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Impact of Tigris River Pollution on the Performance of Water Treatment Plants Efficiencies in Baghdad City

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Abstract

The determination of river pollution impact on the performance of water treatment plants is achieved by two main objectives. The first is to study raw and treated water qualities and comparing them with standards and the second is to evaluate the treatment plants efficiency. The analyzed data were those water quality parameters in relation to physical, chemical and bacteriological characteristics for river water and produced water by seven water treatment plants located on Tigris River passing through Baghdad City.

The results of this study indicated that all raw water characteristic are within the surface water standards established by Iraqi and USA criteria except Bacterial Counts.

Tigris River water is of good quality to be treated at the intake of KWTP and tends to be of less quality as it flows to south of city, where it is highly polluted at intake of RWTP.

The analysis of treated water quality parameters supplied by all water treatment plants indicated that most of these characteristics are within the Iraqi criteria and WHO guide lines except for the produced in RWTP.

RWTP exceeded the water quality standards which recommended by WHO particularly Bacterial Counts and Turbidity.

The analysis showed that all water treatment plants have little effect on the in removal of the most of inorganic chemicals pollutants, the increasing Level of Sulfate, Hardness, and Total Dissolved Solid in treated water could be related to the absence of any chemical treatment units in the conventional Baghdad water treatment works, and to the increasing of the concentration of these variables in river water.

The statistical analysis had indicated that the correlation coefficient between Turbidity and Total Coliform Bacteria in river water for KWTP, EWTP and KRWTP were good, and begin to increase at other water treatment plants reaching RWTP because the water quality of the river is deteriorated as the river flow downstream in Baghdad city.

Introduction

Water Quality of Tigris River at Baghdad City

The present average water demand in Baghdad is about 2900 million liters per day; the city is being supplied with water from Tigris River after conventional treatment (sedimentation, coagulation, filtration and chlorination) by water treatment plants. These plants are located on the banks of the Tigris River along a distance of about (50-60) km, the quality of the Tigris water within the city area is being changed mainly due to disposal large quantities of wastewater from different sources and made it unsuitable for drinking purposes from view point of public health.

Mutlak **[1]** performed a surveying along Tigris River passing therough Baghdad city during the year 1977 and 1978, he evaluated the suitability of the river for different purposes, he concluded that bacterial counts of Tigris River exceeded the standard recommended for various purposes.

Al-Masri **[2]** evaluated some pollutants concentration in Tigris River through Baghdad city, the results have indicated that concentrations of total hardness, Sulfate

and Calcium exceeded the permissible limits established by the GDHE.

Abu-Hammdeh **[3]** had studied Tigris water quality and treated water at the water treatment plants in Baghdad city. His study aimed to find out the suitability of Tigris water quality for the use as a source for drinking water, the study indicate that Tigris water was classified as a good and suitable source for drinking water in KWTP and EWTP intakes, and it was classified as a polluted and heavy polluted source in the other intakes. Thus, its unsuitable to de used as a source for drinking water by using conventional water treatment plant and advanced treatment are required.

Nawar **[4]** had studied the variation of salty ions in Tigris River as it pass through Baghdad city during period 1990-1999. the results indicated that the maximum concentration of total hardness and Sulfate in Tigris River are above the allowable limits for (WHO, 1984) drinking water standards.

The area of study is Baghdad city, in which seven water treatment plants located on Tigris River are to be studied as follow (Al-Karkh, East Dijlah, Karama, Wathba, Qadisiya, Doura and Al-Rasheed) see **Fig. 1**.

The Water Quality Parameters selected in this study are Color, Temperature, Turbidity, Total Solids, Suspended Solids, Total Dissolved Solid, and Total Hardness as $CaCo_3$, Alkalinity as $CaCO_3$, PH, Calcium, Magnesium, Chloride, Sulfate, Nitrate, Nitrite, Aluminum, Iron, Fluoride, Total Coliform Bacteria and Fecal Coliform Bacteria.

The analyzed data were these water quality data for raw water (River water near intake) and those of the produced water by the plants during the year 2004.

Raw Water Quality Criteria

The Iraqi Directorate General of Human Environment set in 1967 **[3]** the limits of regulation of rivers and public waters from the pollution No.25, these criteria have been compared with those of U.S.A. set by the Federal Water Pollution Control Administration **[5] Table 1**.

Drinking Water Quality Standards

Drinking Water Quality Standards are used as measures to ensure high quality of drinking water supplies World Health Organization WHO **[5]** set down guidelines for drinking water which are intended to supersede both the European and International Standards, this standard are shown in **Table 1**.

Objectives

The main objective of this study are the following:-

1. Evaluate raw and produced water quality among comparison with raw and drinking water standard respectively.
2. Obtain some useful regression equations for Total Coliform Bacteria production from turbidity which is easily obtained.

Data Collection:-

Data of this study were collected from the routine chemical and bacteriological water analysis data carried out by the laboratory of quality control of Baghdad Water Supply Administration for the year 2004.

