). The ranges of reactive phosphorus concentration were ranged between 0.15 µg.at.P-PO_4.l^{-1} at (St. 3) of Ifraz 1 during Aug. 2008 and 10.5 µg.at.P-PO_4.l^{-1} at (St.1) in Ifraz 1 during Sept. 2008 (Table 15). The high values of PO_4 in raw water of Greater Zab may come from the pollution of water with fertilizer that used in neighbor villages. The obtained results by (6 and 18) confirm the results of the current study. While in other units of treatment, PO_4 concentrations were decreased due to the treatment process.

Alum was needed for sedimentation of suspended particles from raw water and their concentration depends on the jar test results, to determine an optimum dose of Alum. Minimum Jar test result was 4ppm in Ifraz 2 at Jan. 2009 and their turbidity was 1.5NTU and maximum Jar test result was 28ppm in Ifraz 1 at Dec. 2008 when turbidity was 29 NTU (Table 16).

Fecal coliform bacteria originate from intestinal tracts of animal and human indicate the possible presence of pathogenic organisms. In the present study, the recorded value for the fecal coliform bacteria was >16 MPN.100 ml^{-1} in raw water of all WTPs, all units of Ifraz 1 in Dec. 2008 and flash mixer of Ifraz 1 in Aug. 2008 considered unsatisfied for drinking according to guidelines (4). Also it indicates that Greater Zab river water is polluted due to the effects of sewage effluents of nearby villages (6, 7 and 18). While in other sites of WTPs have less than 2.2 MPN.100 mL^{-1} and in the safe side for drinking purposes due to the chlorination effects and filtration (4).

Conclusions and Recommendations

1) Adequate chlorine adding is essential for successful operating WTPs.
2) Rapid sand filters should be checked, and regulating their back washes.
3) Continuous maintenance and analysis will lead to precise evaluation of plant performance and required modifications.
4) The performance of Ifraz 3 is higher than other WTPs (This concludes that the 1st and 2nd treatment plants needs more necessary repairs in their unites especially in filtration and sedimentation process).

Table (1): Turbidity values (NTU) recorded for sampling sites with mean and SE for WTPs in Erbil Governorate.

WTPs / Dates	Ifraz 1 (Old Ifraz project)					Ifraz 2					Ifraz 3 (New Ifraz project)					Mean ±SE 1.155
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
May	3.8	2.5	2.1	1.1	0.9	3.2	2	1.7	1.4	0.9	4.6	1.2	1.4	0.3	0.6	1.84 a
June	3.5	0.2	0.5	1	0.2	5.6	1.2	2.7	3	1.7	6.3	5.2	7.3	1.3	1.1	2.7 a
July	13.1	11.6	7.2	1.9	2	11.9	10	5.5	1.2	1.5	12.8	10.6	4	1.1	1.1	6.37 b
August	28.5	20.2	7.3	21.3	17.3	25.2	31.3	19.6	17.4	4.21	27.8	19.8	8.3	1.47	1.57	16.7 d
September	21.2	10.5	11.2	3.2	3.3	19.5	14.5	15	3	3.2	21.4	10.5	11.5	1	1.2	10.0 c
October	14.2	9.7	9.1	1.7	1.9	12.8	6.3	7.1	1.1	1.4	14	9.9	10	1	1	6.75 b
November	10.5	3.06	1.81	2.19	1.3	9.2	5.5	2	0.9	1	10.2	4.2	1.52	0.49	0.78	3.64 a, b
December	29	28.4	13.42	20.1	17.1	24.7	23.7	4.55	1.32	2.08	23.1	9.8	7.6	0.25	0.57	13.7 d
January	2.5	5.8	2.53	2.38	2.55	1.5	2.45	1.57	1.7	0.75	2.2	2.55	1.8	0.42	0.6	2.09 a
Mean ±SE 1.49	14.03 g	10.29 d,e,f,g	6.12 b,c,d,e	6.09 b,c,d,e	5.17 a,b,c	12.62 f,g	10.7 e,f,g	6.63 b,c,d,e	3.44 a,b,c	1.86 a,b	13.60 g	8.19 c,d,e,f	5.93 b,c,d	0.81 a	0.94 a	**(P<0.05)**

***Same letters means significant differences not exist, while different letters means significant difference exist.**

Table (2): pH values recorded for sampling sites with mean and SE for WTPs in Erbil Governorate.

WTPs / Dates	Ifraz 1 (Old Ifraz project)					Ifraz 2					Ifraz 3 (New Ifraz project)					Mean±SE 0.049
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
May	8.11	7.16	7.34	7.5	7.39	8.43	7.78	7.8	7.87	7.53	8.03	7.6	7.62	7.73	7.62	7.701 c
June	8.06	7.22	7.84	8.43	8.1	7.79	7.91	7.42	7.65	7.6	8.09	7.62	7.6	7.83	7.69	7.790 c
July	8.03	7.61	7.69	7.73	7.7	8.07	7.8	7.83	7.85	7.8	8.01	7.69	7.7	7.75	7.71	7.798 c
August	7.01	7.05	7.43	7.54	7.49	7.75	7.26	7.36	7.47	7.36	7.14	7.32	7.43	7.66	7.52	7.386 a
September	7.82	7.53	7.61	7.68	7.65	8	7.65	7.73	7.78	7.75	7.78	7.51	7.56	7.76	7.69	7.700 c
October	7.84	7.79	7.75	7.84	7.8	7.87	7.81	7.86	7.8	7.71	7.88	7.64	7.69	7.74	7.7	7.781 c
November	7.81	7.05	7.09	7.23	7.27	7.84	7.69	7.72	7.76	7.72	7.71	7.45	7.48	7.57	7.53	7.528 b
December	7.82	7	7	7.05	7.04	7.83	7.34	7.22	7.7	7.39	7.77	7.15	7.17	7.35	7.26	7.339 a
January	8.23	8.1	8.09	8.08	8.11	8.11	7.84	7.79	7.81	7.59	8.09	7.81	7.81	7.93	7.85	7.949 d
Mean ±SE 0.06	7.859 e,f	7.859 a	7.54 a,b,c	7.67 b,c,d,e	7.61 b,c	7.97 e	7.68 b,c,d,e	7.64 b,c,d	7.74 c,d,e	7.61 b,c	7.83 d,e,f	7.53 a,b	7.56 a,b,c	7.70 b,c,d,e	7.6 b,c	**(P<0.05)**

