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The Effects of Intake Water Quality and Filtration Unit Performance on the Efficiency of the Al-Rasheed Water Treatment Plant in Baghdad, Iraq

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Abstract

Water treatment plants play an important role in the purification and distribution of safe drinking water to the public. The present study focused on the performance assessment of the Al-Rasheed water treatment plant [ARWTP]. The main objectives of the assessment were to determine the efficiency of various plant units as well as the quality of inlet water from the Tigris River. Results obtained from the collected data indicated the presence of high concentrations of soluble nitrate and phosphate ions in the filtered water. The removal efficiency of alkalinity, EC, total hardness, SO_4, Cl, NO_3 and PO_4 were found to be (+11.05%), (-0.67%), (-29.33%), (-2.64%), (-6.25%), (-32.13%), and (0%) respectively. The removal efficiency was negative for some parameters which means that the concentration before treatment was less than the concentration after treatment. Water treatment facilities in Al-Rasheed water treatment plant need modernization and rehabilitation. Using pre-chlorination as an effective method for the controlling algal growth in the conventional water treatment plants is highly recommended.

Keywords: Physiochemical parameters, Filtration units, Water quality index, Al-Rasheed water treatment plant, Assessment.

تاثير نوعية المياه الخام الداخلة للمحطة واداء وحدات الترشيح على كفاءة محطة الرشيد لتصفية المياه الشرب

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الخلاصة

توفر محطات تصفية مياه الشرب ضمان الوصول لمياه شربٍ آمنة للاستهلاك البشري من خلال تحسين جودة المياه عن طريق ازالة الملوثات الموجودة في المياه، ومنها: الملوثات العضوية وغير العضوية، الملوثات الميكروبية واي مواد غير مرغوب فيها تضر بالصحة العامة. يهدف البحث الى تقييم كفاءة عمل محطة الرشيد لتصفية مياه الشرب في الزعفرانية جنوب بغداد من خلال تقييم نوعية مياه نهر دجلة كمصدر للمياه الخام عند مأخذ المحطة وتقييم المياه الخارجة من المحطة ومقارنتها مع المواصفات القياسية . اضافة الى تقييم عمل وحدة الترشيح لأهميتها في ازالة الملوثات. بينت النتائج عدم كفاءة المحطة في ازالة الملوثات حيث كانت نسب الإزالة متدنية الى سالبة لكل من القلوية ،الايصالية الكهربائية، العسرة الكلية، الكلورايد، الكبريتات، النترات و الفوسفات وقد بلغت (11.05%)،(-0.67%)، (-29.33%) ، (-2.64%) ، (-6.25%), ، (-32.13%)،

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%zero على التوالي. محطة الرشيد تحتاج الى تحديث واعادة تأهيل اضافة الى ادارة جيدة وتدريب العاملين فيها على احدث التقنيات للحصول على مياه صالحة للشرب.

1.0 Introduction

Water treatment is the process of improving water quality by removing contaminants and any undesirable components so it becomes fit for its desired end-use.

Rivers are main sources of water for various uses. Main cities and industrial activities are commonly located on rivers and are considered as main sources of contamination. River water is mainly contaminated by physical and biological impurities such as total suspended solids, turbidity, bacteria, virus, algae etc. which need to be removed by various treatment processes, particularly when the river water is drawn to a water treatment plant. The location of the water treatment plant with respect to the pollution source also determines the nature of the required treatment [1].

Treating polluted water produced from both domestic and industrial sources before being disposed into rivers, is necessary to reduce pollution level of a river water. Wastewater from industrial and municipal discharges can deteriorate the physicochemical properties of water in receiving water bodies when discharge quality does not comply with the standard level. This has resulted in serious problem in water treatment plants. Inlet water is a point of entry to the water treatment system and usually installed directly on a water source such as rivers. Depending on the quality of the inlet water to treatment plants, it may or may not require pretreatment before its entry to the treatment plant[2].

Desye *et al.*[3] investigated the variation of parameters in treated water from a treatment plant and proposed an adequate preliminary treatment like screening to reduce the incoming organic loading, proper chlorination of the drinking water system and frequent monitoring and maintenance of the treatment plant system.

Al-Ani *et al.*[4] evaluated the water quality of Tigris river within Baghdad city by monitoring the variation of some physicochemical parameters during wet and dry seasons. The results indicated a higher level of contamination in the Tigris River at the Baghdad city center (Al-Sarrafia Bridge and Al-Shuhada Bridge), pinpointing that due to the anthropogenic impact, the contamination has led to deterioration in water quality.

Khudair [5] evaluated WQI from the influent of eight water treatment plants along the Tigris River within Baghdad city from 2004-2010. The results showed that the state of water quality of Tigris River was ranged as poor at the upstream and was unsuitable for drinking at the downstream which reflected the effects of pollution by domestic and industrial effluents.

Al-Suhaili [6] estimated the water quality index (WQI) for three water treatment plants (AL Kharkh, Al Wathba and Al Rasheed) that exist along the Tigris River. . The results showed that the value of water WQI for the Al Rasheed water treatment plant was greater than the value of the WQI for Al Wathba as well as the value of the WQI for Al Karkh treatment plants, indicating that the water quality of Tigris River deteriorated towards south of Baghdad.

Ezzat *et al.* [7] assessed the quality of water from entries and exits of six drinking water treatment plants. Based on annual data, the results revealed a seasonal variation in chemical, physical and microbiological properties of river water. Presence of suspended solids and any particulate matter in the inlet water increased the resistance of most microbes to disinfection. Therefore, granular filtration performance with low particle removal reduces the effectiveness of disinfection [8].

Al-Anbari and Muter[9] evaluated the removal efficiency of chemical, physical and microbial parameters from two drinking water treatment plants, namely AL-Wihda and Al-Rasheed in Baghdad, Iraq. Three treatment units from each plant were selected for assessment. The selected units were sedimentation, filtration and storage reservoirs before distribution. They measured turbidity, electrical conductivity, total hardness, nitrate, phosphate and heavy metals. The results showed that the drinking water produced from the AL-Rasheed plant contained more contaminants than that produced by AL-Wihda plant. Mahmood *et al*. [10] investigated the presence of antibiotics in rivers and potable water from two treatment plants namely, Al-Wihda and Al-Rasheed. They found antibiotic drugs in both intake raw water from Tigris River and the water treated by the studied plants. The removal efficiency of a certain constituent in a treatment plant or treatment unit is frequently reported as the percent (%) removal efficiency. The removal efficiency is calculated by the well-known concept described in equation (1).

$$E(\%) = \{ \qquad (1)$$

Whereas E(%) is the percentage of removal efficiency, C_{in} is the inlet concentration and C_{out} is the output concentration.

