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Evaluating the Performance of Sharq Dijila Water Treatment Plant

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Abstract

The study aims mainly to evaluate the performance of Sharq Dijila water treatment plant in removing turbidity for the period of 1-4-2001 to 31-3-2004. Daily data for turbidity of raw, clarified, filtered, and supplied water were analyzed. The results of the study showed that there is a wide variation in turbidity levels of raw water fluctuating between 10-1000 NTU with mean value of 41.3 NTU. Turbidity values of the clarified water varied between 1.4-77 NTU. Based on the turbidity value of 10 NTU and 20 NTU (the design maximum turbidity) the readings gave an acceptable percentage of 32.4% and 86% respectively. The turbidity of filtered water ranged between 0.2-4.5 NTU which are completely in compliance with Iraqi and WHO standards. In accordance with the American Environmental Protection Agency (USEPA) and based on the analysis of 2-day moving average of 5 NTU and 30-day moving average of 1 NTU, it was found that the filters operated at acceptable percentage of 100% and 45% respectively. Turbidity value of the supplied water averaged between 0.4-9.5 NTU which is higher than the turbidity of the filtered water due to the mixing of the water from all other filters. Also turbidity values from the unwashed filters are higher than the washed filters and the precipitation in the treated water reservoir. Based on the Iraqi Drinking Water Standard, USEPA 2-day and 30-day moving average, the supplied water was within the permissible limits of 98%, 98.6%, and 98.6% respectively.

Key words: *Treatment plant, turbidity, Sharq Dijila, raw water, filtered water.*

1. Introduction

The common impurities in water may be classified as physical impurities, chemical impurities, and bacteriological impurities. Raw water, especially surface water contains impurities in the form of suspended, dissolved and colloidal solids, bacteria, poisonous substances, color, odor and mineral organic matter. Water in reservoirs may be purified to some extent due to storage, but may still contain colloidal matter and bacteria; raw water is undesirable for drinking without treatment. The amount of treatment required depend on the quantity and quality of raw water and required standards of purified water (Raju, 1995).

Water leaving the treatment plant must be safe to drink-free from potentially harmful organisms, aesthetically pleasing-without color and/or turbidity, palatable-devoid of unpleasant taste and/or odor, and chemically stable-as far as is possible, non corrosive (Buckley,1984).

The performance of each treatment unit affects the efficiency and operation of subsequent units, e.g., increased detention time in flocculation might result in larger flocs formation, better removal in sedimentation, and larger filter runs. The efficiency of a process such as flocculation, sedimentation and filtration depends on the number, size, and mass of the particles in the water to be treated (Rammaley et al., 1981).

Turbidity refers to suspended solids, i.e. muddy water, is very turbid. Turbidity is undesirable for three reasons, aesthetic considerations, solids may contain heavy metals and pathogens or other contaminants, and turbidity decreases the effectiveness of water treatment techniques by shielding pathogens from chemical or thermal damage, or in the case of UV (ultra violet) treatment, absorbing the UV lights itself (Cheremisinoff, 2002).

Raw water turbidity can vary over a very wide range, from virtually zero to several thousand NTU. Effective treatment should be able to consistently produce final waters with turbidity levels of less than 1 NTU. Turbidity meters are therefore an essential tool in optimizing and controlling water treatment processes (Twort et al., 2009).

Some surface waters carry loads of sediment so high that water treatment plants employ a pre-sedimentation step prior to the conventional treatment train. The conventional treatment train can treat a wide range of source waters, some may be so challenging that even conventional treatment requires a form of pretreatment (Letterman, 1999).

The main objective of this study was to evaluate the performance of Sharq Dijjla water treatment plant. Turbidity was selected as a main parameter because it is a conventional treatment plant (did not remove dissolved solids) so turbidity is very important tool in the evaluation of performance.

2. Site Description and Treatment Process

The Sharq Dijjla water supply project is one of the two large treated water supply systems in Baghdad. It was constructed in 1973 to produce 100 M.G.D and was expanded to 120 M.G.D in 1986 to meet the increasing water demand in Russafa side of Baghdad. Figure1 shows the plan of Sharq Dijila water treatment plant. The description of treatment plant is (Paterson Candy International, 1987).