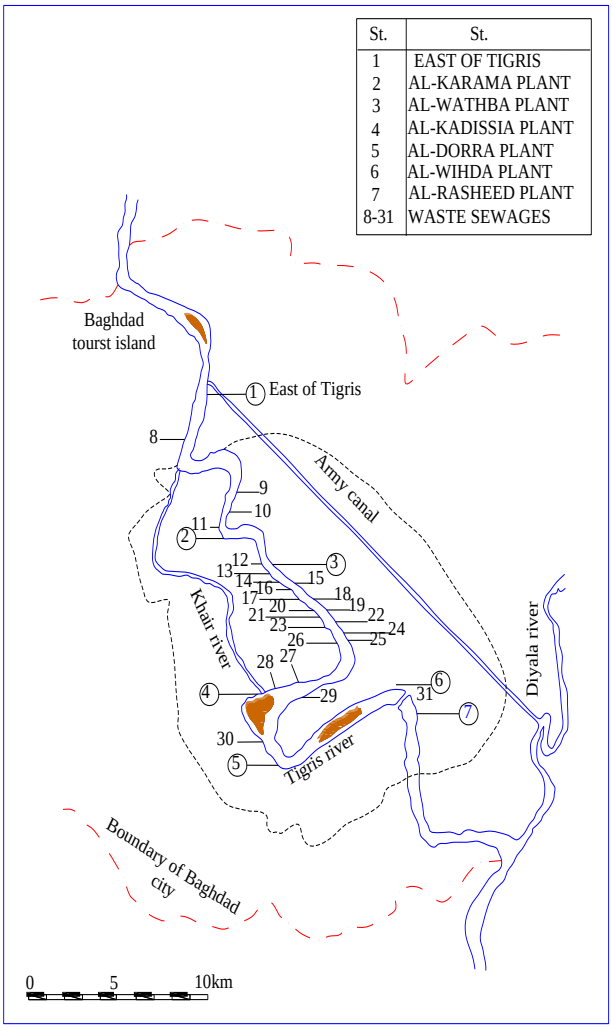

Fig. 1: Location of Water Treatment Plants and Waste Sewages along Tigris River passing through Baghdad

Table 1 Raw and Treated Water Quality Standards [3,14and15]

Constituent or Characteristic	Units	Raw Water		Treated Water	
		Iraqi-Criteria	U.S.A. Criteria	Iraqi Stand.	WHO GL 1984
Physical					
Color	TCU	Normal		10	15
Temperature	C				
Turbidity	NTU			<10	5
Inorganic chemical					
Total Solid TS	Mg/L				
Suspended Solid TSS	Mg/L				
Total Dissolved Solid TDS	Mg/L			1500	1000
Total Hardness TH	Mg/L		Narrative	500	500
Alkalinity	Mg/L		Narrative	170-200	
Hydrogen-ion-Cons. PH	PH value	6.5-8.5	6.5-8.5	6.8-8.5	6.5-8.5
Calcium Ca	Mg/L			200	
Magnesium Mg	Mg/L			50-150	
Chlorid CL	Mg/L	200+	250	200-600	250
Sulfate SO4	Mg/L	200+	250	200-400	400
Nitrate NO3	Mg/L	15	10	20	10
Nitrite NO2	Mg/L			0.1	
Aluminium Al	Mg/L	0.1		0.2	0.2
Iron Fe	Mg/L	0.3	0.3	0.5	0.3
Fluoride F	Mg/L	0.02+	Narrative	1.0	1.5
Bacteriological					
Coliform bacteria TC	MPN/100ml		10000	0-5	
Fecal Coliform FC	=		2000	<1	

RESULTS AND DISCUSSION

Raw Water Quality

The results clearly indicate that most raw water characteristics (physical and chemical variables) are within the permissible limits established by Iraqi Directorate General of Human Environment, Ministry of Health, GDHE, and Federal Water Pollution Control Administration.

Physical properties of Raw Water:

The Color of the raw water is less than 5 CU indicates the non-necessity the color reduction process in the treatment plant operation. Average monthly reading of raw water Temperature is ranging from 12C-32C; temperature is the major environmental factor that affects the survival of bacteria in water. The temperature increase leads to kill most of the Bacteria especially in summer time, while its survival chances increase in low temperature, Evison **[6]**
The raw water turbidity had shown a high variation during winter, and low variation in summer, it is ranging from 20NTU to 314NTU, Turbidity is caused by the presence of suspended matter such as clay, silt, organic matter, and inorganic matter, it can carry nutrient to support microbial growth, clay and suspended matter can form a case to protect bacteria from the effect of sunlight and salinity, Lechevallier **[7]**

Inorganic Chemical

The monthly analysis of the inorganic chemical in raw water show that all the analyzed parameter were within permissible limits except Sulfate, the maximum concentration of Sulfate was 309 ppm in QWTP while the minimum Sulfate was 69ppm in KWTP (**Table 2** to **Table 8**). The values recorded near intake of KWTP were the lowest values because KWTP is located upstream of AL-Thrathar Tigris Canal Junction, For this reason the values of all parameter had increased at all water treatment plants which is downstream AL-Thrathar Tigris Canal Junction.