The principal objective of this study was to investigate the operational status of Al- Rasheed water treatment plant (ARWTP), including the efficiencies of the treatment units and the contamination level in the inlet water to the plant.

2.0 Materials and Methods

2.1 Site Description

Al-Rasheed water treatment plant (ARWTP) is located in Al-Za'franiya neighborhood southeast of Baghdad, Iraq, on the left Bank of the Tigris River. The quality of treated water by the ARWTP is affected by the wastewater dumped directly into the Tigris River from Al-Numan factory and by the hot water disposed by South Baghdad Power Station (SBPS). The location of the Al-Numan factory is 169 m upstream of the intake of ARWTP while the SBPS is located 333 m from the ARWTP (Figure 1). This shows how near the locations of these pollution sources are from the intake of the ARWTP. Table 1 shows the coordinates of the pollution sources and the ARWTP.

Figure 1: General location of case study (Source: Google Earth).

Table1: The coordinates of Al- Numan factory, south Baghdad power station and Al-Rasheed water treatment plant.

Geographical Study Sites	North Coordinates	East Coordinates	Distance (m)
Al-Rashid Water Treatment Plant	33° 17’ 09.74”	44° 27’ 14.63”	Reference Point Distance
Al-Numan Factory	33° 17’ 15.21”	44° 27’ 11.55”	169
Electrical Power Station in South Baghdad	33° 17’ 18.22”	44° 27’ 07.19”	330

•The distance of each source of pollution is given reference to the Al-Rasheed water treatment plant.

2.2 Components of Al-Rashid Water Treatment Plant

The main components of ARWTP are intake structure on Tigris River, coagulation basins, flocculation basins, sedimentation basins, filtration, disinfection, storage reservoirs and pumping units. Figure 2 outlines the general layout, number of units and dimensions of various components of the ARWTP.

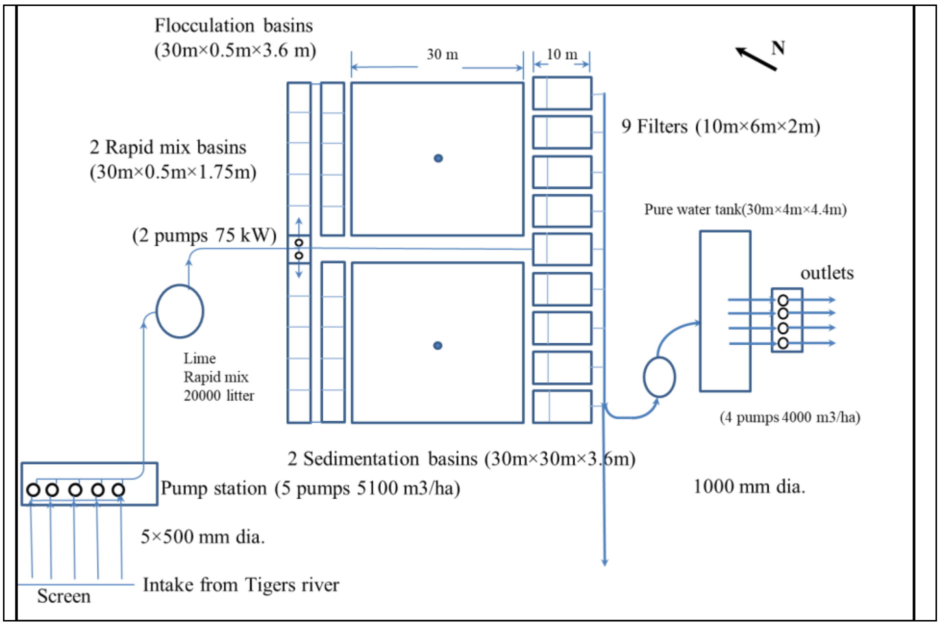

Figure 2: The general layout and components of Al-Rasheed water treatment.

2.2.1The Plant Water Intake

The intake of the ARWTP is located on the left bank of Tigris River and is comprised of 5 ductile iron pipes, each with 500 mm diameter and 5 pumps of different capacities. The total capacity of the pumps is 5100 m^3/hr. Raw water is screened before being pumped to the raw water reservoir. At this stage big particles that come together with the raw water from the river are removed.

2.2.2 Coagulation and Flocculation Basins

Coagulation is used to concentrate pollutants into high-quality silk flowers type structures (flocs) by adding coagulant [11]. These flocs tend to sediment quickly and can be removed by subsequent precipitation and filtration processes. The factors that influence coagulation–flocculation are, among others, temperature, pH, effluent quality, dosage and coagulant type (2) [12]. Coagulation is the first treatment step of water after it has been pumped from the intake. Two pumps of 75 kW supply water to left and right rapid mixing basins each with dimensions of 30m×0.5m×1.75m (L*W*D). Flocculation is the second treatment step and in ARWTP the water inters two flocculation basins each basin is with a dimensions of 30m×0.5m×3.6m (L*W*D).

2.2.3 Sedimentation

After the chemical dosage process, the water goes into two sedimentation basins with each basin having dimensions of 30m×30m×3.6m (L*W*D). The flocs formed through coagulation process are settled down and thereby separated from the water.

2.2.4 Filtration

During this process, all flocs that did not settle in the sedimentation tanks are removed using three different layers of sand and gravel. Filtration enhances the effectiveness of the disinfection. In ARWTP, there are nine filters, each filter with an area of 10m×6m and a depth of 2m.

2.2.5 Disinfection

After the water flows through the gravity sand filters, the next step is typically disinfection or chlorination. The disinfection is injected to remove the bacteria from the treated water.

2.2.6 Storage Reservoir and Distribution

The plant has one storage reservoir with dimensions of 30m×4m×4.4m (L*W*D). The reservoir is connected to high lift pumping station. The station is composed of 4 pumps with each pump having a capacity of 1060 m^3/hr and 250 kW power. High lift pumps are used to distribute the supply water to the Al-Za'franiya neighborhood via 1000 mm diameter main pipe.

2.2.7 Sampling and Laboratory Work

Water samples were collected at seven sites distributed in the ARWTP. Samples were taken from the river (close to the intake), coagulation units, flocculation unit, sedimentation basin, before and after filtration and from the tap to represent the supplied water. The selected eight parameters were electrical conductivity (Ec), pH and turbidity (Tu.) were measured instantaneously in the station of ARWTP in situ. Analysis of total hardness (Th.), alkalinity (Alk), chloride (Cl), sulfate (SO_4), nitrate (NO_3), and phosphate (PO_4) were done in the laboratory. The experiments were conducted by following the standard methods for the examination of water and wastewater [3].

3.0 Result and Discussion

This study focused on assessing the quality of water at the intake of the ARWTP plant and the treated water before pumping to the network in order to determine the efficiency of the plant in treating raw water and exploring the crucial parameters that affect its water quality. The study also included determining plant filtration units efficiency.