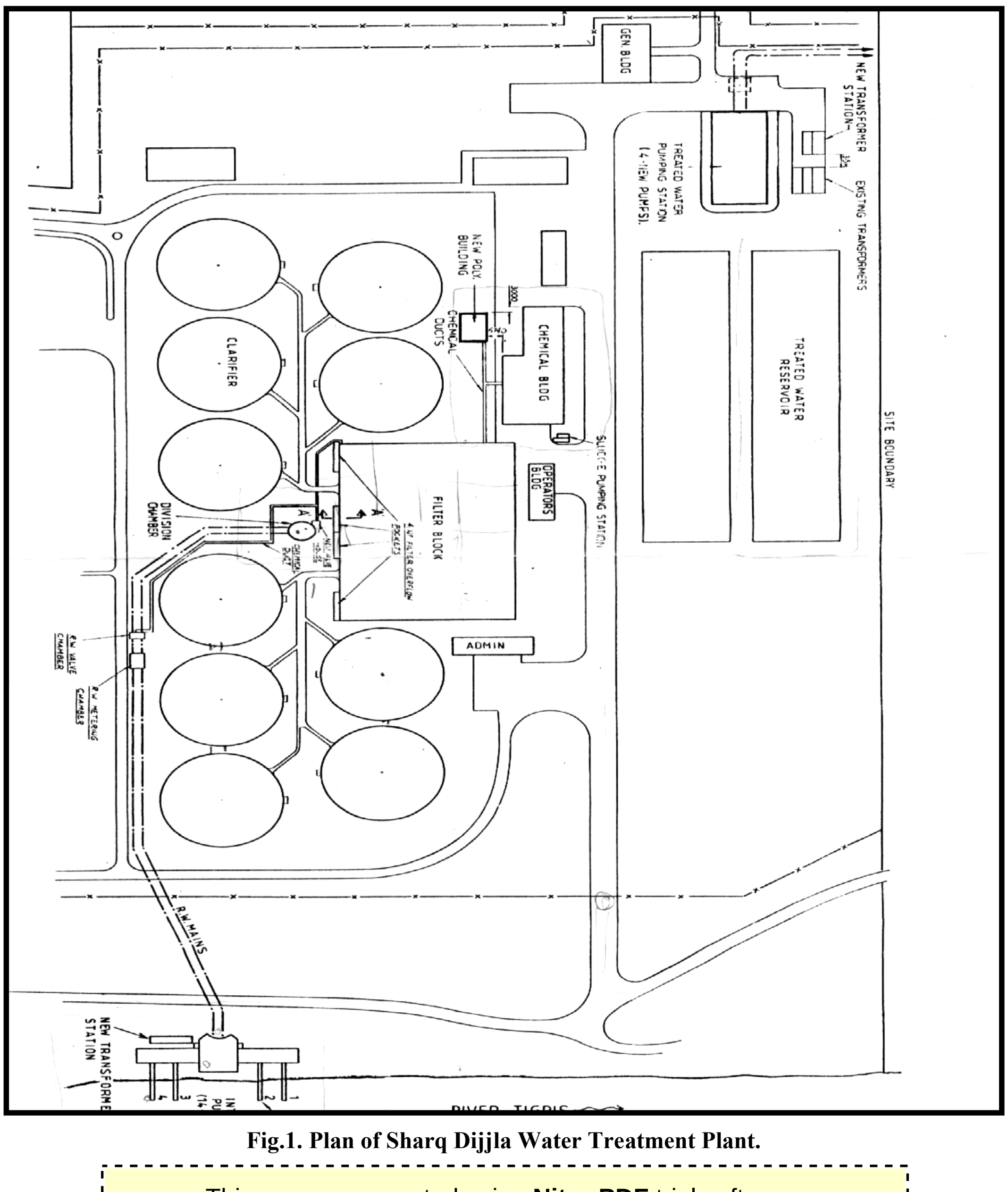

Fig.1. Plan of Sharq Dijjla Water Treatment Plant.

Raw water from the Tigris River flows via four bank side intakes, into the raw water pumping station wet sumps. Each intake channel is provided with raked bar screen for the removal of trash and debris. Vertical spindle pumps lift the raw water from the sumps and delivers, via twin raw water mains, to a division chamber where the total flow is equally divided to serve the two groups of clarifiers. In this position alum solution and pre-chlorination are applied. The aluminum sulphate solution is delivered, via two splitter boxes each of which serves five clarifiers. There are ten clariflocculators dividing into two groups. Inside the clariflocculator there is a mixer in order to achieve the required flocculation. Sludge which is discharged from the concentrators and the central chamber of each clarifier, flows under gravity to the sludge pumping station. The filters are divided into two groups, which are rapid sand filters with single filtration media consisting of sand supported by gravel. The chlorination unit passes chlorine gas whenever motive water passes through an associated injector; the vacuum produced at the chlorinator gas outlet connection, will pull gas through the instrument. The gas flow can be manually adjusted to the desired rate by means of a control valve. There are three ground baffled tanks, two of which are similar with a capacity of 40,000 m^3 and the third of 50,000 m^3. These tanks required detention time for chlorine reaction.

3. Data Analysis and Discussion

To evaluate the performance of Sharq Dijila water treatment plant, the raw, clarified, filtered, and supplied water quality are analysed. Turbidity data are used in this analysis because this treatment plant is of the conventional type. The data were collected from daily laboratory water quality analysis reports covering the period from1-4-2001 through 31-3-2004.

3.1. Analysis of Raw Water Turbidity Data

Figure 2 shows a plot of time series of raw water turbidity data at the intake. This figure shows the drastic changes of turbidity levels in winter while they are more stable in summer and spring. Table 1 also shows a statistical description of raw water turbidity data. A wide range of turbidity level is observed which ranges from 10 to 1000 NTU with a standard deviation of 59.5. The mean value is found to be 41.3 NTU, this results in C_v of 144.88% which reflects the wide variation in raw water turbidity levels of the Tigris River and indicates the need for pre-settling tanks especially in rainy seasons.

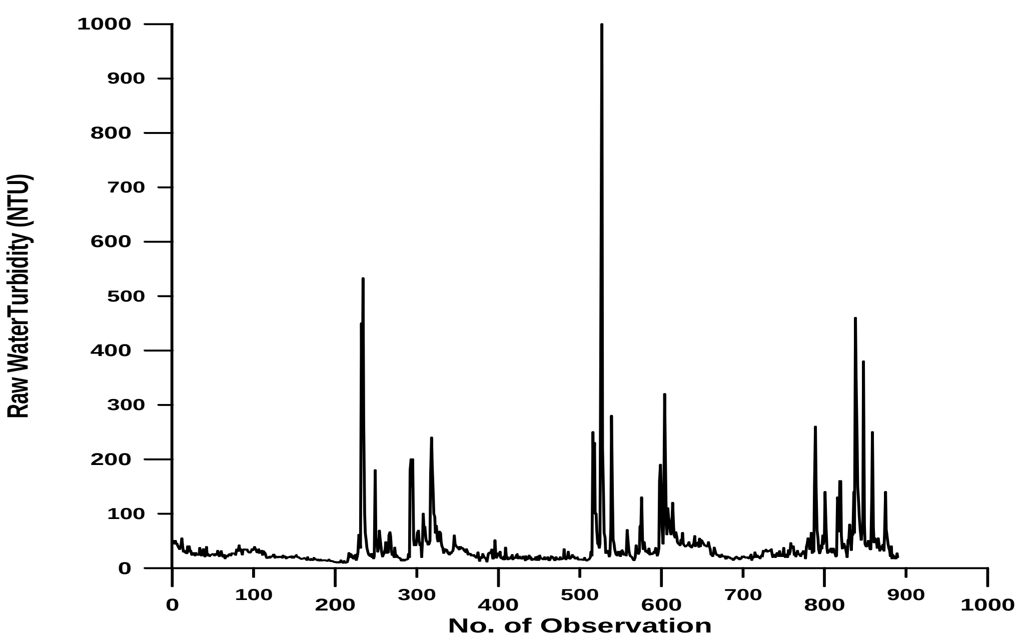

Fig.2. Time Plot for Raw Water Turbidity.