Table (3): Electrical conductivity ($\mu s.cm^{-1}$) values recorded for sampling sites with mean and SE for WTPs in Erbil.

WTPs / Dates	Ifraz 1 (Old Ifraz project)					Ifraz 2					Ifraz 3 (New Ifraz project)					Mean±SE 3.525
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
May	447	471	456	456	460	440	459	455	457	460	451	453	452	452	455	454.9 d
June	536	577	574	540	525	542	561	558	490	533	544	543	553	543	547	544.4 g
July	480	493	498	508	511	487	496	502	507	514	479	486	487	493	495	495.7 f
August	768	757	737	740	736	738	745	730	746	748	773	750	739	733	739	745.2 h
September	561	548	528	532	535	556	538	532	546	542	560	553	547	551	554	545.5 g
October	484	490	466	470	479	478	483	469	458	467	481	493	474	467	478	475.8 e
November	437	432	433	427	424	430	427	427	420	414	421	420	447	417	422	426.5 c
December	392	411	407	401	398	351	346	342	348	340	373	385	389	392	398	378.2 a
January	392	390	386	389	392	373	402	393	395	401	394	382	383	387	385	389.6 b
Mean ±SE 4.53	500 a,b	508 b	498 a,b	496 a,b	496 a,b	488 a	495 a,b	490 a	485 a	491 a	497 a,b	496 a,b	497 a,b	493 a,b	497 a,b	**($P<0.05$)**

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Table (4): Total alkalinty (mg $CaCO_3.l^{-1}$) values recorded for sampling sites with mean and SE for WTPs in Erbil.

WTPs / Dates	Ifraz 1 (Old Ifraz project)					Ifraz 2					Ifraz 3 (New Ifraz project)					Mean±SE 3.211
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
May	113	120	98	92	104	117	126	109	107	116	120	136	138	110	140	116.4 a
June	118	113	107	119	110	123	116	112	114	111	127	121	128	123	131	118.2 a
July	142	127	140	144	138	142	131	137	126	112	161	148	149	131	128	137.0 b
August	181	142	160	166	162	164	154	156	162	164	186	160	168	158	160	162.8 d
September	170	138	144	148	144	176	140	146	152	148	168	132	138	142	140	148.4 c
October	148	122	128	130	126	156	128	132	134	128	150	132	134	138	132	134.5 b
November	136	96	128	116	114	146	137	140	132	124	140	132	122	126	130	127.9 b
December	144	128	126	120	126	160	168	184	196	192	148	128	130	130	136	147.7 c
January	190	182	174	178	168	166	170	190	186	178	194	170	192	176	170	178.9 e
Mean ±SE 4.14	149 c,d	130 a	134 a,b	135 a,b	132 a,b	150 c,d	141 a,b,c	145 b,c,d	145 b,c,d	141 a,b,c	155 d	140 a,b,c	144 b,c,d	137 a,b,c	141 a,b,c	**($P<0.05$)**

Table (5): Total hardness (mg $CaCO_3.l^{-1}$) values recorded for sampling sites with mean and SE for WTPs in Erbil.

WTPs / Dates	Ifraz 1 (Old Ifraz project)					Ifraz 2					Ifraz 3 (New Ifraz project)					Mean±SE 5.81
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
May	221	206	227	186	211	186	174	178	178	180	194	192	208	228	182	197 a,b
June	200	212	200	192	208	148	212	116	160	128	192	194	198	222	202	186 a
July	218	202	208	198	204	192	174	170	174	182	220	196	204	208	214	198 a,b
August	262	240	208	192	148	146	192	196	196	192	276	244	222	220	224	211 b,c
September	266	238	240	212	220	168	182	186	180	184	266	232	236	238	244	219 c
October	254	215	222	210	218	176	184	186	190	192	248	200	208	214	228	210 b,c
November	262	276	276	276	288	208	216	192	184	190	256	268	296	256	296	249 d,e
December	244	268	282	244	268	236	264	288	308	300	248	276	272	232	252	265 e
January	240	232	292	260	224	200	244	212	202	240	284	248	220	244	260	240 d
Mean ±SE 7.50	241 d	232 d	239 d	219 b,c,d	221 c,d	184 a	205 a,b,c	192 a	197 a,b	199 a,b,c	243 d	228 d	229 d	229 d	234 d	**(P<0.05)**

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Table (6): Calcium hardness (mg $CaCO_3.l^{-1}$) values recorded for sampling sites with mean and SE for WTPs in Erbil.