Bacterial Analysis:

The behaviors of Total Coliform (TC) and Fecal Coliform (FC) bacteria in river water passing through Baghdad city have been shown in **Fig. 2** to **Fig. 3**. It could be noticed from both figures that there is a big differences between KWTP and RWTP in bacterial densities, the first station is located in the northern part of the city (the inlet of the river) while the second station RWTP is located in the southern part of the city (the outlet of the river). Maximum and minimum monthly average for TC at KWTP 300 MPN/100ml and 100 MPN/100ml respectively while at RWTP they were 130000 MPN/100ml and 2000 MPN/100ml.
Maximum and minimum monthly average for FC at KWTP 130and 80 respectively while at RWTP they were 110000 MPN/100ml and 1800 MPN/100ml,

bacterial counts recorded at RWTP were 330 times for TC higher that recorded at KWTP.

Presence of Total Coliform bacteria in surface waters indicates any one or combination of three sources: wastes of man, farm animals, or soil erosion, Hammer **[8]**

TC and FC counts were more than the permissible levels in most months for all stations, so it is concluded there is a tendency of increasing bacterial counts in the river through Baghdad city, this increase is due to the effect of wastewater disposal to the river or the river water carried extra counts of bacteria with turbidity by the effect of runoff and intermittent rainfall occurring up stream.

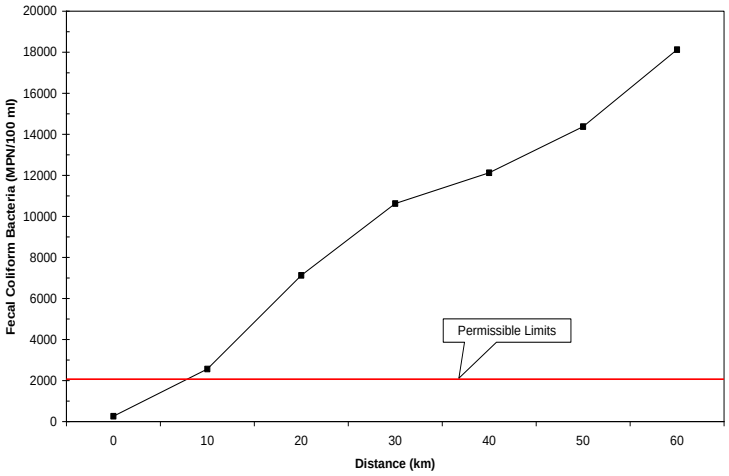

Fig. 2: Annual average of Total Coliform Bacteria versus distance at Baghdad City for year 2004.

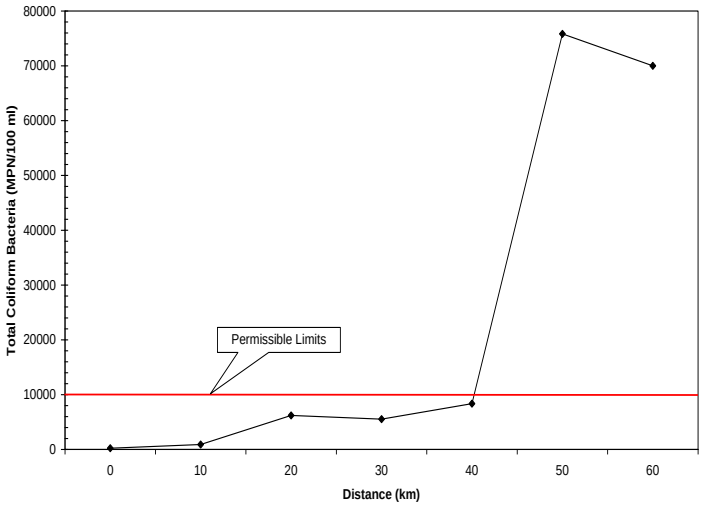

Fig. 3: Annual average of Fecal Coliform Bacteria versus distance at Baghdad City for year 2004.

Treated Water Quality

The analysis of treated water quality characterized supplied by seven water treatment plants are summarized in (**Table 2** to **Table 8**), most of these characteristic were within Iraqi standards and WHO guidelines, the results are briefly described below:

Physical Properties of Treated Water

The treated water color was 5CU for all stations. The treated water has a Temperature ranged from 12C to 32C with an average 22C.Temperature test dose not carry any significance because there is no treatment which can be imparted to control the temperature in any water supply project. The most desirable temperature for water supply is between 10°C to 15°C. Temperatures above 25°C are undesirable, Gurcharan & Jagdish**[8]**

The average monthly Turbidity for treated water in Baghdad was less than 5NTU, except for RWTP; the average Turbidity level in RWTP was 20NTU.

The turbidity of supply water is mostly used as a measure of water quality in water treatment plants, the desirable level less or equal to 1NTU was recommended by WHO and up to 5NTU will indicate inadequate efficiency of treatment plant and possibly correlate with increased total Coliform bacteria, McCay and Olson **[9]**

Inorganic Chemical

The monthly analysis of inorganic chemicals in treated water show that all the analyzed parameters were within permissible limits except Sulfate. The average monthly of Sulfate concentration of produced water was greater than the favourable level of 200mg/L (Iraqi Standard) In KRWTP (206.5mg/L), WWTP (209mg/L), QWTP (226.5mg/L), DWTP (228.5mg/L) and RWTP (200.5mg/L),(**Table 2** to **Table 8**).