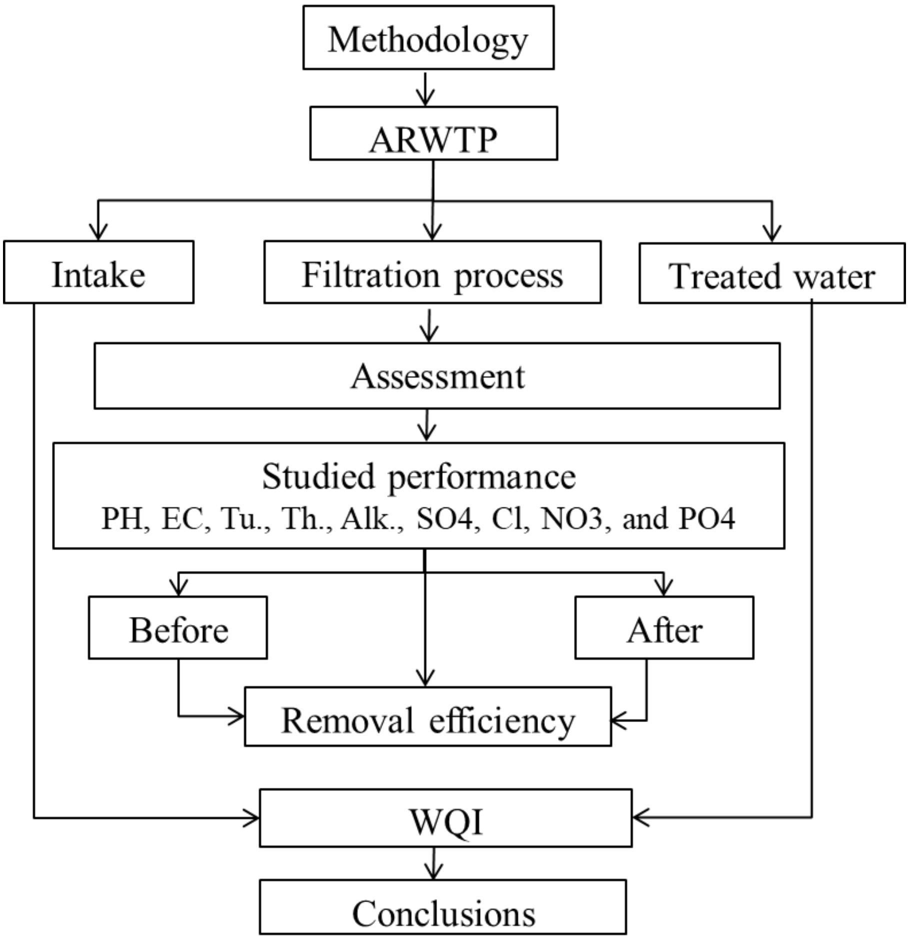

Figure 3: Flow chart for the methodology used in the Al-Rasheed water treatment plant evaluation.

3.1 Inlet Water from the River (Intake Water of the ARWTP Plant)

River water quality is subjected to direct environmental input. It may vary considerably in solids content, temperature, physiochemical and biological contaminants. ARWTP is primary source of drinking water supply to Al-Za'franiya and its surrounding areas. The change in water quality of the inlet water to the plant, limits the plant production efficiency and increases the operational cost. ARWTP operators are facing two major sources of pollution: Al- Numan factory which discharges industrial waste directly into the river and electrical power station which discharges hot water. Based on water quality index and using selected physiochemical parameters, Ezzat *et al.*[7] assessed the quality of Tigris River at the site of ARWTP. The source of these parameters is the effluent of Al-Rasheed power plant. The results concluded that the effluent had a significant effect on the quality of the Tigris River. Results also indicated that calculated values of water quality index for drinking and aquatic life showed that the quality of Tigris River was classified as poor in winter and fair to marginal in the other seasons.

3.2 Assessment of the Intake Water Quality to the ARWTP Plant from Tigris River

In this study, the concentrations of physicochemical parameters such as PH, EC, Tu. Th., Alk, SO_4, Cl, NO_3, and PO_4 in the intake water to the ARWTP plant were compared with the Iraqi standard for surface water [13] as well as with the World Health Organization (WHO) standards [14]. Table 3 shows the concentrations of the studied parameters in the intake water of Tigris River at the location of ARWTP, Iraqi standards 2009 and WHO standards 2011. The comparison showed that the quality of the intake water to the ARWTP was within the acceptable limits as required by the Iraqi standards for surface water and by WHO standards 2011, except PO_4 concentration (Table 2).

Table2: Comparison between surface water standards as given by WHO (2011) and IQS (2009) and Tigris River water at the location of the intake of the ARWTP.

Parameters	Units	Iraqi Standards (IQS)2009	WHO Standards 2011	**Measured Parameters of Tigris River Water at the Location of the Intake of the ARWTP Plant**
PH	-----	6.5-8.5	6.5-8.5	6.96
EC	μS/cm	1500	1500	889
Tu.	NTU	N.A.		
Th. as CaCO3	mg/L	500	500	375
Alk. as CaCO3	mg/L			
SO4	mg/L	250-400	250-400	164.8
Cl	mg/L	250-350	200-600	56.8
NO3	mg/L	50	10-45	13.07
PO4	mg/L	1	1	4.5

3.3Water quality index (WQI) for Tigris River Water at the Location of the Intake of the ARWTP

Suitability of intake water of the ARWTP was evaluated based on the water quality index using Bhargava method. The parameters used to determine the (WQI) were PH, EC, Tu. Th., Alk, SO_4, Cl, NO_3, and PO_4 concentrations. The results showed that the main contaminant accounted for the poor quality was PO_4. The concentration of PO_4 exceeded that required by WHO (the maximum allowable concentration is 1 mg/L). Based on water quality requirements, the intake water to the ARWTP was classified as “unsuitable” with mean value of 938.63, as shown in Table 3.

Table 3: WQI for Tigris River at the location of the intake to the ARWTP.