WTPs / Dates	Ifraz 1 (Old Ifraz project)					Ifraz 2					Ifraz 3 (New Ifraz project)					Mean±SE 4.71
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
May	90	98	84	90	92	102	114	106	104	114	118	130	118	116	126	107 d
June	64	84	62	120	112	92	64	52	60	56	100	132	68	132	112	87 c
July	54	68	62	66	76	46	54	52	50	58	54	62	60	62	68	59 b
August	46	32	40	36	36	48	52	52	44	52	48	44	44	44	40	44 a
September	54	44	48	48	52	54	62	60	56	62	54	58	58	52	58	55 a,b
October	110	122	108	102	112	94	104	100	96	102	114	120	114	108	116	108 d
November	180	172	168	160	144	132	148	150	122	130	164	132	168	172	168	154 f
December	132	140	144	156	160	68	92	152	152	154	88	160	220	160	168	143 e,f
January	134	140	136	148	112	120	120	116	110	128	184	160	162	140	164	138 e
Mean ±SE 6.08	96 a,b,c	100 a,b,c	95 a,b,c	103 a,b,c	100 a,b,c	84 a	90 a,b	93 a,b,c	88 a	95 a,b,c	103 a,b,c	111 c	112 c	110 b,c	113 c	**(P<0.05)**

Table (7): Magnesium hardness (mg $CaCO_3.l^{-1}$) values recorded for sampling sites within WTPs during periods of study in Erbil Governorate.

WTPs / Dates	Ifraz 1 (Old Ifraz project)					Ifraz 2					Ifraz 3 (New Ifraz project)					Mean SE± 7.03
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
May	131	108	143	96	119	84	60	72	74	66	76	62	90	112	56	90 a
June	136	128	138	70	96	36	148	64	100	72	92	62	130	90	90	97 a
July	164	134	146	132	134	146	120	118	124	124	166	134	144	146	146	139 b
August	216	208	168	156	112	98	140	144	152	140	228	200	178	176	184	167 c
September	212	194	192	164	168	114	120	126	124	122	212	174	178	186	226	167 c
October	144	93	114	108	106	82	80	86	94	90	134	80	94	106	112	101 a
November	82	104	108	116	144	76	68	42	62	60	92	136	128	86	128	95 a
December	112	128	138	88	108	168	172	136	156	146	160	116	52	72	84	122 b
January	106	92	156	112	112	80	124	96	92	112	100	88	58	104	94	102 a
Mean ±SE 9.07	145 c	132 b,c	145 c	116 a,b,c	122 a,b,c	98 a	115 a,b,c	98 a	109 a,b	104 a,b	140 c	117 a,b,c	117 a,b,c	120 a,b,c	124 a,b,c	**(P<0.05)**

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Table (8): Dissolved oxygen ($mg.l^{-1}$) values recorded for sampling sites with mean and SE for WTPs in Erbil.

WTPs / Dates	Ifraz 1 (Old Ifraz project)					Ifraz 2					Ifraz 3 (New Ifraz project)					Mean ±SE 0.18
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
May	7	6.4	7.6	6.8	8	7.8	7	7.4	7.2	8.2	7.2	6	7.6	3.2	6	6.9 c
June	3.6	5.2	4.4	5.2	5.2	6	6.4	6	4	4.4	5.2	4.4	5.2	4.4	4.4	4.9 a
July	5.2	5.8	6	6	6.4	5.4	5.5	5.2	5	5.6	5	5.3	5.5	5.9	6	5.6 b
August	5.9	6.8	6	6	6.9	7.1	7.4	6.5	6.2	6.9	6.2	6.7	7.8	6.9	6.9	6.7 c
September	6	6.5	6.3	6	5.7	6.3	6.7	6	6	5.8	6.1	6.4	6	5.7	5.1	6.0 b
October	6.5	6.9	6	5.5	5.2	6.9	7.2	7	6.9	6.6	6.3	6.9	7.2	7	6.6	6.6 c
November	10.8	11.2	10.8	11	9.9	10	10.3	9.6	10	10.4	9.6	10.4	10.8	10	10.4	10.3 d,e
December	9	9.6	9.6	10.1	10	10	11.6	10.4	11.2	10	8.8	11.2	10.8	10	9.8	10.1 d
January	9.7	10	10.8	11.2	10.8	10.9	11.1	11	10.4	10.1	10.4	10.3	10	12.8	12	10.7 e
Mean ±SE 0.23	7.08 a	7.6 a,b	7.5 a,b	7.5 a,b	7.6 a,b	7.8 a,b	8.1 b	7.7 a,b	7.4 a,b	7.5 a,b	7.2 a	7.5 a,b	7.8 a,b	7.3 a	7.4 a,b	**(P<0.05)**

Table (9): Biochemical oxygen demand for five days incubation (mg.l⁻¹), recorded for sampling sites with mean and SE for WTPs in Erbil Governorate.

WTPs	Ifraz 1 (Old Ifraz project)					Ifraz 2					Ifraz 3 (New Ifraz project)					Mean ±SE 0.18
Dates	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
May	1.9	0.4	2.4	1.6	0.4	1.9	0.5	2	1.2	0.2	2.2	0.4	2.6	2.4	0.2	1.35 b,c
June	2	1.6	0.8	0.4	0.1	2.8	1.6	3.6	2.4	0.4	3.2	0.8	0.4	0.4	0.4	1.39 b,c
July	2	1.3	1	0.9	0.5	1.5	0.6	0.5	0.4	0.1	1.5	1	1	0.8	0.3	0.89 a,b
August	1.9	0.8	0.2	0.2	0.4	1.1	0.9	0.3	0.4	0.1	0.9	0.6	1.5	1	0.1	0.69 a
September	2.5	2	1.4	1	0.5	3	2.2	2	1.5	0.7	2.1	1.9	1.3	1	0.5	1.57 c
October	2.9	2.4	1.9	1	0.9	3.5	2.6	2	1.5	0.6	3.1	1.9	1.8	1	0.6	1.84 c
November	4.2	4.8	3.2	5.4	1.3	4	3.6	3	3.2	1	4.8	4.6	5.2	4	2	3.62 d
December	0.7	0.1	0.4	0.9	1.2	0.4	0.8	0.3	0.5	0.3	0.8	1.6	1.2	0.4	0.6	0.68 a
January	0.7	0.4	0.9	0.4	0.8	1.9	0.6	0.9	0.6	0.3	0.4	0.6	0.4	2.4	1.3	0.84 a,b
Mean ±SE 0.23	2.09 d,e	1.5 c,d,e	1.36 b,c,d	1.3 b,c	0.68 a,b	2.2 e	1.49 c,d,e	1.6 c,d,e	1.3 b,c	0.4 a	2.1 d,e	1.49 c,d,e	1.7 c,d,e	1.49 c,d,e	0.67 a,b	**(P<0.05)**

