Environmental impact assessment of domestic effluents on water quality of Tigris River discharged from Wasit Thermal Power Plant

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ABSTRACT

Present study was conducted at Tigris river, near Wasit Thermal Power Plant (WTPP) in Al Zubiadiyah city to evaluate the impact of discharging domestic sewage during construction period (2010-2016) on water quality of the river; to assess the level at which effluents discharged from WTPP affect the quality of Tigris river water; and to compare the quantity of pollutants in the water with the acceptable limits of Iraqi Standards. Observation recorded during the three months study depicted that the river is polluted in certain areas downstream the river as comparatively higher values of biological oxygen demand (BOD) and chemical oxygen demand (COD) were recorded. The level of total dissolved solids (TDS), dissolved oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD), total hardness, sodium ion, and sulfates (SO_4) in the water sample were quite high. With the exception of pH, all other physical-chemical parameters measured are between 100% and 180% higher and have exceeded the maximum permissible limit given by the permissible Iraqi standards. The domestic wastewater is discharged directly to river without any treatment during this period (construction period), there is tendency of these pollutants to persist in the water and its uptake may cause long term health problems when the water is used as drinking water, especially in areas near the point of discharge, since there is an intake of a water compact unit 1 km downstream from the point of discharge (Al-Bokhauder village), as well as the adverse effects on plants when the contaminated water used for plant irrigation .

Key words: domestic effluent, river water quality, pollution.

تقييم الأثر البيئي لمياه الصرف الصحي لمحطة كهرباء واسط الحرارية على جودة مياه نهر دجلة

الخلاصة

أجريت الدراسة الحالية على نهر دجلة قرب مدينة الزبيدية في محافظة واسط وبالتحديد عند مشروع محطة واسط الحرارية لتوليد الطاقة الكهربائية في مدينة الزبيدية وذلك لتقييم الأثر البيئي الناتج عن تصريف مياه الصرف الصحي وخلال فترة إنشاء المحطة (٢٠١٠ – ٢٠١٦) على نوعية مياه نهر دجلة مع مقارنة قيم الملوثات المطروحة مع الحدود المسموح بها ضمن المواصفات العراقية . ومن خلال النتائج التي تم التوصل إليها طيلة فترة الدراسة (ثلاثة أشهر) لوحظ إن منطقة أسفل النهر ملوثة بنسبة عالية جدا من الملوثات (الأملاح المذابة الكلية ، الأوكسجين المذاب ، الأوكسجين البايلوجي المطلوب ، الأوكسجين الكيماوي المطلوب، العسرة الكلية ، ايون الصوديوم ، الكبريتات) في نماذج المياه المأخوذة حيث كانت تراكيزها عالية جدا. وفي ما عدا قيم الأس الهيدروجيني فأن كل الملوثات الكيميائية والفيزيائية كانت تزيد عن الحدود المسموح بها حسب المواصفات العراقية بأكثر من (١٠٠% – ١٨٠%). إن مياه الصرف الصحي كانت تصرف مباشرة إلى نهر دجلة دون أي معالجة تذكر وخلال الفترة الحالية (فترة إنشاء المشروع) وهنالك ميل قوي لهذه الملوثات إن تبقى في الماء وممكن إن تسبب العديد من المشاكل الصحية على المدى الطويل عند استخدامها كمياه شرب وخصوصا على المناطق القريبة على نقطة التصريف حيث إن هنالك مأخذ لوحدة ماء مجمعة تابعة لقرية البوخضر يبعد حوالي ١ كم عن نقطة التصريف ، إضافة إلى ذلك التأثير السلبي على النباتات عند استخدام تلك المياه الملوثة في ري المزروعات.

1. Introduction

Water is the basic and primary need of all vital life processes and it is now well established that the life first arose in aquatic environment. Ever since the pre-historic times man has been intimately associated with water and the evidences of past civilization that all historic human settlements were developed around inland freshwater resources have conclusively proved it. Even today it is the major consideration for all socio-economic cultural, industrial and technological developments. Besides drinking, water is also used for fish and aquaculture, irrigation hydropower generation etc. but these days water the elixir of life is becoming more and more unfit and dearer to mankind due to unwise use, neglect and mismanagement.