The majority of Sulfates are soluble in water, Aluminium Sulfate, which is extensively used as flocculant's for water treatment may add 20-50 mg used as Sulfate per litre to the final water, since Sulfate is not removed from water by conventional water treatment method. High Sulfate concentration in water may contribute to the corrosion of metals in the distribution system, particularly in water having low alkalinity, Hammer **[10]**

The increasing level of Sulfate, Hardness, and Total Dissolved Solid in treated water could be related to the absence of any chemical treatment units in Baghdad water treatment works and increasing the concentration of these variables in river water.

Bacterial Analysis

Bacterial counts of all station for both TC and FC when compared with the drinking permissible levels were indicated that TC and FC bacteria counts at all station were below the permissible levels except in DWTP and RWTP (**Table 2** to **Table 8**).

The selection of adequate raw water intake location has been regarded as a major or almost essential "first line of defence" against the transmission of water-born diseases, Twort **[11]**, RWTP has the highest TC and FC counts are due to direct effect of wastewater discharged from untreated Karada sewage 500m upstream the RWTP intake.

Table 2 Max., Min. and Average Monthly Raw and Treated Water Quality Parameters for Al-Karkh (KWTP) Water Treatment Plant (2004)

Constituent	Raw Water			Treated Water		
	Min.	Max.	Ave.	Min.	Max.	Ave.
Physical Properties						
Color	<5	<5	<5	<5	<5	<5
Temperature	17	27	22	16	27	21.5
Turbidity	47.5	345	196.25	0.9	5.1	3.0
Inorganic chemical						
TS	266	380	323	264	393	328.5
TSS	45	260	152.5	17	26	21.5
TDS	251.52	378.88	315.2	241.92	360.96	301.44
T.H	216	562	389	216	273	244.5
Alkalinity	118	144	131	116	142	129
PH	7.7	7.9	7.8	7.4	7.6	7.5
Ca	52	60	58	52	60	56
Mg	20	29	24.5	20	29	24.5
CL	26	47	36.5	25	48	36.5
SO4	69	140	104.5	70	140	105
NO3+NO2	-	-	-	-	-	-
Al	0.01	0.01	0.01	0.09	0.15	0.12
Fe	0.49	3.68	2.085	0.02	0.06	0.04
F	0.09	0.14	0.115	0.09	0.14	0.115
Bacterial Analysis						
TC	100	300	200	-	-	-
FC	80	130	105	-	-	-

Table 3 Max., Min. and Average Monthly Raw and Treated Water Quality Parameters for East of Dijlah (EWTP) Water Treatment Plant (2004)

Constituent	Raw Water			Treated Water		
	Min.	Max.	Ave.	Min.	Max.	Ave.
Physical Properties						
Color	<5	<5	<5	<5	<5	<5
Temperature	13	28		12	28	20
Turbidity	118	28	73	1.0	3.0	2.0
Inorganic chemical						
TS	270	487	378.5	290	475	282.5
TSS	42	261	151.5	16	26	21
TDS	332.8	570.3	451.5	326.4	556.2	441.3
T.H	232	710	471	234	296	265
Alkalinity	139	147	143	130	141	135.5
PH	7.8	8.1	7.95	7.4	7.7	7.55
Ca	60	75	67.5	58	72	65
Mg	20	30	25	20	29	24.5
CL	42	75	58.5	39	69	54
SO_4	139	210	174.5	129	194	161.5
NO_3+NO_2	0.223	0.526	0.375	0.12	0.44	0.28
Al	0.01	0.02	0.015	0.08	0.17	0.12
Fe	0.7	1.9	1.3	0.03	0.07	0.05
F	0.1	0.22	0.16	0.07	0.10	0.08
Bacterial Analysis						
TC	1700	3000	2350	-	-	-
FC	1400	300	850	-	-	-

Table 4 Max., Min. and Average Monthly Raw and Treated Water Quality Parameters for Al-Karama (KRWTP) Water Treatment Plant (2004)

Constituent	Raw Water			Treated Water		
	Min.	Max.	Ave.	Min.	Max.	Ave.
Physical Properties						
Color	<5	<5	<5	<5	<5	<5
Temperature	11	30	20.5	12	30	21
Turbidity	26.5	109	67.75	2.4	5.9	4.15
Inorganic chemical						
TS	304	538	421	328	536	432
TSS	61	203	132	18	29	23.5
TDS	416.64	641.92	529.28	413.44	632.32	522.88
T.H	268	895	581.5	258	373	315.5
Alkalinity	127	158	142.5	125	156	140.5
PH	7.0	8.1	7.55	7.5	7.9	7.7
Ca	64	103	83.5	62	101	81.5
Mg	20	33	26.5	20	32	26
CL	55	86	70.5	54	86	70
SO_4	157	260	208.5	155	258	206.5
NO_3+NO_2	0.822	1.16	0.991	1.1	1.49	1.295
Al	0.01	0.13	0.07	0.06	0.18	0.12
Fe	0.21	3.7	1.96	0.01	0.45	0.23
F	0.14	0.25	0.195	0.08	0.19	0.135
Bacterial Analysis						
TC	1000	13000	7000	-	-	-
FC	800	11000	5900	-	-	-