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Table (10): Nitrite values (μg at. N-NO_2. l^{-1}) recorded for sampling sites with mean and SE for WTPs in Erbil.

WTPs	Ifraz 1 (Old Ifraz project)					Ifraz 2					Ifraz 3 (New Ifraz project)					Mean ±SE 0.10
Dates	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
May	0.25	0.19	0.14	0.21	0.18	0.21	0.16	0.11	0.2	0.21	0.27	0.21	0.2	0.25	0.25	0.20 a
June	0.8	0.82	0.64	0.82	0.6	0.1	1.84	2.96	1.8	1.68	1	2.22	2.1	1.92	2	1.42 d
July	0.31	0.17	0.15	0.21	0.12	0.26	0.13	0.12	0.16	0.21	0.37	0.22	0.17	0.2	0.14	0.19 a
August	0.92	0.86	0.08	0.62	0.3	1.4	0.22	0.82	0.3	0.006	0.9	0.4	0.28	0.42	0.22	0.51 a,b
September	0.83	0.76	0.41	0.5	0.21	0.49	0.17	0.04	0.2	0.37	0.6	0.47	0.3	0.39	0.4	0.40 a,b
October	0.49	0.32	0.15	0.19	0.33	0.21	0.14	0.09	0.25	0.3	0.56	0.41	0.19	0.2	0.52	0.29 a,b
November	0.29	0.21	0.04	0.52	0.7	0.25	0.19	0.08	0.35	0.4	0.46	0.46	0.14	0.02	0.06	0.28 a,b
December	1.2	1	1.14	1.62	1.84	0.3	1.14	1.1	1.54	1.14	1.14	0.14	0.22	0.14	0.18	0.92 c
January	0.17	0.94	0.76	0.5	1.58	1.46	0.68	0.84	0.21	1.08	0.14	0.02	0.08	0.06	0.02	0.57 b
Mean ±SE 0.14	0.58 a	0.58 a	0.39 a	0.57 a	0.65 a	0.52 a	0.52 a	0.68 a	0.56 a	0.60 a	0.60 a	0.50 a	0.41 a	0.40 a	0.42 a	**(P<0.05)**

Table (11): Sodium ion (mg.l-1) values recorded for sampling sites of WTPs in Erbil Governorate.

WTPs / Dates	Ifraz 1 (Old Ifraz project)					Ifraz 2					Ifraz 3 (New Ifraz project)					Mean ±SE 0.65
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
May	31	31	33.2	34	36.2	29.2	31.6	36	38.2	39	29.5	33	31.2	32	32.5	33.2 d
June	30	34.5	31.6	26.2	29	28.5	30.8	29.1	30	31.5	30.8	31.2	30	30.8	32	30.4 c
July	41	45	40.4	36.5	39	36	38.5	37	32.3	35	40.8	29	33.1	34	34.8	36.8 e
August	67	70	69.2	72.3	70	70.6	72.4	78	74.2	73	70.9	81.7	71.3	71.8	76.5	72.6 f
September	31	32.5	32	35.5	35.9	27.5	30	29.2	30.2	31	31.7	32.5	31	34	34.5	31.9 c,d
October	21.5	24	22	26.5	29.3	19.9	20	20.2	21	21.8	20	22.2	23	23.5	27	22.8 b
November	3.4	4	4.3	4.5	4.3	3	3.6	3.8	3.9	4.1	3.7	4.7	4.3	4.5	4.3	4.03 a
December	3.5	3.7	3.6	3.7	3.4	2	2.8	2.8	3.5	3.6	3.8	4.4	5.5	4.8	4.4	3.7 a
January	2.8	3	1.9	1.9	2.1	2.2	2.6	2	2.4	2.1	3	3	3.1	3.5	3.2	2.6 a
Mean ±SE 0.84	25.7 a,b	27.5 b	26.5 a,b	26.8 a,b	27.7 b	24.3 a	25.8 a,b	26.4 a,b	26.2 a,b	26.8 a,b	26. 0 a,b	26.8 a,b	25.8 a,b	26.5 a,b	27.7 b	**(P<0.05)**

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Table (12): Potassium ion (mg.l-1) values recorded for sampling sites, with mean and SE for WTPs in Erbil.