Parameters	Units	**Intake of the ARWTP**	Si	1/Si	Wi	Qi=Vi/Si(%)	Wi*Qi
Tu. (NTU)	NTU	210	5	0.2	0.14495	4200	608.7692
EC (µs/cm)	µs/cm	889	2000	0.0005	0.0004	44.45	0.016107
PH		6.96	7.5	0.1333	0.0966	8	0.77304
Alk. (mg/l)	mg/l	256.5	100	0.01	0.0072	256.5	1.85892
T.h.(mg/l)	mg/l	375	500	0.002	0.0014	75	0.108709
Cl (mg/l)	mg/l	56.8	100	0.01	0.0072	56.8	0.411644
SO_4 (mg/l)	mg/l	164.8	250	0.004	0.0029	65.92	0.191096
NO_3(mg/l)	mg/l	13.07	50	0.02	0.0145	26.14	0.378886
PO_4 (mg/l)	mg/l	4.5	1	1	0.7247	450	326.1263
						∑ Wi*Qi =	938.6339

3.4 Assessment of Plant Filtration Units

The assessment of the ARWTP plant filters included determination of the filtration process efficiency. Some selected physicochemical parameters concentrations such as PH, EC, Tu., Th., Alk, SO_4, Cl, NO_3, and PO_4 were measured after sedimentation and before entering the filters, and after filtration process had completed. The efficiency was calculated by using equation (1). Table 4 shows the values of the measured parameters before and after filtration in addition to the calculated efficiency.

Table4: Physiochemical parameters concentration and removal efficiency of filtration units in ARWTP.

Parameters	Units	Inlet Water to Filter	Outlet Water from Filter	Removal Efficiency %
PH	-----	5.29	5.85	----
EC	µS/cm	915	905	1.10
Tu.	NTU	89.1	2.26	97.46
T.h. as $CaCO_3$	mg/L	385	375	2.56
Alk as $CaCO_3$	mg/L	228.75	181.17	20.8
SO_4	mg/L	172.8	137.07	20.67
Cl	mg/L	53.25	53.25	0
NO_3	mg/L	13.025	17.58	-34.9
PO_4	mg/L	2.833	4.5	-58.84

Note: Negative sign means that the value of the parameter after filtration was more than that before entering the filter.

The mean values of the turbidity in the water (after sedimentation) before entering the filters and that leaving the filter were found to be 89.1 NTU and 2.26 NTU respectively. Figure 4 shows the measured turbidities during different processes of the plant. The removal efficiency of turbidity for filtration process was found to be 97.46% (Table 4).

The mean values of the pH in the water (after sedimentation) before entering the filters and that leaving the filter were found to be 5.29 and 5.85 respectively. Figure 5 shows the measured pH at different processes of the plant. The lower pH value of5.29 might be due to the presence of pollutions, or the degradation of organic materials which produced dissolved carbon dioxide [15].

The mean values of EC in the water (after sedimentation) before entering the filters and that leaving the filter were found to be 915 µS/cm and 905 µS/cm respectively. The values of EC were found higher than that in the intake water from Tigris River. Figure 6 shows the measured EC at different processes of the plant. The removal efficiency of EC for filtration process was found to be 1.10% (Table 4).

The mean values of total hardness in the water (after sedimentation) before entering the filters and that leaving the filter were found to be 385 mg/L and 375 mg/L respectively. Figure 7 shows the measured total hardness during different processes of the plant. The removal efficiency of total hardness for filtration process was found to be 2.56% (Table 4).

The mean values of alkalinity in the water (after sedimentation) before entering the filters and that leaving the filter were found to be 228.75 mg/L and 181.17 mg/L respectively. Figure 8 shows the measured alkalinity during different processes of the plant. The removal efficiency of alkalinity for filtration process was found to be 20.8% (Table 4).

The mean values of sulphate in the water (after sedimentation) before entering the filters and that leaving the filter were found to be 172.8 mg/L and 137.067 mg/L respectively. Figure 9 shows the measured sulphate during different processes of the plant. The removal efficiency of sulfate for filtration process was found to be 20.67% (Table 4).

The mean values of chloride in the water (after sedimentation) before entering the filters and that leaving the filter were found to be the same value 53.25 mg/L and 53.25 mg/L respectively. Figure 10 shows the measured chloride during different processes of the plant. The removal efficiency of chloride for filtration process was found to be 0% (Table 4).

The mean values of nitrate in the water (after sedimentation) before entering the filters and that leaving the filter were found to be 13.025 mg/L and 17.585 mg/L respectively. Figure 11 shows the measured nitrate during different processes of the plant. The removal efficiency of nitrate for filtration process was found to be (-34.9%) (Table 4).

The mean values of phosphate in the water (after sedimentation) before entering the filters and that leaving the filter were found to be 2.833 mg/L and 4.5 mg/L respectively. Figure 12 shows the measured phosphate during different processes of the plant. The removal efficiency of phosphate for filtration process was found to be -58.84% (Table 4).

3.5 Assessment of Treated Water Quality

The concentrations of physicochemical parameters such as PH, EC, Tu. Th., Alk, SO_4, Cl, NO_3, and PO_4 in the treated water of the ARWTP plant, were measured and compared with the Iraqi standard for drinking water (Iraqi standards (IQS)2009), as well as with WHO standards 2011. Table 5 shows comparison between drinking water standards as given by WHO (2011) and IQS (2009) and the treated water by ARWTP. The comparison showed that the quality of the treated water of ARWTP was within the acceptable limits of the Iraqi standards for surface water as well as that of WHO (2011) standards, except alkalinity and PO_4 concentrations (Table 5).

Table 5: Comparison between drinking water standards as given by WHO (2011) and IQS (2009) and the treated water by ARWTP.

Parameters	Units	Iraqi Standards (IQS)2009	WHO Standards 2011	**Treated Water by ARWTP**
PH	-----	6.5-8.5	6.5-8.5	6.19
EC	μS/cm	0-2000*	200	895
Tu.	NTU	5	5	2.52
T.H as $CaCO_3$	mg/L	100-500	100-500	485
Alk. as $CaCO_3$	mg/L		20-200 mg/L	228.14
SO_4	mg/L		200-400	169.174
Cl	mg/L	350	350	60.35
NO_3	mg/L		50	17.263
PO_4	mg/L	1	1	4.5

*The maximum permissible level if no alternative source available, limit extended up to.

Table6: The concentrations of physiochemical parameters of raw water, treated water by ARWTP and removal efficiencies.

Parameters	Units	Inlet to Plant	Outlet from Plant or Treated Water	Removal Efficiency %
PH	-----	6.96	6.19	-------
EC	μS/cm	889	895	-0.67
Tu. as $CaCO_3$	mg/L	210	2.52	98.8
T.h as $CaCO_3$	mg/L	375	485	-29.33
Alk.	mg/L	256. 5	228.14	11.05
SO_4	mg/L	164.8	169.16	-2.64
Cl	mg/L	56.8	60.35	-6.25
NO_3	mg/L	13.07	17.27	-32.13
PO_4	mg/L	4.5	4.5	0

3.5.1 Turbidity (Tu)

The mean values of the turbidity in the treated water were found to be 2.52 NTU (Figure 4). The removal efficiency of turbidity for ARWTP was found to be 98.8% (Table 6).