Table 1,
Descriptive Statistics for Raw Water Turbidity.

	N	Min.	Max.	Mean		Std.	Variance	Skewnees		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std.Error	Statistic	Statistic	Statistic	Std.Error	Statistic	Std.Error
Turbidity (Raw)	890	10.00	1000.0	41.368	1.9950	59.518	3542.375	7.846	0.082	92.682	0.164
Valid (list wise)	890										

3.2. Analysis of Clarified Water Turbidity Data

Clarified water turbidity is shown in Figure 3, it is clear that turbidity level increases as the turbidity of raw water increased. From the cumulative frequency curve (Figure 4) there are 290 days out of 895 the turbidity levels were below 10 NTU, this gives a probability success of (290/895 = 0.324) for the clarified water with turbidity levels below or equal to 10 NTU, as recommended by Steel and McGhee (1979). However the probability of compliance with the plant design guarantee of 20 NTU is (771/895=0.861). Table 2 lists the statistical description of the daily turbidity data of the clarified water. The mean value of the turbidity level was found to be 14 NTU with a standard deviation of 6.54 resulting in C_v of 46.5%, this value is somewhat high as confirmed by the range, which is found to be 1.4 to 77 NTU.

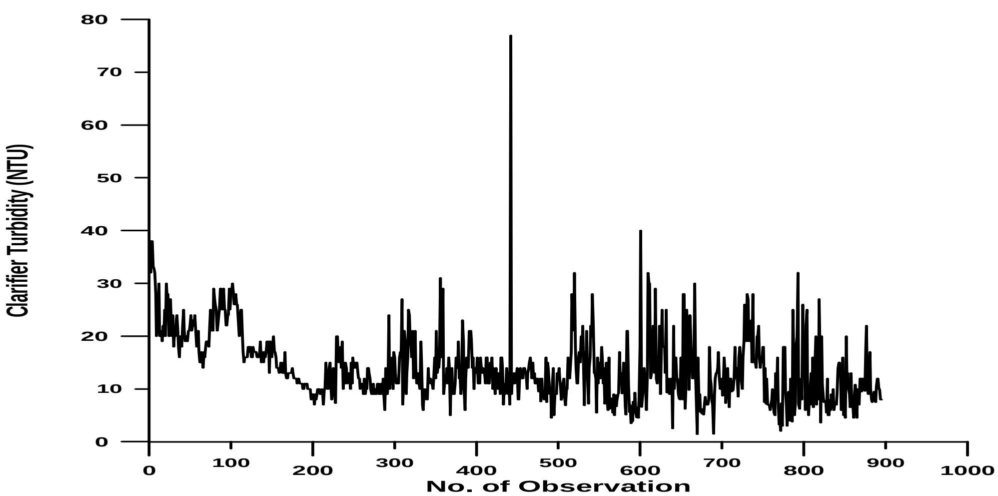

Fig.3. Time Plot for Clarified Water Turbidity.

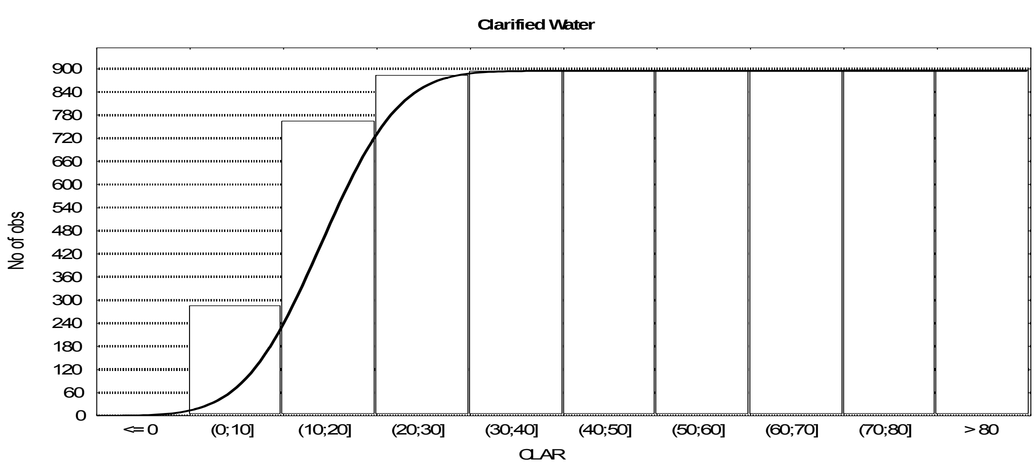

Fig.4. Cumulative Frequencies for Clarified Water Turbidity.

Table 2,
Descriptive Statistics for Clarified Water Turbidity.

	N	Min.	Max.	Mean		Std.	Variance	Skewnees		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std.Error	Statistic	Statistic	Statistic	Std.Error	Statistic	Std.Error
Turbidity (Clarified)	895	1.40	77.00	14.059	0.2188	6.5446	42.832	1.765	0.082	9.781	0.163
Valid (list wise)	895										

3.3. Analysis of Filtered Water Turbidity Data

Time plot for daily filtered water turbidity data is shown in Figure 5. From Figure 6 it can be seen that there is on the average about 100% compliance with the Iraqi drinking water standards, which calls for 5 NTU. The mean value of the turbidity level of filtered water from table 3 was found to be 1.0588 NTU with a standard deviation of 0.56, resulting in C_v of 52.9%. This value is somewhat high as confirmed by the range 0.2-4.5 NTU. This demonstrates that the performance of the filter has not been affected by the high raw water turbidity because the clarifiers have enough ability to treat raw water of high turbidity. According to the United State Environmental Protection Agency (USEPA) standard limits on drinking water which calls for a maximum of 2-day average of 5 NTU maximum turbidity level, Figures 7 and 8 show a time plot and a cumulative frequency curve for the 2-day moving average and table 4 lists the statistics for a 2-day turbidity average. The mean of 2-day moving average is found to be 1.059 NTU with a standard deviation of 0.464. This gives C_v 43.8%, with a range value of 0.3 to 3.68 NTU. It could be stated that there is100% compliance with this standard as far as turbidity quality is concerned and the filters operate perfectly and according to their design limitations.