WTPs / Dates	Ifraz 1 (Old Ifraz project)					Ifraz 2					Ifraz 3 (New Ifraz project)					Mean ±SE 0.15
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
May	3.6	3	3.3	4.3	3.1	3.3	2.9	3.1	4.9	3.3	3.5	3.6	4	3.6	3	3.64 c
June	4.2	4.2	4.4	4.7	4	3.6	3.9	4	5.1	3.8	4	4.2	4.5	4.2	4.2	4.23 d
July	3.2	3.9	4.2	4	2.9	2	2.1	2.3	4.9	3.1	3.3	3.5	3.8	3.2	3.9	3.47 c
August	1.4	2.4	0.6	2.7	0.1	2.8	1.7	0.2	2.5	3.7	0.2	0.5	2.3	1.4	2.4	1.57 b
September	1.4	1.7	1	1.6	1.3	1.3	1.5	0.9	2.1	1.1	1.3	1.4	0.6	1.4	1.7	1.35 a,b
October	1.2	1.9	1.1	1.7	1.4	1.5	1.5	0.9	2.2	1.3	1.5	1.7	1.1	1.2	1.9	1.45 a,b
November	1	1.3	1	1.4	1.7	1.1	1.2	1.4	0.9	1.2	1	1	1	1	1.3	1.15 a,b
December	0.9	1	1	0.6	0.8	0.7	1	0.9	1.1	1.2	1.3	1.4	1.2	0.9	1	1.0 a
January	1.6	1.6	1.6	1.6	1.8	1.6	1.5	2.4	0.7	0.9	0.9	1	1.1	1.6	1.6	1.45 a,b
Mean ±SE 0.19	2.68 c	2.01 a,b	2.06 a,b	2.3 a,b,c	2.02 a,b	2.51 b,c	1.90 a,b	1.99 a,b	1.92 a,b	1.79 a	2.71 c	2.18 a,b,c	1.89 a,b	2.03 a,b	2.18 a,b,c	**(P<0.05)**

Table (13): Chloride ion (mg.l⁻¹) values recorded for sampling sites of WTPs in Erbil Governorate.

WTPs / Dates	Ifraz 1 (Old Ifraz project)					Ifraz 2					Ifraz 3 (New Ifraz project)					Mean SE± 0.65
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
May	10	12	11	11	12	11	13	11	13	12	9	12	11	14	10	11.9 a
June	16	13	16.1	16	12	23	12	15	18	16	12	12	12	8	16	14.0 b
July	20	25	22	23	23	20	24	23	25	27	21	24	22	24	20	23.2 e
August	18	16	20	18	18	24	26	26	22	26	24	22	23	22	18	21.8 d
September	20	24	22	24	20	20	24	22	26	26	24	28	24	26	20	23.5 e
October	20	22	20	22	22	24	28	22	22	22	20	26	24	28	20	23.0 e
November	18	22	24	18	20	20	24	22	24	24	14	20	22	20	18	20.8 d
December	15	14	12	12	14	18	24	22	20	24	16	15	16	16	15	16.8 c
January	16	20	16	16	16	16	18	16	18	24	16	22	20	18	16	18.1 c
Mean ±SE 0.84	17.0 a	18.7 a,b,c,d	18.1 a,b,c	17.8 a,b	17.4 a,b	19.5 a,b,c,d	21.4 d,e	19.9 b,c,d,e	20.9 c,d,e	22.3 e	17.3 a,b	20.1 b,c,d,e	19.3 a,b,c,d	19.5 a,b,c,d	19.2 a,b,c,d	**(P<0.05)**

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Table (14): Sulphate values (mg.l⁻¹) recorded for sampling sites with mean and SE of WTPs in Erbil Governorate.

WTPs / Dates	Ifraz 1 (Old Ifraz project)					Ifraz 2					Ifraz 3 (New Ifraz project)					Mean SE± 8.05
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
May	310	282	242	215	225	288	251	227	206	215	296	266	241	221	229	247.6 a
June	324	290	246	209	218	274	244	214	191	193	319	268	246	211	217	244.2 a
July	390	326	270	219	234	349	294	274	247	261	385	359	359	317	326	307.3 b
August	541	484	412	392	301	395	372	310	325	300	520	463	408	340	347	394.0 e
September	510	459	395	343	329	452	415	377	327	335	495	435	295	267	274	380.5 a,b
October	509	446	382	318	275	386	335	316	284	291	500	438	384	338	315	367.8 d
November	458	325	269	226	231	421	389	334	293	311	413	377	342	301	322	334.1 c
December	499	454	370	381	362	423	387	355	360	337	472	430	355	390	382	397.1 e
January	500	418	357	299	317	405	373	366	313	294	509	462	433	359	317	381.4 a,b
Mean ±SE 10.4	449 e	387 d	327 b,c	289 a	277 a	377 d	340 c	308 a,b	283 a	282 a	434 e	389 d	340 c	305 a,b	303 a,b	**(P<0.05)**

Table (15): Reactive phosphorus (µg.at.P-PO_4.l^{-1}) values recorded for sampling sites in WTPs of Erbil Governorate.

WTPs / Dates	Ifraz 1 (Old Ifraz project)					Ifraz 2					Ifraz 3 (New Ifraz project)					Mean ±SE 0.309
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
May	3.2	1.9	1.1	1.4	1.8	1.9	1	0.9	1.1	1.7	2.35	0.85	0.4	0.45	0.4	1.36 a
June	4.2	2	1.3	1.7	1.8	2.7	1.8	1	1.6	2	5.3	1.5	1.4	1.8	1.9	2.13 a,b
July	7.1	1.9	1.8	2	2.5	5.4	3	1.9	2.4	2.8	6.8	2.2	1.8	2.2	2.4	3.08 b,c
August	7.5	2.9	0.15	2.55	0.4	3.6	0.95	5.35	1.4	1.45	6.9	6.6	2.1	0.8	0.7	2.89 b,c
September	10.5	3.4	2.6	1.7	2	4.7	2	1.7	2	2.4	10	2.1	1.2	1.8	2	3.34 C
October	6	1.9	1.7	2	2.5	5.1	1.6	1	1.2	0.9	5	2.6	2	2.2	2.7	2.56 b,c
November	6.8	1.5	1.3	2.55	3.25	3.6	1.2	0.94	1.2	1.32	8.4	1.9	1	1.4	1.05	2.49 b,c
December	5.2	1.9	1.25	1.8	2.65	1.7	2.45	1.25	1.1	2.25	7.1	3.85	3.55	2.8	1.3	2.67 b,c
January	10.3	2	2.55	2.15	1.35	2	3.3	2.5	1.9	2.4	11.8	2.3	1.7	1.9	1.75	3.32 c
Mean ±SE 0.399	6.76 c	2.16 a	1.53 a	1.99 a	2.03 a	3.41 b	1.92 a	1.84 a	1.54 a	1.91 a	7.07 c	2.66 a,b	1.68 a	1.70 a	1.58 a	(P<0.05)