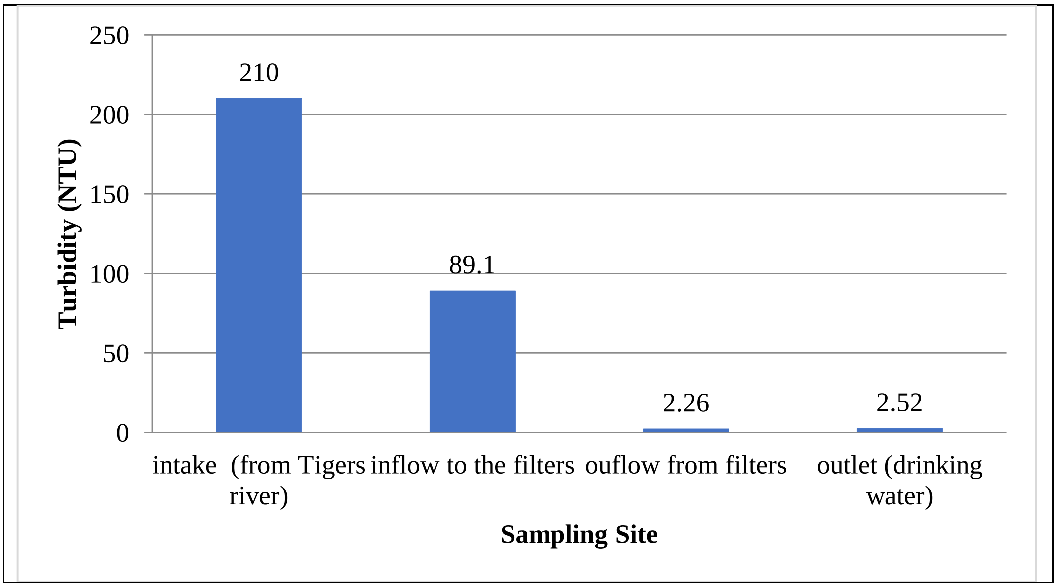

Figure 4: Turbidity trend along the ARWTP units.

3.5.2 PH Values

The mean value of pH in treated water was found to be 6.19 (Figure 5). This value was lower than acceptable limit (6.5 to 8.5) as recommended by the Iraqi standards 2009 and WHO standards 2011 (Table 5). The possible reason for the acidity of the treated water by ARWTP can be related to the use of excess quantities of chemical alum ($Al_2(SO_4)_3$) in the coagulation process. The pH value less than 6.5 enhances corrosion in distribution water pipes [14].

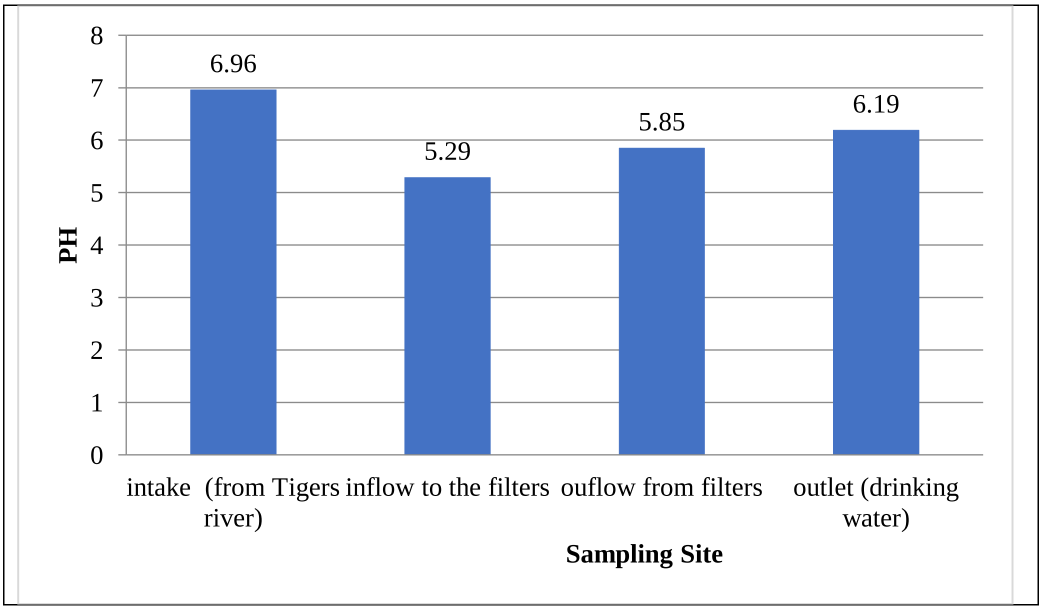

Figure 5: PH trend along the ARWTP units.

3.5.3 Electrical Conductivity EC Values

The mean value of EC in treated water was found to be 895 µS/cm (Figure 6). This value was close to the upper limit required by the WHO standards (should not exceed 1000 µS/cm in drinking water) [3, 15]. High EC values lead to formation of scales and corrosion in pipes and boilers. The increments of EC might be attributed to the addition of excess chemicals for coagulation [16]. In addition, the high EC values can also be attributed to poor maintenance of the sedimentation basins and filters [17]. The removal efficiency of EC for ALWTP was found to be -0.67% (Table 6).

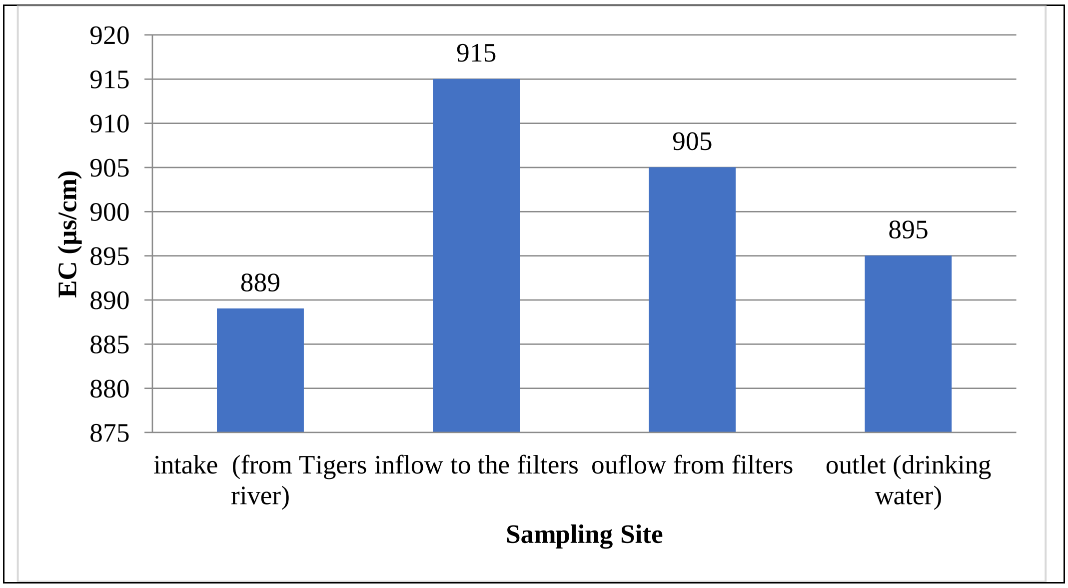

Figure 6: Electrical conductivity trend along the ARWTP units.