Table **5** Max., Min. and Average Monthly Raw and Treated Water Quality Parameters for Al-Wathba (WWTP) Water Treatment Plant (2004)

Constituent	Raw Water			Treated Water		
	Min.	Max.	Ave.	Min.	Max.	Ave.
Physical Properties						
Color	<5	<5	<5	<5	<5	<5
Temperature	12	30	21	12	30	21
Turbidity	20	118	69	1.0	2.7	1.85
Inorganic chemical						
TS	371	537	454	376	539	457.5
TSS	44	392	218	18	33	25.5
TDS	372.48	572.16	472.32	376.5	574.5	475.84
T.H	252	871	561.5	255	396	325.5
Alkalinity	131	170	150.5	123	163	143.0
PH	7.7	8.1	7.9	7.1	7.8	7.45
Ca	67	111	89	67	111	89
Mg	22	35	28.5	22	35	28.5
CL	44	83	63.5	45	84	64.5
SO_4	155	275	215	142	276	209
NO_3+NO_2	0.44	3.7	2.07	0.45	3.4	1. 925
Al	0.01	0.10	0.01	0.04	0.17	0.105
Fe	0.02	3.8	1.91	0.01	0.10	0.055
F	0.09	0.24	0.165	0.08	0.11	0.095
Bacterial Analysis						
TC	1000	13000	7000	-	-	-
FC	800	11000	5900	-	-	-

Table 6 Max., Min. and Average Monthly Raw and Treated Water Quality Parameters for Al-Qadisiya (QWTP) Water Treatment Plant (2004)

Constituent	Raw Water			Treated Water		
	Min.	Max.	Ave.	Min.	Max.	Ave.
Physical Properties						
Color	<5	<5	<5	<5	<5	<5
Temperature	13	30	21.5	13	31	22
Turbidity	39	161	94	1.7	3.55	2.62
Inorganic chemical						
TS	391	635	513	401	637	519
TSS	49	360	204.5	15	31	23
TDS	386.56	663.04	524.8	401.9	664.96	533.44
T.H	259	873	566	267	387	327
Alkalinity	132	167	149.5	124	161	142.5
PH	7.9	8.1	8	7.5	7.8	7.65
Ca	64	109	86.5	67	109	88
Mg	26	33	29.5	25	33	29
Cl	47	93	70	49	93	71
SO_4	141	309	225	146	307	226.5
NO_3+NO_2	0.562	0.187	0.375	0.541	0.612	0.577
Al	0.01	0.03	0.02	0.08	0.20	0.14
Fe	0.34	2.9	1.62	0.04	0.15	0.09
F	0.08	0.16	0.12	0.08	0.16	0.12
Bacterial Analysis						
TC	2300	22000	12150	-	-	-
FC	1500	16000	8750	-	-	-

Table 7 Max., Min. and Average Monthly Raw and Treated Water Quality Parameters for Al-Doura (DWTP) Water Treatment Plant (2004)

Constituent	Raw Water			Treated Water		
	Min.	Max.	Ave.	Min.	Max.	Ave.
Physical Properties						
Color	<5	<5	<5	<5	<5	<5
Temperature	11	29	20	12	27	19.5
Turbidity	43	293	168	0.8	2.0	1.4
Inorganic chemical						
TS	407	587	497	412	585	498.5
TSS	47	384	215.5	15	28	21.5
TDS	368.64	638.08	503.36	360.32	638.72	499.52
T.H	262	869	565.5	263	391	327
Alkalinity	134	168	151	125	160	142.5
PH	7.5	8.2	7.85	7.2	7.7	7.45
Ca	66	113	89.5	67	113	90
Mg	24	32	28	23	36	29.5
CL	51	88	69.5	51	88	69.5
SO_4	168	292	230	170	287	228.5
NO_3+NO_2	0.443	0.447	0.445	0.001	0.691	0.345
Al	0.01	0.03	0.02	0.08	0.2	0.14
Fe	0.15	3.4	1.77	0.01	0.54	0.275
F	0.08	0.15	0.11	0.08	0.13	0.10
Bacterial Analysis						
TC	10000	95000	52500	-	-	-
FC	9000	80000	44500	-	-	-

Table 8 Max., Min. and Average Monthly Raw and Treated Water Quality Parameters for Al-Rasheed (RWTP) Water Treatment Plant (2004)

Constituent	Raw Water			Treated Water		
	Min.	Max.	Ave.	Min.	Max.	Ave.
Physical Properties						
Color	<5	<5	<5	<5	<5	<5
Temperature	14	32	23	14	32	23
Turbidity	34	250	142	4	36	206+
Inorganic chemical						
TS	365	558	461.5	400	560	480
TSS	51	540	295.5	18	31	24.5
TDS	380.16	629.76	504.96	390.4	645.12	517.76
T.H	250	965	607.5	265	384	324.5
Alkalinity	137	162	149.5	129	155	142.0
PH	7.6	8.2	7.9	7.4	7.8	7.6
Ca	62	105	83.5	63	109	86
Mg	24	33	28.5	23	34	28.5
CL	44	88	66	46	89	67.5
SO_4	148	258	203	132	269	200.5
NO_3+NO_2	0.7	0.7	0.7	0.001	1.0	0.5
Al	0.01	0.01	0.01	0.01	0.24	0.17
Fe	0.1	6.0	3.05	0.01	0.54	0.032
F	0.11	0.26	0.18	0.06	0.21	0.135
Bacterial Analysis						
TC	2000	130000	66000	-	-	-
FC	2000	110000	56000	-	-	-

Evaluation of Water Treatment Plant Efficiency

The quality of treated water is generally associated with the efficiency of water treatment plants when treated water contains salts or turbidity or organisms, more than recommended level this may inadequate treatment.