***Same letters means significant differences not exist, while different letters means significant difference exist.**

Table (16): Jar test values recorded for sampling sites within WTPs in Erbil Governorate.

WTPs / Dates	Ifraz 1	Ifraz 2	Ifraz 3	Mean ±SE 0.35
May	12	11	12	11.7 d
June	9	9	9	9.0 b,c
July	10	10	10	10.0 c
August	14	14	14	14.0 e
September	24	23	24	23.7 g
October	16	16	16	16.0 f
November	8	8	8	8.0 b
December	28	25	25	26. 0 h
January	5	4	5	4.7 a
Mean ±SE 0.2	14.0 b	13.3 a	13.67 a,b	(P<0.05)

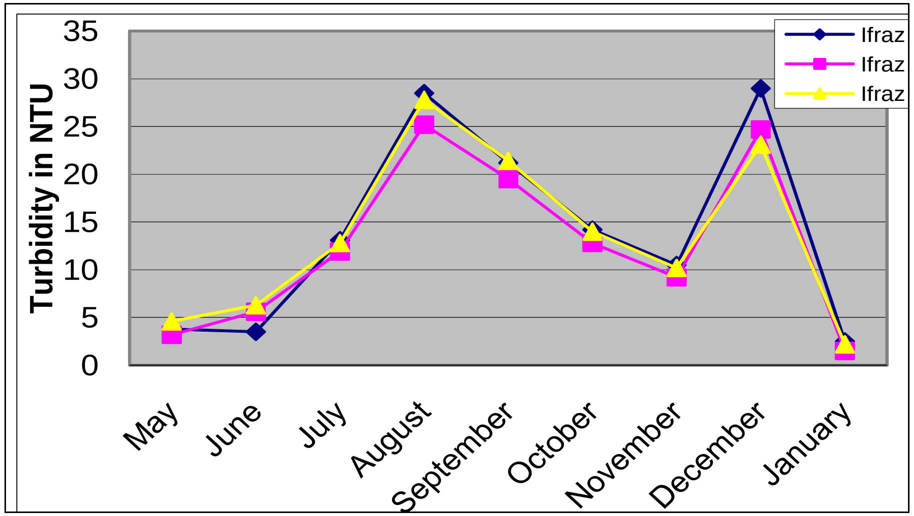

Figure (2): Monthy variations in Turbidity of Greater Zab river (raw water).