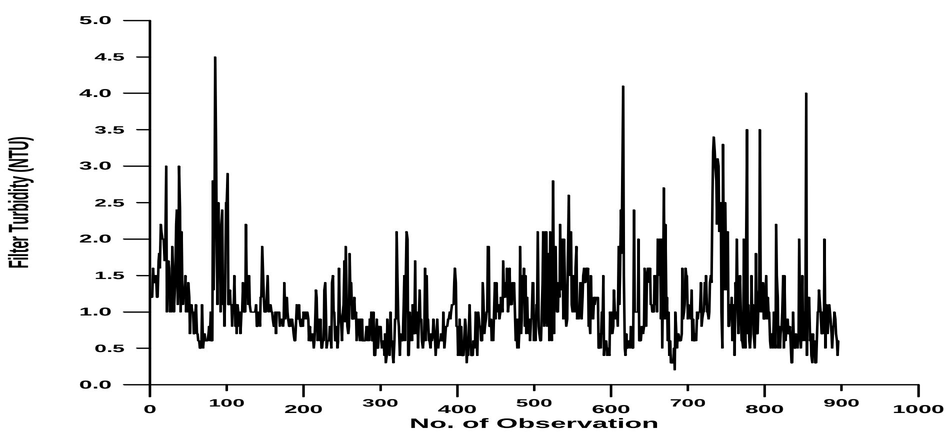

Fig.5. Time Plot for Filtered Water Turbidity.

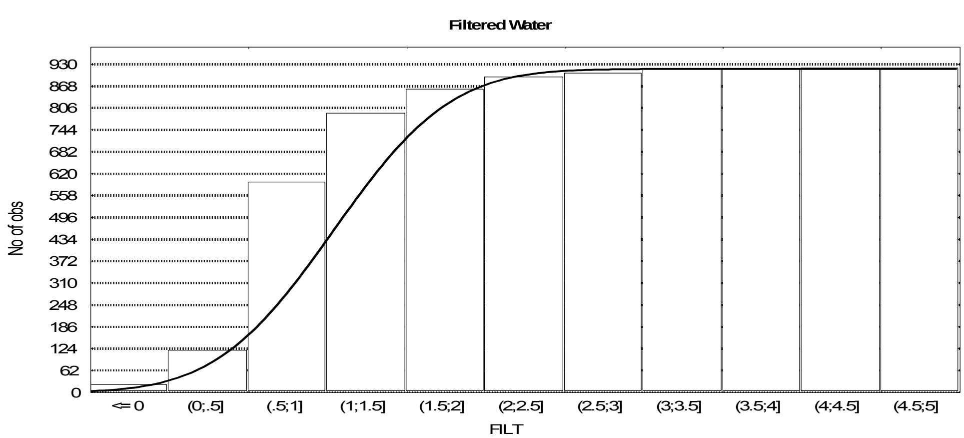

Fig.6. Cumulative Frequencies for Filtered Water Turbidity.

Table 3,
Descriptive Statistics for Filtered Water Turbidity.

	N	Min.	Max.	Mean		Std.	Variance	Skewnees		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std.Error	Statistic	Statistic	Statistic	Std.Error	Statistic	Std.Error
Turbidity (Filt.)	896	0.20	4.50	1.0588	0.0189	0.5671	0.322	1.917	0.082	5.308	0.163
Valid (list wise)	896										

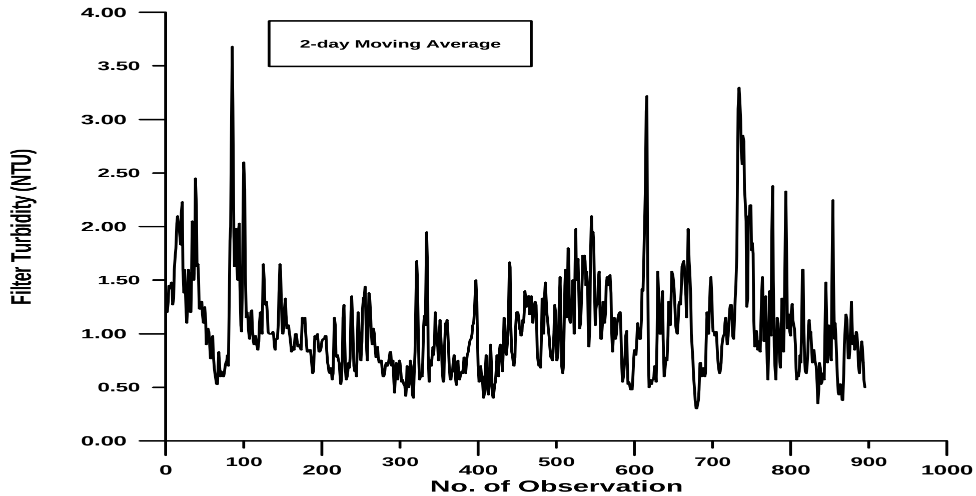

Fig.7. Time Plot of 2-Day Moving Average for Filtered Water Turbidity.