The results of study showed that all water treatment plants has little effect on most of the water constituents. TDS is a measure of all solids impurities other than suspended this including salts of Ca, Mg, SO4, CL, CO3, HCO3, the percent removal of TDS in all water treatment plants were less than 4% except in WWTP and QWTP the percent removal of TDS less than zero(in minus).

The percent removal of Hardness was ranged between (37.1-47.2) and Alkalinity was ranged between (1.4_5.6) and the percentage removal of SO4 was ranged between (0.95-7.45) and less than zero in KWTP and QWTP and DWTP, while the percentage removal of CL was ranged between (0.7-7.69) and zero in KWTP and DWTP while less than zero in WWTP and QWTP and RWTP (**Table 9**).

Total Dissolved Solids is homogeneously dispersed in the liquid, dissolved solids can be simple atoms (as small as 0.2 μm) or complex molecular compounds up to about 1mm in size, dissolved solids are present in the a liquid in one phase and cannot be removed from the water without accomplishing a phase change such as distillation, precipitation, adsorption, or extraction, Mackenzie & David **[9]**

Although the percentage monthly of NO3, AL, F, Fe concentration were low in raw water and treated water but the percent removal of these parameters were not high except Iron (**Table 9**). It is obvious that all water treatment plants were not efficient in removing pollutant especially inorganic chemical from raw water for many reasons:

1. The deficit in performance of water treatment plants depend on other factors in additional to source quality like design criteria, management of treated works, quantities of treated water, plant operations, and schedule maintains work.
2. The load on the water treatment plants was reduced their efficiency, the population of Baghdad increase so must water production increased but capacity of water treatment plants remains the same.
3. Conventional method for treated raw water was not enough to remove all inorganic chemicals; water treatment plants has needed to additional unit (chemical treatment unit) in order to remove those parameters.
4. Tigris River water tends to be less quality as it flows to south of city, where it is highly polluted.

Table 9 Evaluation of Water Treatment Plants Efficiency

Constituent	Percent Removal						
	Al-Karkh	East Dijlah	Al-Karama	Al-Wathba	Al-Qadisiya	Al-Doura	Al-Rasheed
Turbidity	98.47	97.26	97.32	93.87	97.21	99.17	85.92
TS	-1.702	25.363	-2.612	-0.770	-1.169	-0.30	-4.008
TSS	85.573	86.138	82.196	88.3	88.753	90.023	91.70
TDS	4.365	2.267	1.209	-0.745	-1.646	0.763	-2.535
T.H	37.146	47.211	45.74	42.06	42.226	42.175	46.584
Alkalinity	1.526	3.244	1.4	4.983	4.68	5.6	5.0
Ca	3.448	3.704	2.395	zero	1.734	-0.558	-2.99
Mg	zero	zero	1.886	zero	1.69	-5.357	zero
CL	zero	7.692	0.7	-1.574	1.428	zero	-2.27
SO_4	-0.40	7.449	0.95	2.790	-0.66	0.652	1.2
NO_3	-	0.253	0.402	7.0	-0.53	22.47	28.97
Al	-51.16	-7.0	-0.71*100	-9.5	-6*100	-6*100	-16*100
Fe	98	96.15	88.23	95.02	94.44	98.8	98.9
F	zero	50	30.76	42.42	zero	10.0	25.0

STATISTICAL ANALYSIS

In this study the Statistical Analysis which carried out was the correlation and regression analysis, they are commonly used to interpret the relationships between two or more variables and to develop statistical models. The relationship that exits between Turbidity (dependent variable) associated with a given value of the (independent variable) Total Coliform Bacteria for raw water at intake of all water treatment plants.

Regression and correlation analysis for these data were conducted several models were analyzed using computer software (Excel, SPSS) to obtain best coefficient of correlations. The exponential model used for single regression analysis was:-

Exponential model $$y = a + b * e^{x/c}$$

Where:-

y: - dependent variable.

x: - independent variable.

a, ***b***, ***c***: - regression coefficients

The correlation coefficients between Turbidity and Total Coliform Bacteria in river water for KWTP, EWTP and KRWTP were good 0.73, 0.76 and 0.76 respectively but the results reflected high correlation coefficient for other water treatment plants (**Table 10** and **Fig. 5** to **Fig. 11**), because the source of bacteria at north of Baghdad was probably the intermittent rainfall and storm water runoff, surface water generally contain suspended and colloidal solids from land erosion, decaying vegetation, and micro-organisms, Hammer **[8]**. However the additional bacteria at other water treatment plants were affected by the bacteriological pollutants, which increased by waste water discharged directly to the river or by storm networks systems, which are combined illegally to the sewerage systems or by the overflow from some sewerage pump stations.