3.5.4 Total Hardness

Hardness is a term used to express the properties of highly mineralized waters. The mean value of total hardness in treated water was found to be 485mg/L (Table 5 and Figure 7). The removal efficiency of total hardness for ALWTP was found to be -29.33% (Table 6).

Water with more than 300 mg/L of hardness is generally considered to be hard while that with less than 75 mg/L is considered to be soft. There are no health concerns associated with drinking hard water. However, it is often undesirable as it can cause lime buildup (scaling) in pipes and water heaters. Hard water reacts with soap which can decrease its cleaning ability and causes build-up of soap scum. Some people who use hard water for showering may notice problems with dry skin. From the health viewpoint, hardness up to 500 mg/L is safe but more than that may cause a laxative effect [18].

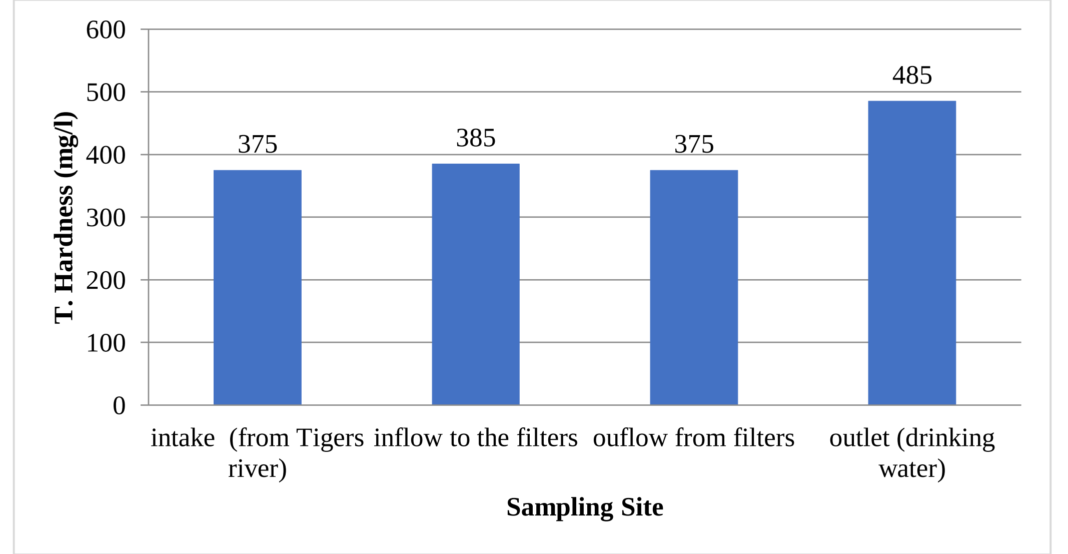

Figure 7: Total hardness trend along the ARWTP units.

3.5.5 Alkalinity

Alkalinity and total hardness are usually nearly equal in concentration (when they are both reported in mg/L $CaCO_3$ (calcium carbonate) because are from the same minerals. Alkalinity can exist in water in three basic forms: carbonate (CO_3), bicarbonate (HCO_3), or hydroxide (OH). High levels of either acidity or alkalinity in water may be an indication of industrial or chemical pollution. Water with low levels of alkalinity (less than 150 mg/L) is more likely to be corrosive. High alkalinity water (greater than 150 mg/L) can lead to clogging of pipes and other water supply network accessories [18]. The mean value of alkalinity in treated water was found to be 228.14mg/L (Figure 8). The removal efficiency of alkalinity for ALWTP was found to be 11.05% (Table 6).

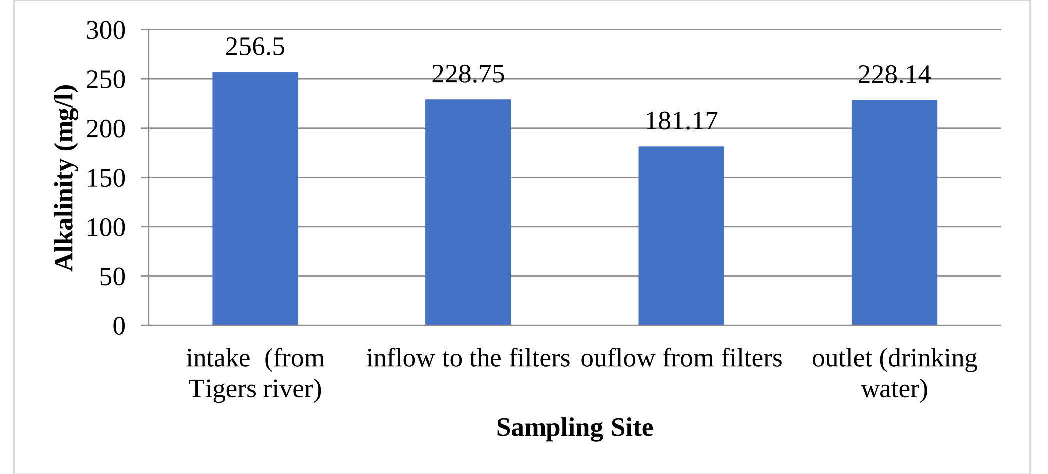

Figure 8: Alkalinity trend along the ARWTP units.

3.5.6 Sulphate

The mean value of sulfate in treated water was found to be 169.17mg/L (Figure 9). The removal efficiency of sulfate in treated water by ALWTP was found to be -2.64%(Table 6). Presence of high concentration of sulfate in drinking water causes noticeable taste or unwanted laxative effects and might contribute to the corrosion of distribution pipe network system [15].