According to the World Commission on water for the 21stcentury, more than half of the world's major rivers are so depleted and polluted that they endanger human health and poison surrounding ecosystems. When waste water finds its way into any water body it pollutes the water, water pollution is primarily associated with domestic and industrial waste. Both types of waste-water pose threats to water quality which may be classified into health hazards and sanitary nuisances. Many fresh water resources are contaminated through human activities. Each day some 25,000 people (in the developing countries) are said to die from their everyday use of wastewater. Many millions more suffer from frequent and devastating water borne illnesses,[1]. About half of the people that live in developing countries do not have access to safe drinking water and 73% have no sanitation, some of their wastes eventually contaminate their drinking water supply leading to a high level of suffering [2]. Every human use of water, whether for drinking, irrigation, and industrial processes or for recreation has some quality requirements in order to make it acceptable. This quality criterion can be described in terms of physical, chemical and biological properties of such water[1]. In many places both surface and ground water is fouled with industrial, agricultural, and municipal wastes.

Today water resources have been the most exploited natural systems. Pollution of water bodies is increasing steadily due to rapid population growth, industrial proliferation, urbanization, increasing living standard and wide sphere human activities. Most of our cities developed without proper development plan.

Consequently sewage systems of these cities are not well planned. Therefore wastes of homes and industries mixed with the catchment areas of water by the fault sewage system.

Water quality studies have focused on cases where sever pollution problems are arises, especially in heavily populated urban areas. For example Baghdad city is over populated and produced a huge amount of wastewater from different sources which are disposed into Tigris river directly or after treatment. In the last few years, an increase of wastewater directly disposed in the river using pump stations of storm sewer network have caused high pollution levels in the river's water [3].

Most potential negative environmental impacts from the application of recycled water to the environment come from recycled water's origin as wastewater. These impacts include other water resources, potential contamination of surface and groundwater sources. Public health hazards, and other environmental impacts that may directly or indirectly affect the public. Fortunately, very few significant negative impacts have ever occurred. It is important that all public water systems serve water of the best possible quality to their customers[4].

In Wasit province (middle of Iraq), Tigris river facing the effect of conservative pollution due to the continuous discharge of domestic wastewater in it during the current construction phase (2010-2016) of Wasit Thermal Power Plant (WTPP) project. The present research is to study the effect of wastewater pollutants discharged from the residential complex directly into the river on the water quality during the construction period.

2-MATERIALS AND METHODS

2-1 Water sampling

Collection of water samples was done in the morning between 9am and 10am. These samples were collected using Grab method which according to World Bank, 1988 [5]; Samples were collected into clean 2liter plastic bottles and were stored in an ice box of 4ºC and were taken to the laboratory within twenty-four hours for analysis. Water samples were collected by lowering pre-cleaned plastic bottles into the bottom of the water body, 30 cm deep, and allowed to over flow before withdrawing. Ten sampling points were used and the sampling points are approximately 1km away from each other. A total of 40 samples were analyzed. Four samples were collected from each of the ten sampling points. The first location was 1km up stream; the second location was at (Chinese residential camp) waste water discharge point. The third to the eighth locations were at the 1km, 2kms, 3kms, 4kms, 5kms, and 6kms, downstream. The study was carried out through three months.

2-2 General description of the Project environment

Wasit Thermal Power Plant (WTPP) is located in the land of Wasit governorate. The station is located about 120 km southeast of Baghdad Fig. (1). Water source which the project depends on is the Tigris river, which the right bank of the river about 100 meters from the project.

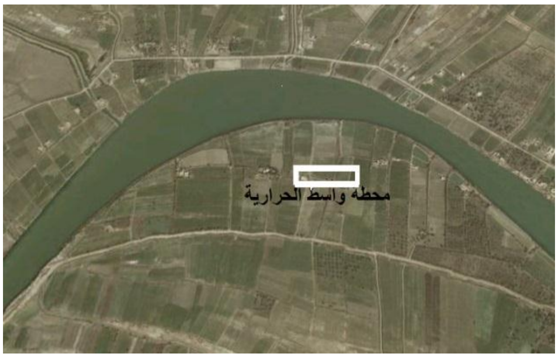

Figure (1) Location of Wasit thermal power plant project in Wasit Province.