Table 10 the coefficients of the regression function and the correlation coefficients for all Water Treatment Plants.

tation	r^2	Adj. r^2	a	b	c	Equation
KWTP	0.73	0.54	81.47	$1.55x10^{-4}$	20.95	Exponential
EWTP	0.76	0.40	43.38	$3.42x10^{-10}$	53.69	Exponential
KRWTP	0.76	0.40	47.15	$7.93x10^{-5}$	829.64	Exponential
WWTP	0.92	0.81	30.17	0.48	2507.78	Exponential
QWTP	0.95	0.87	47.06	$86x10^{-5}$	1996.78	Exponential
DWTP	0.98	0.97	50.14	$2.19x10^{-5}$	5855.37	Exponential
RWTP	0.95	0.93	8.92	31.75	62647.13	Exponential

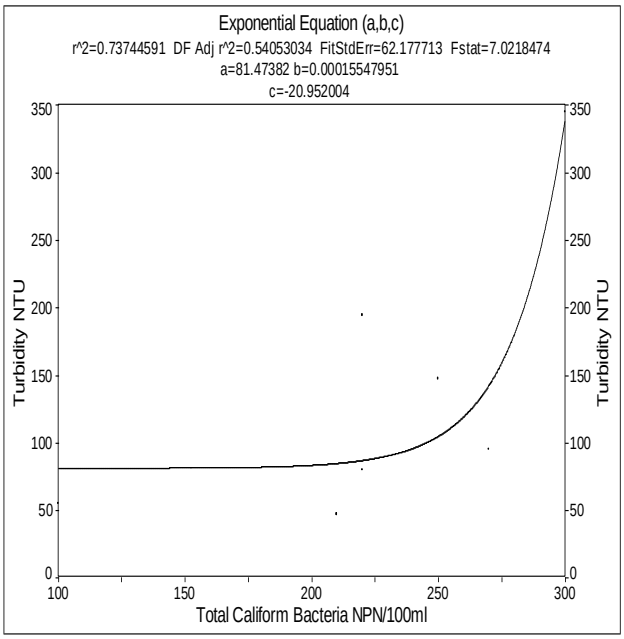

Fig. 5: Coefficients of the Regression function and Correlation Coefficients for KWTP

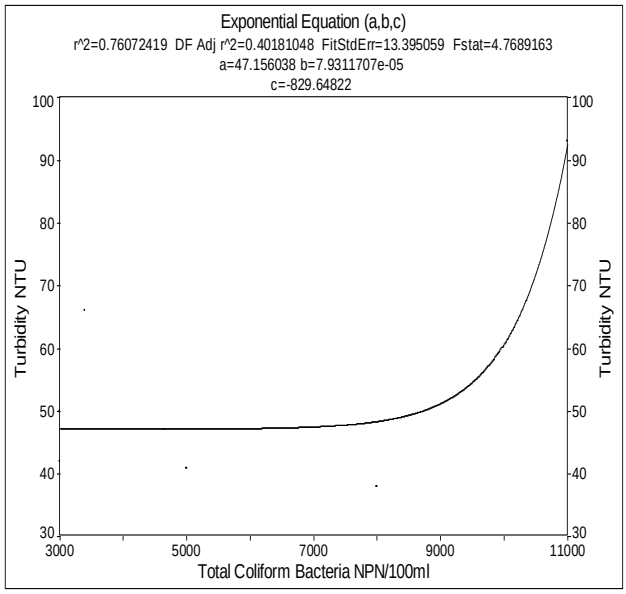

Fig. 7: Coefficients of the Regression function and Correlation Coefficients for KRWTP

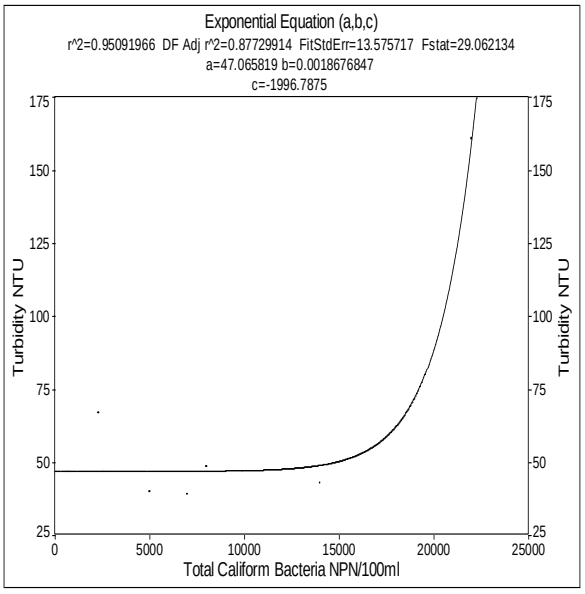

Fig. 9 Coefficients of the Regression function and Correlation Coefficients for QWTP