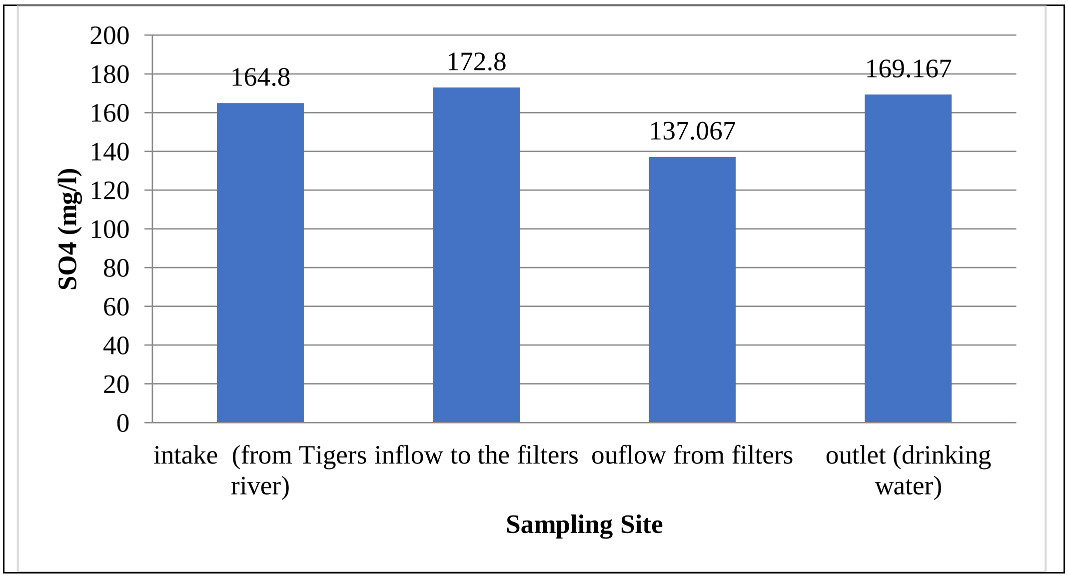

Figure 9: Sulphate trend along the ARWTP units.

3.5.7 Chloride

Chloride ions Cl^{-} in drinking water do not cause any harmful effects on public health. However, high concentrations can cause an unpleasant salty taste for most people. Levels more than 250 mg/L may cause a salty taste or corrosion of some metals. Sodium (which is sometimes found with chloride) may be a concern for individuals on physician prescribed “no salt diets”. The mean value of chloride in treated water was found to be 60.35 mg/L (Figure 10). Removal efficiency of chloride in treated water by ALWTP was found to be -6.25%(Table 6).

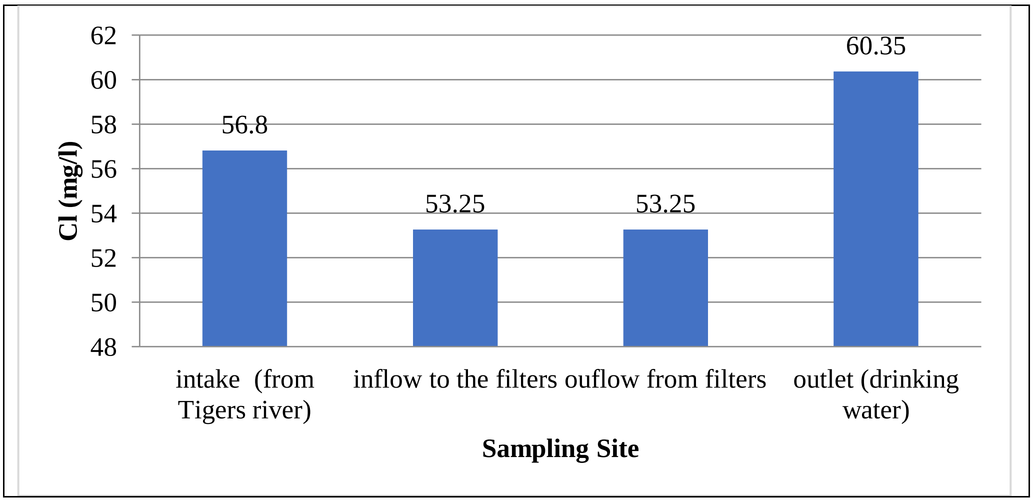

Figure 10: Chloride trend along the ARWTP units.

3.5.8 Nutrients Level (Nitrate NO_3)

Nutrients include nitrate and phosphate and are formed due to the decomposition of waste materials such as manure or septic effluent. The WHO standards and the Iraqi standards require that the concentration of nitrate-nitrogen in drinking water to be 10 mg/L. Value greater than 10 mg/L should not be consumed by infants under 6 months of age or pregnant women. Excessive nitrate concentration (more than 10 mg/L) in drinking water causes an immediate and severe health threat to infants. The nitrate ions react with blood hemoglobin, thereby reducing the blood's ability to hold oxygen which leads to a disease called blue baby or methemoglobinemia [19]. The WI Dept. of Public Health recommends people of all ages avoid long-term consumption of water with nitrate concentrations less than 2 mg/L is preferred. High levels can turn skin to a bluish or gray color and cause more serious health effects like weakness, excess heart rate, fatigue and dizziness. The mean value of nitrate in treated water by LWTP was found to be 17.263mg/L (Figure 11). Removal efficiency of nitrate for ALWTP was found to be -32.13(Table 6).

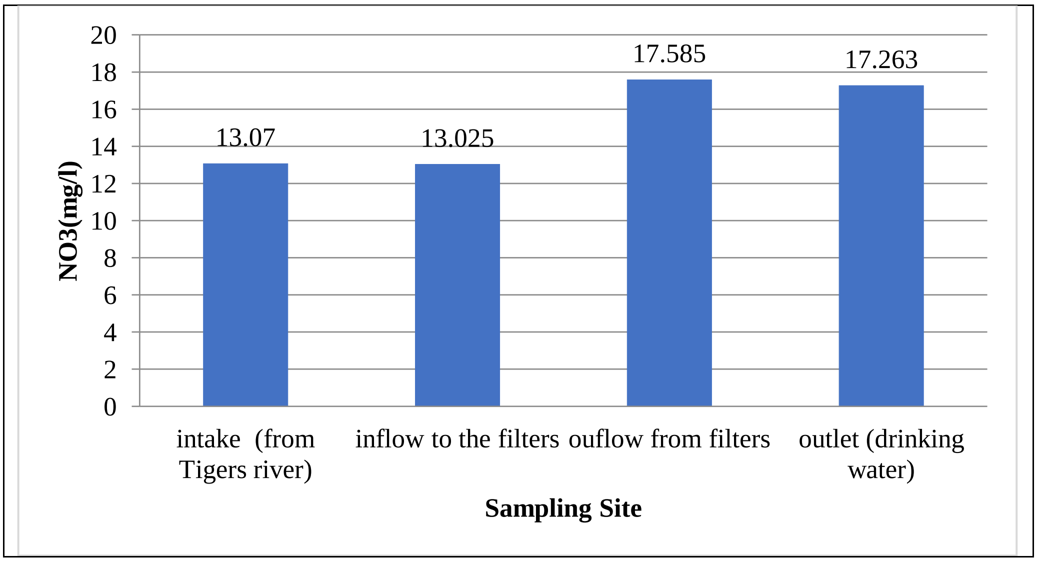

Figure 11: Nitrate trend along the ARWTP units.