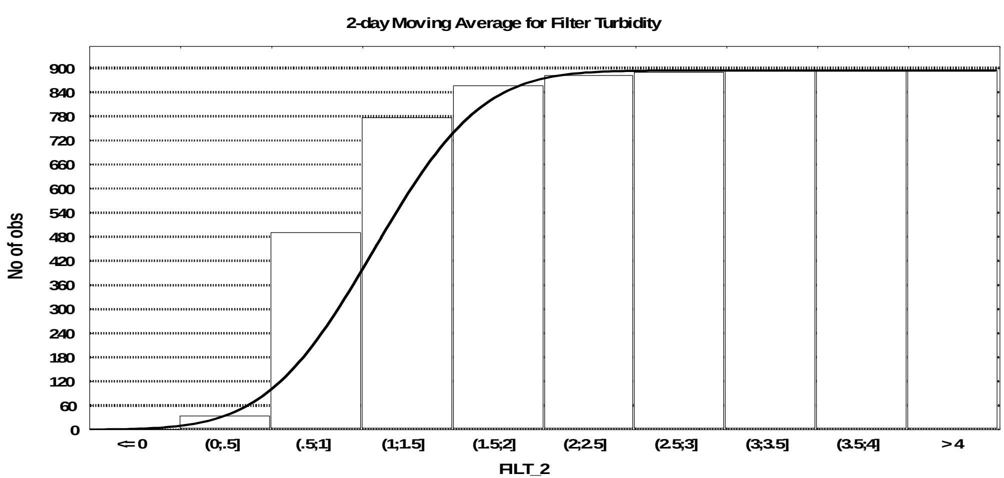

Fig.8. Cumulative Frequency of 2-Day Moving Average for Filtered Water Turbidity.

Table 4,
Descriptive Statistics of 2-day Moving Average for Filtered Water Turbidity.

	N	Min.	Max.	Mean	Std.	Variance	Skewnees		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std.Error	Statistic	Std.Error
(Turb.Filter.,2 ,2)	894	0.30	3.68	1.0592	0.4639	0.215	1.681	9.082	4.416	0.163
Valid (list wise)	894									

According to the USEPA standards the 30-day moving average (turbidity should be less than 1 NTU, Figures 9 and 10 show a time plot and a cumulative frequency curve for the 30-day moving average. From these figures it can be seen that the probability of success for the filters is equal to 0.5023, and the compliance with this standard limit is not more than 50.23%. This means that there is violation average of this standard limit of about 49.77% in the day of the year. Table 5 gives the statistical description of the 30-day moving average of turbidity for the filtered water. The annual average value of the turbidity of the filtered water is about1.054 NTU with a standard deviation of 0.279. This gives C_v of 26.5% which is somewhat low as confirmed by the range, which is found to be 0.6 to 2 NTU.

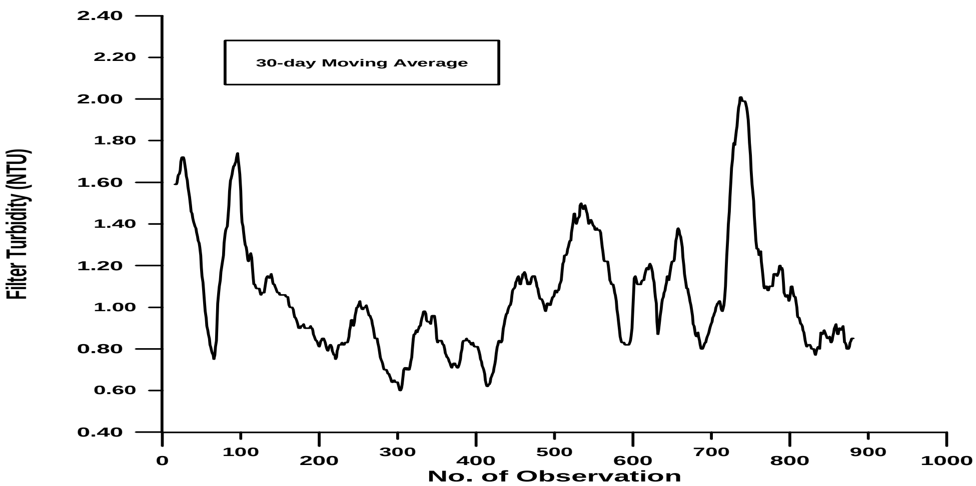

Fig.9. Time Plot of 30-day Moving Average for Filtered Water Turbidity.

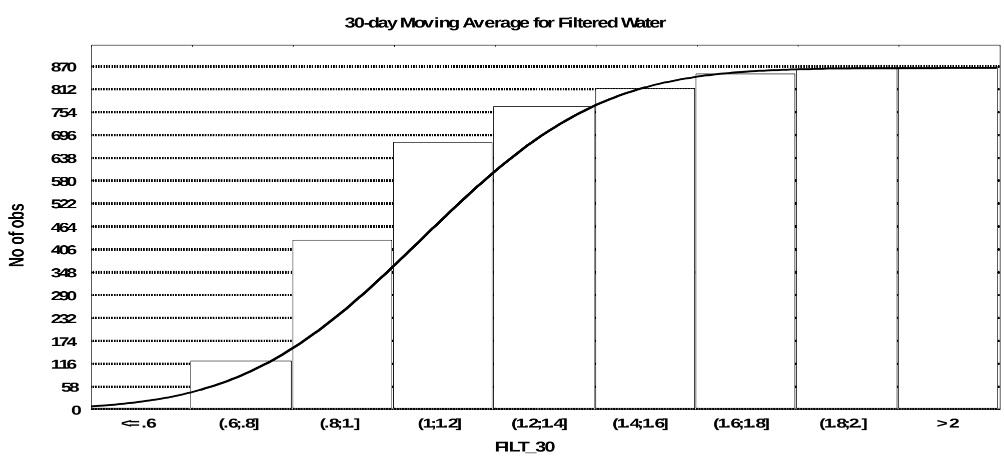

Fig.10. Cumulative Frequency of 30-day Moving Average for Filtered Water Turbidity.

Table 5,
Descriptive Statistics of 30-Day Moving Average for Filtered Water Turbidity.

	N	Min.	Max.	Mean	Std.	Variance	Skewnees		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std.Error	Statistic	Std.Error
(Turb.Filter.,30, 30)	866	0.60	2.01	1.0544	0.2795	0.078	1.099	0.083	1.134	0.166
Valid (list wise)	866									

3.4. Analysis of Supplied Water Turbidity Data

Sometimes turbidity of the water supplied is slightly more than that of the filtered water as shown in Figure 11 because the samples of filtered water were taken from clean filters that were washed and operated ideally. The unwashed filters provide filtered water with greater turbidity than the former ones. The mixing of filtered water coming from washed and unwashed filters before entering the treated water reservoir increase in supplied water turbidity. From the cumulative frequency graph (Figure 12) there is about 98% compliance with the Iraqi drinking water standards. The violation of this standard limit is in November-December and March-April. It was well known that November-December is the period of the rainy season, while March-April is the period of high river flow resulting from snow melting up in the Tigris river catchment area, both periods contribute to turbidity. The mean value of the turbidity level of the supplied water from table 6 is 1.8 NTU with a standard deviation of 0.8 resulting in C_v of 43.9%. This value is somewhat high as compared with the range, which is found to be 0.4 to 9.5 NTU.