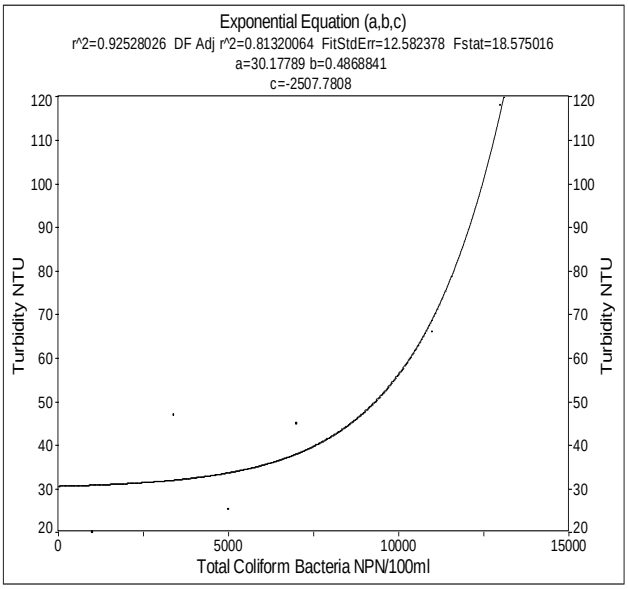

Fig. 8: Coefficients of the Regression function and Correlation Coefficients for WWTP

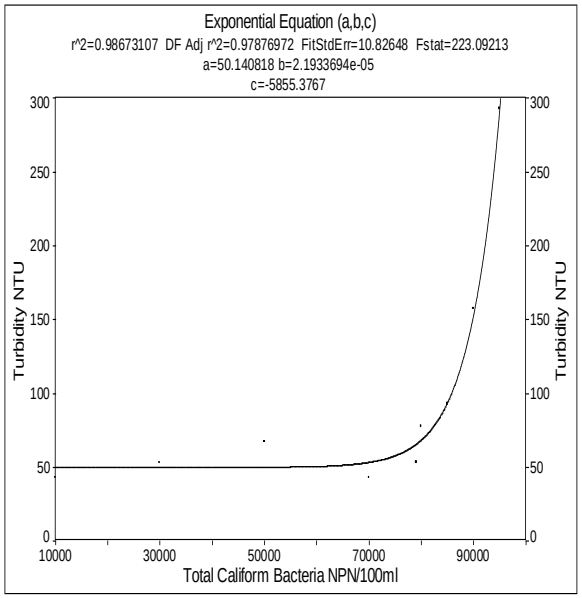

Fig. 10: Coefficients of the Regression function and Correlation Coefficients for DWTP.

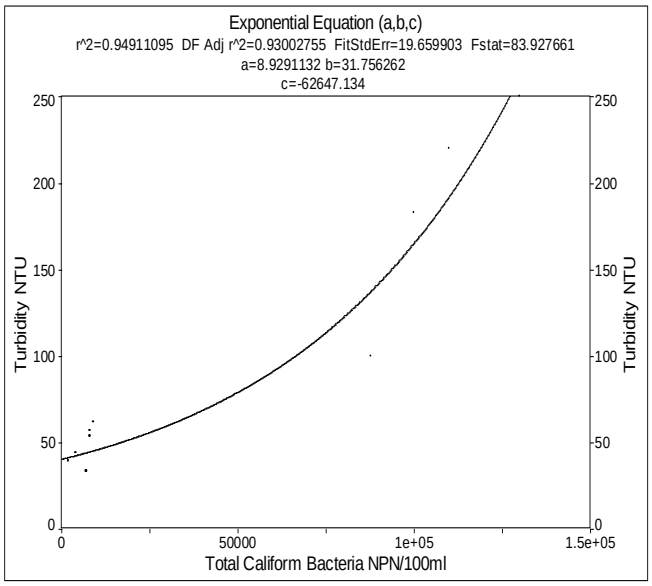

Fig. 11: Coefficients of the Regression function and Correlation Coefficients for RWTP.

CONCLUSIONS

1. Results indicated that Sulfate is the major problem of Baghdad water treatment works south of Tharthar Canal, the average level of Sulfate concentration of produced water for all water treatment plants than the favourable level of 200 mg/L.

2. Inorganic chemicals under study are not affected by the treatment process and the concentration are the same in both river water and drinking water for Alkalinity, Calcium, Magnesium, and Chloride, but few increases in the concentration of Total Dissolved Solids, Total Hardness, and Sulfate, in treated water due to the addition of Alum to the water during the coagulation process, and to the absence of any chemical treatment units in Baghdad water treatment works.

3. Water characteristics at RWTP exceeded the water quality standards which recommended by WHO particularly Bacterial counts and Turbidity, because RWTP with draws raw water of higher bacteria counts as compared with other water treatment plants.

4. The source of Bacterial counts at station (north of Baghdad) was probably to intermittent rainfall and storm water runoff as well as other sources, however the additional bacteria at RWTP can be considered due to wastewater disposed from pollution sources upstream this station.

5. The correlation coefficient between Turbidity and Total Coliform Bacteria in river water were good at KWTP, EWTP and KRWTP while the correlation coefficient began to increase at other water treatment plants due to waste water disposed from pollution sources upstream this stations.

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