3.5.9 Phosphate

Environmental Protection Agency (EPA) [18] established the following recommended criteria for phosphorus: no more than 0.1 mg/L for streams that do not empty into reservoirs; no more than 0.05 mg/L for streams discharging into reservoirs. Phosphate itself does not have notable adverse health effects unless it is present in very high levels. Digestive problems could occur from extremely high levels of phosphate. Phosphate levels greater than 1.0 may interfere with coagulation in water treatment plants. As a result, organic particles that harbor microorganisms may not be completely removed before distribution. The mean value of phosphate in the treated water by ALWTP was found to be 4.5mg/L (Figure 12). Removal efficiency of phosphate by ALWTP was found to be 0% (Table 6).

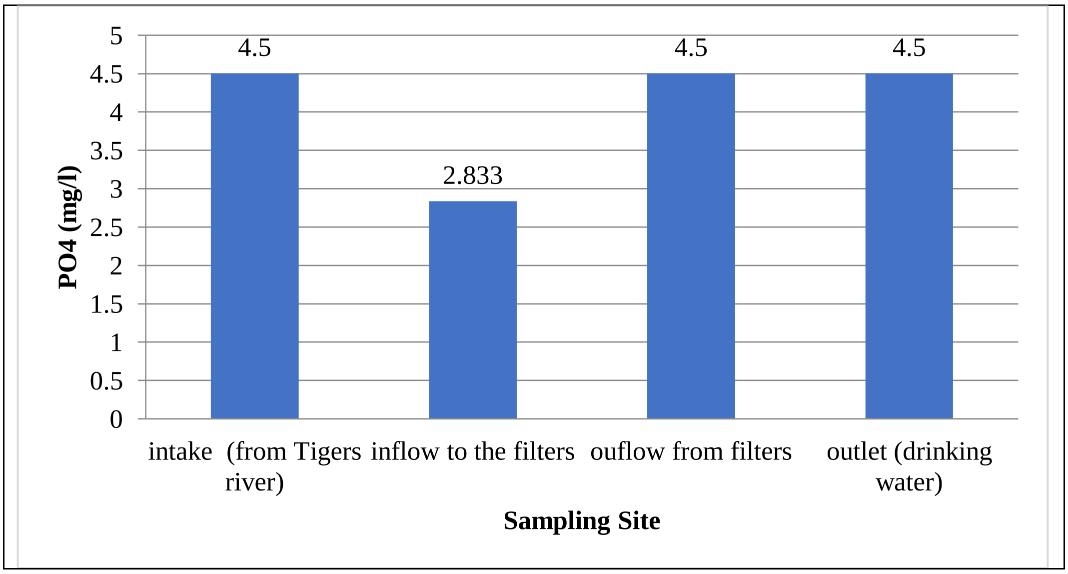

Figure 12: Phosphate trend along the ARWTP units.

3.6 Water Quality Index (WQI) for Treated Water

According to the WQI classification, the general water quality state for treated water from ARWTP was "unsuitable" for drinking where the mean of WQI was 352.02. The results showed that the main contaminant that accounted for the poor quality was PO_4. The concentration of PO_4 exceeds the maximum allowable concentration of 1 mg/L which is required by WHO (Table 7).

Table 7: WQI calculation for the treated water from ARWTP.

Parameters			Si	1/Si	Wi	Qi=Vi/Si (%)	Wi*Qi
Tu.	NTU		5	0.2	0.1449	50.4	7.3052
EC	µs/cm	895	2000	0.0005	0.0004	44.75	0.0162
PH		6.19	7.5	0.1333	0.0966	162	15.6541
Alk.	mg/l	228.14	100	0.01	0.0072	228.14	1.6534
T.h	mg/l	485	500	0.002	0.0014	97	0.1406
Cl	mg/l	60.35	100	0.01	0.0072	60.35	0.4374
SO_4	mg/l	169.167	250	0.004	0.0029	67.6668	0.1962
NO_3	mg/l	17.263	50	0.02	0.0145	34.526	0.5004
PO_4	mg/l	4.5	1	1	0.7247	450	326.1263
						∑ Wi*Qi =	352.0298

3.7 Overall Removal Efficiency of ARWTP

Based on observations from site visits to the ARWTP and the laboratory tests, the failure in the station's performance can be related to the following reasons:

1. The operators did not take into consideration the characteristics of raw water under normal and extreme flow conditions. Seasonal fluctuations must be evaluated and considered in the operation of the ARWTP.
2. Adjust alum rates using jar test
3. In water treatment, sedimentation and filtration processes are essential for removing the algae and particulates from raw water. In this study, the concentrations of nitrate and phosphate ions were recorded at 17.27 mg/L 4.5mg/L respectively. The values were found to be high in the treated water produced from filtration units which caused the presence of the algae blooms.

The problems caused by algal blooms included: reduced filtration detention time, poor coagulation, and ineffective sedimentation. To overcome the problems associated with algal blooms, the ARWTP must consider pre-chlorination, increased coagulant doses and regularly change coagulants [17].

4. Low efficiency of sedimentation basin: sedimentation basin should be cleaned at least twice per year in order to remove the sludge. It is recommended to clean the sedimentation basin during low water demand, and this is expected to be conducted in April and October every year. In case that the sludge is not removed frequently, the effective (useable) volume of the sedimentation tanks will be decreased which effects the efficiency of the ARWTP.
5. Low efficiency of filtration units due to improper backwashing of filtration units: the filtration units should be backwashed on a regular basis in order to avoid the clogging of filters by sediment particles. The presence of suspended solids and other particulate matter in water after filtration increases the resistance of most microbes to disinfection. According to the plant operators, the filter material in ARWTP has not been replaced since 2014, and hence has lost its effectiveness to work due to clogging. The results of study showed the low efficiency removal of filtration units (Table 4).
6. Frequent maintenance is recommended for the storage tanks.
7. Water sampling and testing at various locations through ARWTP in order to ensure the compliance with the required standards.

4. Conclusions

The removal efficiency of the ARWTP is very low since the alkalinity was measured and found to be 11.05% while removal efficiencies were negative for other parameters which means that the concentration of the parameter before treatment was less than the concentration after treatment. The removal efficiency of EC, total hardness SO_4, Cl, and NO_3 were found to be -0.67%, -29.33%, -2.64%, -6.25%, -32.13% respectively. While the removal efficiency of PO_4 was zero. Hence, the quality of drinking water produced by Al-Rasheed water treatment plant in Baghdad is extremely poor due to several factors such as lack of maintenance, lack of training for operating staff, poor monitoring and record keeping, and major problem with the quality of intake from Tigris River. Water treatment facilities in Al-Rasheed water treatment plant need modernization, redevelopment and improvement. Low efficiency of sedimentation basin, infiltration units, and control algae in the tanks. Pre-chlorination is a common and effective method for the controlling algal growth in conventional water treatment plants.

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