Figures 13 and 14 show a time plot and a cumulative frequency curve for the 2-day moving average turbidity. Based on USEPA standard limits of drinking water it can be stated that there is 870/882 = 98.6% compliance with this standard as far as turbidity quality is concerned. This means that the average violation of this standard is of about 1.4%. Table 7 lists the statistics for a 2-day turbidity average of the supplied water. The mean value is found to be 1.829 NTU, where there is 98.6% the compliance with 2-day moving average turbidity level as set by the EPA. The C_v for the 2-day moving average statistic is estimated to be about 26.45%, with an average ranging from 0.45 to 6 NTU, this is rather good according to this standard.

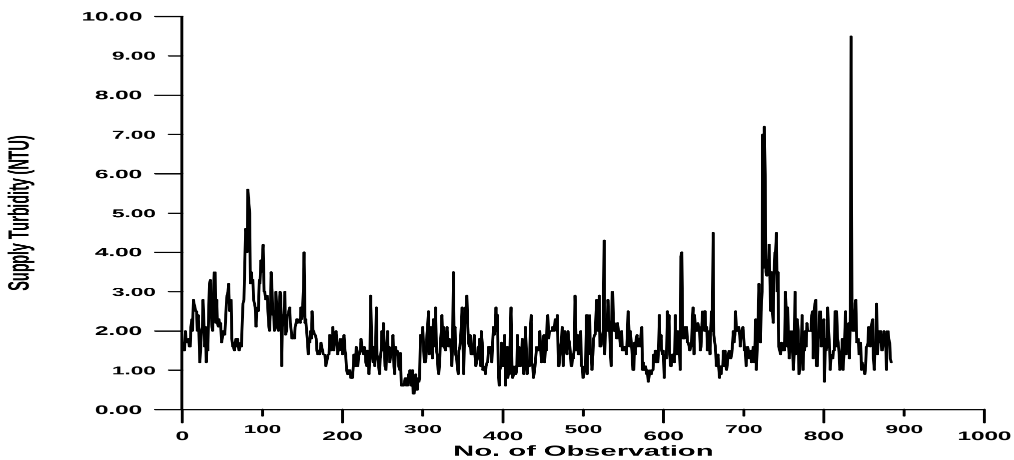

Fig.11. Time Plot for Supplied Water Turbidity.

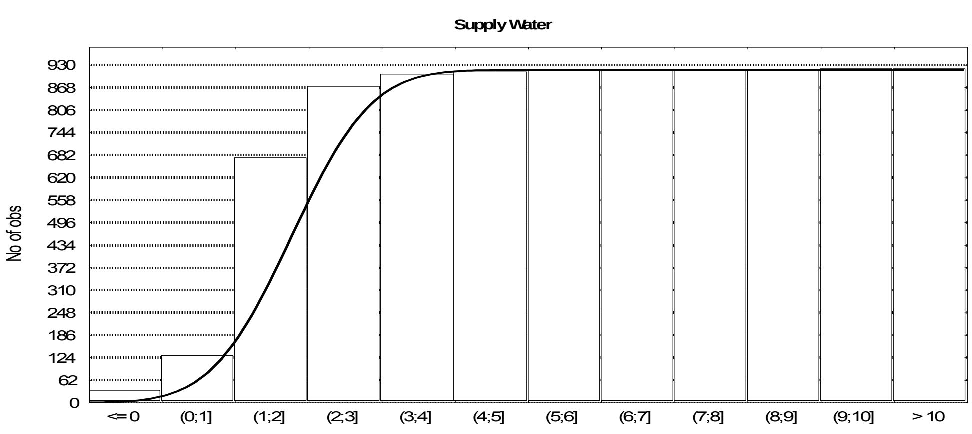

Fig.12. Cumulative Frequencies for Supplied Water Turbidity.

Table 6,
Descriptive Statistics for Supplied Water Turbidity.

	N	Min.	Max.	Mean		Std.	Variance	Skewnees		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std.Error	Statistic	Statistic	Statistic	Std.Error	Statistic	Std.Error
Turbidity (Supply.)	884	0.40	9.50	1.8286	0.0270	0.8032	0.645	2.564	0.082	14.890	0.164
Valid (list wise)	884										

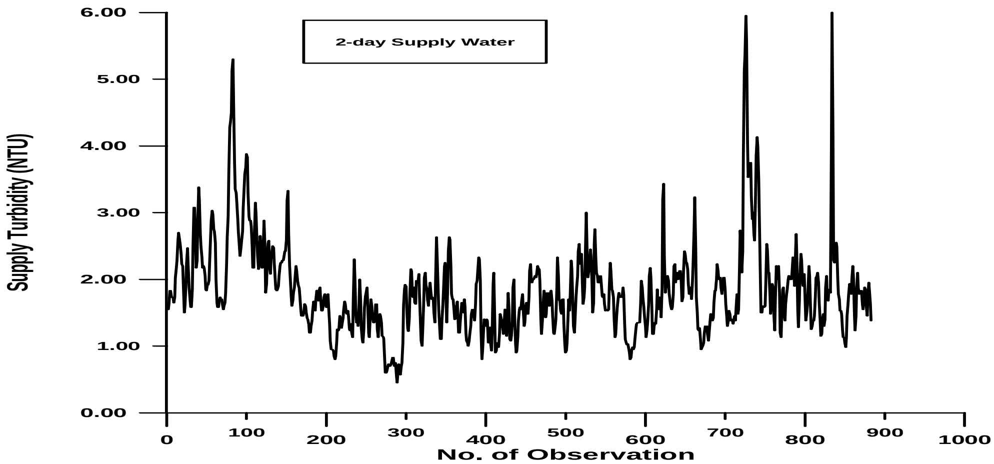

Fig.13. Time Plot of 2-day Moving Average for Supplied Water Turbidity.