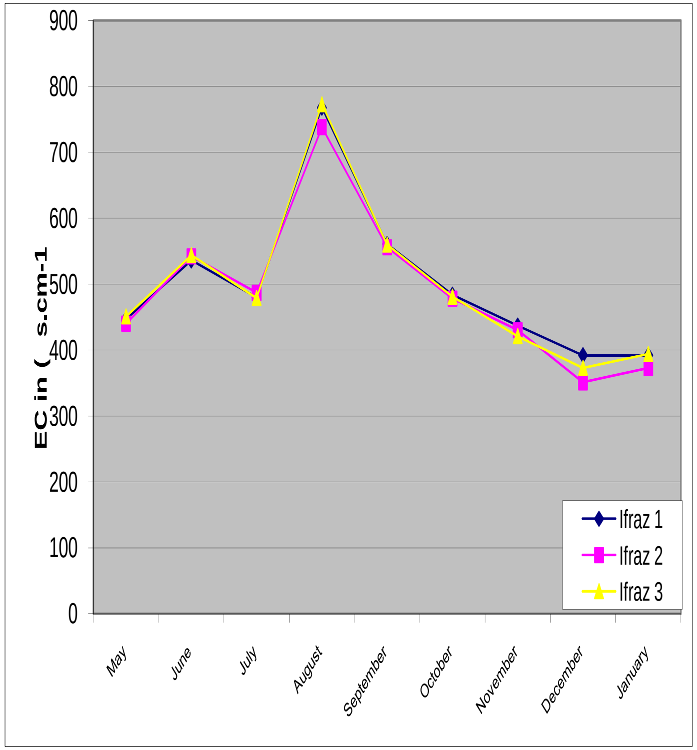

Figure (3): Electrical conductivity of Greater Zab river

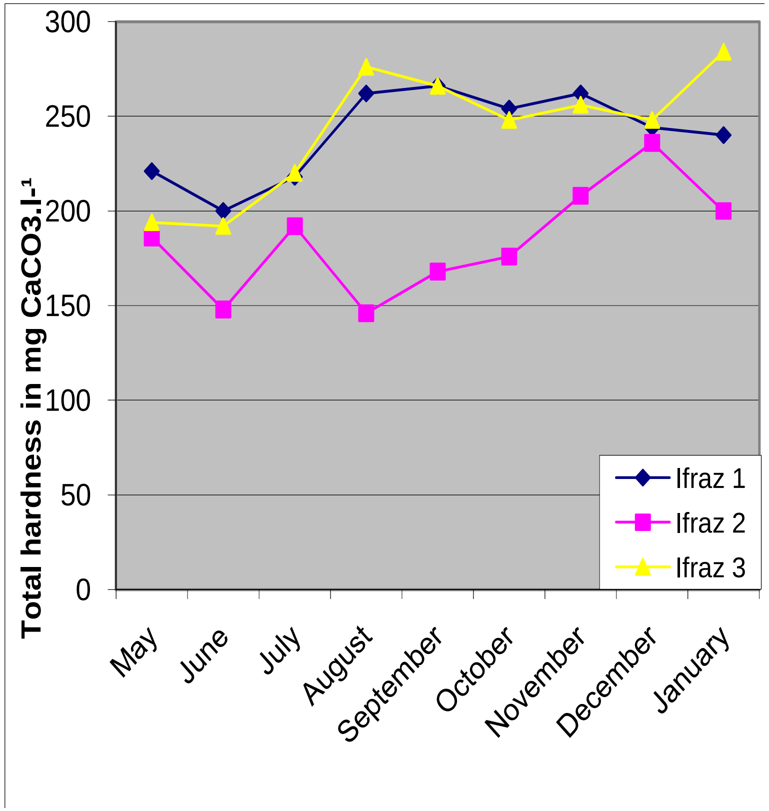

Figure (4): Monthly variations in Total hardness of Greater Zab river during the periods of study.

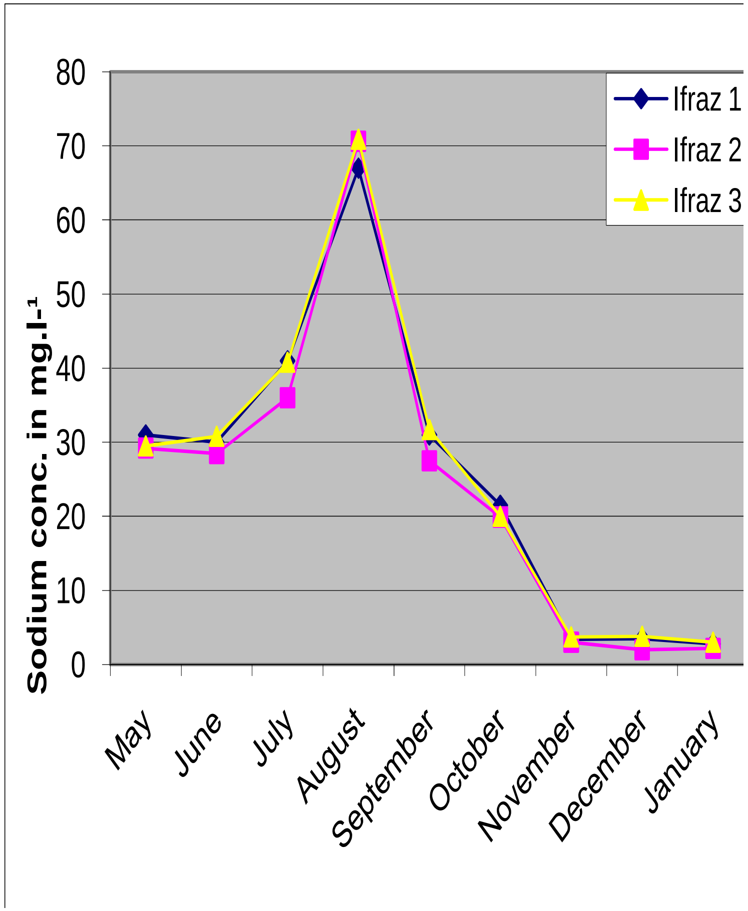

Figure (5): Sodium concentrations in mg.l-¹ for Greater Zab river

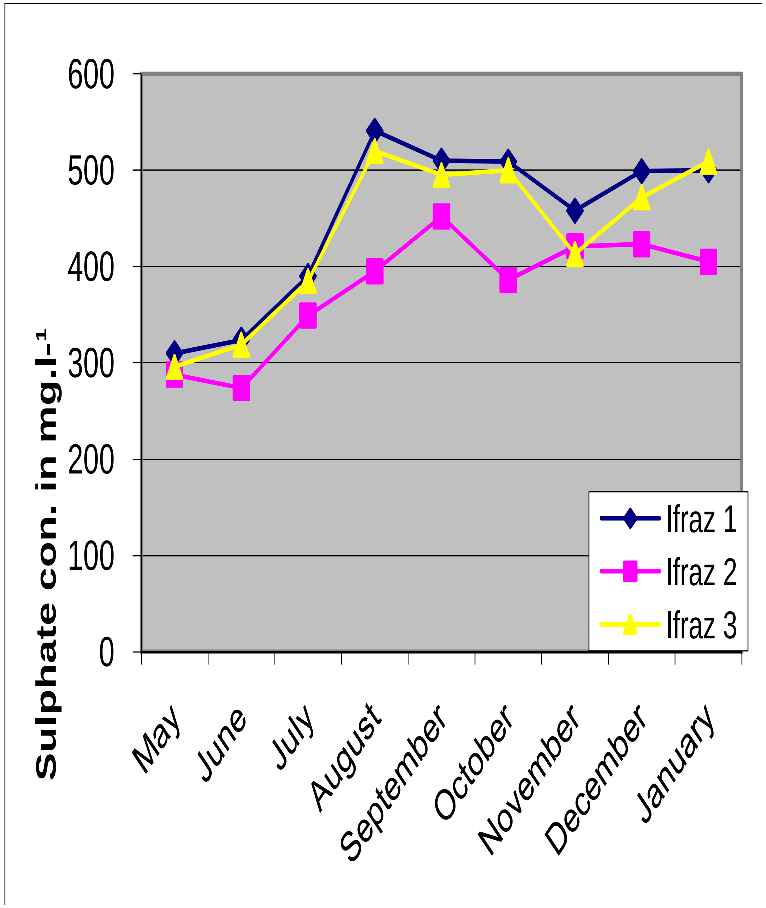

Figure (6): Sulphate values in raw water of Greater Zab river

References

1) USEPA., Edition of the Drinking Water Standards and Health Advisories. Office Of water United States Environmental Protection Agency USEPA. Washington, DC (2004).