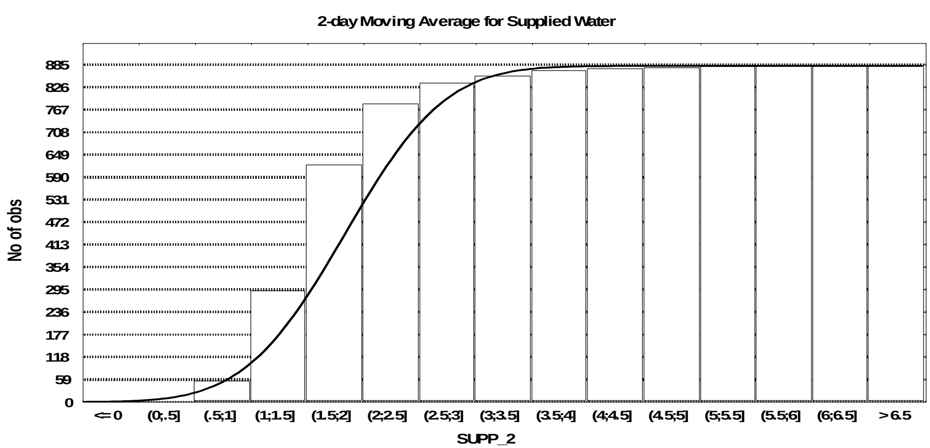

Fig.14. Time Plot of 2-day Moving Average for Supplied Water Turbidity.

Table 7,
Descriptive Statistics of 2-day Moving Average for Supplied Water Turbidity.

	N	Min.	Max.	Mean	Std.	Variance	Skewnees		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std.Error	Statistic	Std.Error
(Turb. Supp..,2,2)	882	0.45	6.00	1.8294	0.7000	0.490	1.883	0.082	6.547	0.164
Valid (list wise)	882									

According to the USEPA standard on drinking water quality, which calls for a monthly average of 1 NTU, it can be seen from Figures 15 and 16 that compliance with this standard limit is not more than 1.4%. This means that there is a violation average of this standard limit reaching 98.6% of the days of year. Table 8 gives the statistical description of 30-day moving average of the turbidity data. From this table, it can be seen that the annual average value of the turbidity is about 1.82 NTU with a standard deviation of 0.483. This gives C_v of 26.45% which is somewhat low as compared with the range value which is 0.81 to 3.42 NTU.

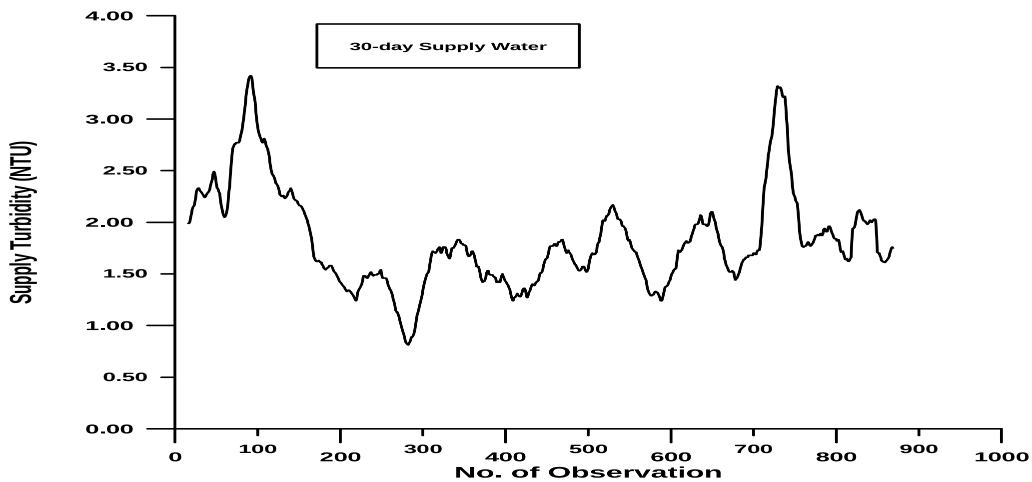

Fig.15. Time Plot of 30-day Moving Average for Supplied Water.

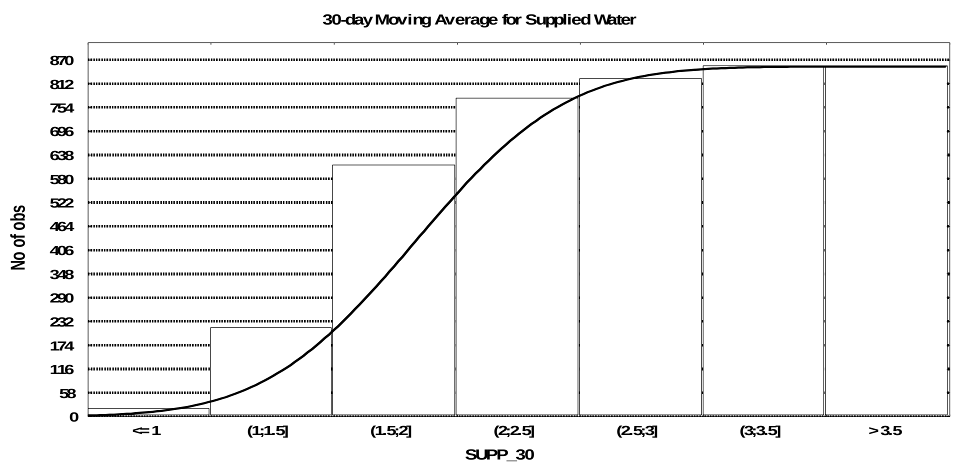

Fig.16. Cumulative Frequency of 30-day Moving Average for Supplied Water Turbidity.

Table 8,
Descriptive Statistics of 30-day Moving Average for Supplied Water Turbidity.

	N	Min.	Max.	Mean	Std.	Variance	Skewnees		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std.Error	Statistic	Std.Error
(Turb.Supp.,30, 30)	854	0.81	3.42	1.8290	0.4839	0.234	1.057	0.084	1.318	0.167
Valid (list wise)	854									

3.5. Correlation Between Parameters

Through the matrix of correlation between parameters (different turbidities) shown in Table 9, the following can be noticed:

1. There is no significant relationship between the turbidity of raw water values with both the turbidity value of the clarified water, filtered water and the supplied water. Their values are 4.8% −1.5% and 2.1% respectively. They are regarded as values even if they do not approach zero.
2. The significant relationship is noted between the turbidity of the supplied water with both the turbidity of the clarified and the filtered water represented by the values of 27.7% and 26.5% receptively.

Table 9,
Correlation Matrix Between The Parameters.

		Turbidity (Raw)	Turbidity (clarifier)	Turbidity (filter)	Turbidity (supply)
Turbidity (Raw)	Pearson correlation	1	0.048	-0.015	0.021
	Sig. (2-tailed)	-	0.15	0.663	0.523
	No.	890	890	890	884
Turbidity (clarifier)	Pearson correlation	0.048	1.0	0.230*	0.277*
	Sig. (2-tailed)	0.15	-	0.000	0.000
	No.	890	895	895	884
Turbidity (filter)	Pearson correlation	-0.015	0.23*	1.0	0.265*
	Sig. (2-tailed)	0.663	0.000	-	0.000
	No.	890	895	896	884
Turbidity (supply)	Pearson correlation	0.021	0.277	0.265*	1.0
	Sig. (2-tailed)	0.523	0.000	0.000	-
	No.	884	884	884	884

* Correlation is significant at the 0.01 level (2-tailed).

4. Conclusions

Daily data for turbidity of raw, clarified, filtered and supplied water of Sherq Dijjla water treatment plant were analysed to the assess the performance of the plant. The conclusions are as follows:

1. There is a wide variation in turbidity levels of the raw water of Tigris River at the intake. Turbidity levels fluctuate between 10 and 1000 NTU with a mean value of 41 NTU and a coefficient of variation of 1.44. High water turbidity levels were encountered during the rainy season covering the time between November, December, January and February of each year this indicates the need for pre-setting tanks.
2. Turbidity values of the clarified water vary between 1.4 and 77 NTU. On 290 days out of 895 days the turbidity level was below 10 NTU. This gave a probability of compliance of 32.4% according to **Steel and McGhee (1979)** and 771 days out of 895 turbidity level was below 20 NTU, where the probability of compliance was 86% according to design guarantee of treatment plant.
3. Turbidity data of the filtered water from Sharq Dijjla water treatment plant was completely in compliance with Iraqi and WHO standards with mean turbidity level of 1.05 NTU. This demonstrates that the performance of the filter has not been affected by the high raw turbidity because the clarifiers work efficiently.
4. For 2-day moving average, turbidity data of the filtered water was completely in compliance with USEPA standard because the values were less than 5 NTU. For 30-day moving average of 1 NTU turbidity value of the filtered water, it was found that filters

operation violated the USEPA standard by 49.77%.

5. Turbidity of the supplied water in the treated water reservoir was greater than the filtered water turbidity for operational reasons.
6. Supplied water turbidity showed about 98% compliance with the Iraqi drinking water standard, with mean value of 1.8 NTU. On the basis of 2-day water turbidity, the turbidity of the supplied water was 98.6% in compliance with the USEPA standard. While for the 30-day moving average turbidity, the supplied water violated USEPA standard by 98.6%.

5. Recommendations for Operation of Treatment Plant

1. Systematic maintenance of the different treatment units.
2. Operating water treatment plant according to the scientific conventional method and operation manual in terms of dosing chemicals, de-sludging and backwashing process is highly recommended.
3. Continuing monitoring different units to get high water quality.

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تقيم اداء محطة ماء شرق دجلة

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قسم هندسة البناء والإنشاءات/ الجامعة التكنولوجية

الخلاصة

إن الهدف من هذه الدراسة هو تقيم اداء محطة تصفية ماء شرق دجلة في ازالة العكورة للفترة من ١-٤-٢٠٠١ ولغاية ٣١-٤-٢٠٠٤ م تم تحليل قياسات العكورة للمياه الخام، المياه المرسبة، المياه المرشحة، والمياه المجهزة. بينت نتائج الدراسة ان هناك اختلاف كبير في درجة العكورة للماء الخام تراوحت بين ١-١٠٠٠ وبمعدل ٤١,٣ وحدة قياس العكورة . قيم العكورة للمياه المرسبة كانت ٤.١-٧ وحدة و بالاعتماد على قيمة عكورة ١٠ و ٢٠ (التصميمية) نرى ان القراءات اعطت نسبة قبول مقدارها ٣٢.٤% و ٨٦% على التوالي اما العكورة للمياه المرشحة فتراوحت بين ٠.٢-٥ وحدة والتي تتوافق كليا مع مواصفة القياسبة العراقية ومواصفة منظمة الصحة العالمية. وبالمقارنة مع مواصفة منظمة حماية البيئة الامريكية وبالاعتماد على تحليل ٢-يوم معدل متغير (٥ وحدة) و ٣٠- يوم معدل متغير (١وحدة) وجد ان الفلاتر تعمل بنسبة قبول قدرها ١٠٠% و٤٥% على التوالي اما المياه المجهزة تراوحت العكورة بين ٠.٤-٩.٥ وحدة وهي اعلى من عكورة المياه الراشحة وهذا نتيجة للخلط الحاصل بين مياه جميع المرشحات كون العكورة للمرشحات الغير مغسولة اكبر من المرشحات المغسولة اضافة للترسبات الطينية داخل الخزان الارضي للمياه المجهزة وبالاعتماد على المواصفات القياسية العراقية، ٢-يوم معدل متحرك، و ٣٠- يوم معدل متحرك فأن المياه المجهزة كانت ٩٨%، ٩٨.٦%، ٩٨.٦% ضمن الحدود المسموح بها على التوالي .