2) Gupta A.K. and Shrivastava R.K., Integral Water Treatment Plant Design Optimization: A Genetic Algorithm Based Approach. Jour. of the Institution of Engineers (India). Vol. 87. P3 (2006).

3) EPA., Distribution System Indicators of Drinking Water. U.S. Environmental Protection Agency. 98pp (2006).

4) World Health Organization (WHO)., Guidelines for Drinking-water Quality. Vol. 1: 3rd ed. 540pp (2004).

5) UNICEF., Water treatment chemicals for South Iraq should have the same level of priority as food supplies. Kuwait. (2003).

6) Al-Naqishbandy L.M.A., Limnological studies on the water treatment plant in Ifraz, Erbil. M.Sc. Thesis, Higher Education Coll. University of Salahaddin-Erbil, Iraq (2002).

7) Bapeer U.H. K.; Al-Naqishabandi L.A.; Toma J. J.; and Ismail H. A., Study some physico-chemical and bacteriological variables of both drinking water purification projects (Ifraz and Ainkawa) in Erbil, Iraq. Zanco Jur. Vol.18(3):19-32p (2006).

8) American Public Health association (A.P.H.A.)., Standard methods for the examination of water and wastewater. 20th.Ed. A.P.H.A., 1015 Fifteenth Street, NW, Washington, DC. 20005-2605 (1998).

9) Parsons T.R.; Maita Y.; and Lalli C.M., A Manual of chemical and Biological Methods for seawater Analysis. Pergamon International Library. Robert Maxwell publisher, M.C. Oxford, U.K.. 171pp (1984).

10) Douglas R.R., Evaluation of Compliance with the Long Term 1, Enhanced Surface Water Treatment Rules. MSc. Thesis, Agricultural and Mechanical College, University Louisiana State (2007).

11) Shekha Y.A., The effect of Erbil city wastewater discharge on water quality of Greater Zab river, and the risks of irrigation. Ph.D. Thesis. College of Science. University of Baghdad (2008).

12) Salih M. A., A limnological study on Tigris River. College of Education. Tikrit University (2000). (In Arabic).

13) Lipp, P. and Baldauf G. Enhanced particle removal in drinking water treatment plants – case studies. Water Science and Technology, Vol. 41 (7) p 135–142 (2000).

14) Maulood B.K. and Hinton G.C.F., Further observations on the distribution of red algae in Iraq, with special reference their ecology. Zanco Jour. 6(3):1-14 (1980).

15) Charles, R. and Melia, O. Coagulation and Sedimentation in Lakes, Reservoirs and Water Treatment Plants. Water Science and Technology, Vol. 37 (2): p 129–135 (1998).

16) Demur N. and Atay D., The Treatment Efficiency of Plankton in the Uvedik Drinking Water Treatment Plant, Ankara. Turk Jour. Biol. 26: 229-234p (2002).

17) Mackereth F.J.H.; Heron J. and Talling J.F., Water Analysis Some Revised Methods for Limnologists. Freshwater Biological Association Scientific Publication. No. 36 (1978).

18) Aziz S.Q., Monitoring variation of some water quality parameters of Greater-Zab River at Ifraz station during fourteen months. Zanco Jour. Vol.20(3):115-133 (2008).

19) AL-Aswad M.B.; Hamadan A.M. and Mohamad M.S., The chemical status of drinking water in Sulaimaniyah city. Zanco Jour.Vol.4 (3):141-156 (1978a).

20) Toma J.J., Weekly and spatial variation of physico-chemicals variables and algal composition in Kasnazan impoundment, Erbil, Iraq. Jou. Babylon Univ. Voll.10 (3) (2004).

21) Goran S.M.A., Limnology and Non-Diatom Phytoplankton Composition of Dilope Spring and Kesnezan Impoundment. M.Sc. Thesis, College of Science, Univ. of Salahaddin, Erbil, Iraq (2006).

22) Bartram J. and Ballance R., Water quality monitoring. United Nations Environmental program (UNEP), and world health organization (WHO). E and FN span an imprint of champian and Hall. 383pp (1996).

23) Othman B.A., Limnology and Hygienic Status of some Water Resources within Koya District. M.Sc. Thesis, College of Science, Univ. of Koya, Erbil, Iraq (2008).

24) Peter H. and Ludemann D., Examination, Assessement, Conditioning, Chemistry, Bacteriology and Biology. Walter de Gruyter Co Berlin. 389pp (1972).

25) Sawyer C.N. and McCarthy P.L., Chemistry for Environmental engineering. 3rdEd. McGraw-Hill Book Company. Singapore. 532pp (1978).

26) Ibrahim, A.M.K., A study on the algal ecology of springs in Sulimaniyah province. M.Sc. Thesis, Univ. of Sulaimaniyah (1981).

27) Wang L.K.: Hung Y.T. and Shammas N.K..Physicochemical treatment processes. Humana Press Inc., Totowa, New Jersey. pp 723 (2005).