2-3 Domestic Wastewater discharge during WTPP construction phase

We have been calculating how much drainage discharged by Chinese camp which contains more than 1,500 workers and the adoption of the international standard for quantitative feedback per person per day and 300 liters of water is the amount of 450,000 liters per day or the equivalent of 450 cubic meters of wastewater per day and several samples of water posed to the river directly have been taking regularly (Fig. 2). For the purpose of checking a range of environmental tests have shown that wastewater is very far from Iraq and global environmental determinants. Table 1 shows the results of the examination rate for several domestic wastewater samples. Waste water as sewage discharged to the irregular and underground septic tanks is a collection of scattered drilling and deployed dozens of meters away from the right bank of the Tigris river, the dimensions of the each underground septic tank are 40 meters length by 15 meters width by 6 meters depth, and roofed with sheets of aluminum. The wastewater is discharged from these underground tanks directly into the Tigris river through the trenches with dimensions 1.25m width and depth of 1.5 meters or through pipes diameter 8 inches. While the other section of the underground tank (reservoirs) water is drained through the nomination process in the soil where the water level is higher than the level of the Tigris river, the nomination process of this waste water from these septic tanks to the river are easy and fast. . However the quality of river water deteriorates at several places due to inflow of sewage. The present study deals with the assessment of the impact of pollution on the Tigris river water quality along the stretch of Wasit Thermal Power Plant (WTPP) boarders with the river.

Figure (2) Chinese camp -underground septic tanks with directly wastewater discharge to the river.

2-4 Physicochemical Analyses

The following parameters were analyzed during the course of study

1. pH

The hydrogen ion concentration is the indicator of acidity and alkalinity of any aqueous system. During present investigation pH was measured with the help of a pH meter.

2. Dissolved Oxygen

Dissolved oxygen level of the samples was measured with the D.O meter. The electrode was dipped into each sample, after it had been rinsed, then readings were taken and the description was given in APHA[6].

3. Total Dissolved Solids

TDS test by filtration followed by oven drying 200 ml (V) of sample was filtered by filter paper to separate the suspended solid, then the beaker was weighted (A) and filled by the filtered sample. The sample was dried in the oven at 105C° for 5 hours, the beaker with the dissolved solid was weighted again (B) [7].Then TDS was calculated by:

$$TDS = \frac{B - A}{V} \quad (1)$$

Where:

V= volume of sample, (L).

A=weight of beaker filled by filtered sample, (mg).

B= weight of beaker with the dissolved solid, (mg).

4. Biochemical Oxygen Demand (BOD)

Biological oxygen demand is an indirect measure quantifying the amount of oxidizable organic matter in wastewater. It is defined as the mass of oxygen that would be required for the complete decomposition of the organic matter in a given volume of water (usually in mg ⁄ l), given sufficient time (Clesceri et al. 1998). The standard five day BOD test (BOD_5) quantifies the extent of oxygen depletion in a sample over 5 days. Excessive BOD in effluent discharged to natural bodies of water can quickly cause anoxic conditions for fish and other aquatic life as decomposers deplete available DO through respiration. Kadlec and Knight (1996) simplify the multitude of processes breaking down BOD through the following equation, analogous to cellular respiration [8]:

$$\text{organic matter } + O_2 \xrightarrow{\text{bacteria}} CO_2 + H_2O \quad (2)$$

They admit that equation (2) overlooks two significant issues: (i) that other pathways exist for breaking down organic matter (e.g. anaerobic methanogenesis), and (ii) that other biological wetland processes demand oxygen (e.g. nitrification).

The first reading of D.O1 was taken with oxygen meter and after 5 days of incubation of water samples in 20°C without light, the second reading of D.O2 was taken. The BOD was determined by the below equation and expressed in mg/L. [9]

$$BOD5 = \frac{D.O1-D.O2}{P} \qquad (3)$$

Where:

D.O1= dissolved oxygen of diluted sample immediately after reparation, mg/l.

D.O2= dissolved oxygen of diluted sample after 5 days incubation at 20˚C, mg/l.

P = decimal volumetric fraction of sample used (dilution factor).

5. Chemical Oxygen Demand (COD)

Chemical oxygen demand (COD) test was conducted in accordance to the procedures outlined in the *Standard methods* (APHA, 1998) using COD reactor (Model: WTW CR 2200, Germany) and Photometer (Model: WTW S6, Germany).

6.Total hardness (T.H)

Total hardness (T.H) test as $CaCO_3$ is done by titration method. A solution was prepared from 10 ml of water sample (V1) and 10 drops of buffer solution (pH=10) in order to give the alkalinity characteristics, the none drop (10 mg) of Erio chrome black T reagent was added, so the solution became pink. This solution was titrated with (1 normality)(N) of H_2SO_4 acid until the solution became blue, the volume of acid was records(V) [10].

The total hardness was calculated by:

$$\text{Total Hardness} = \frac{V \times N \times Mw}{V1} \times 1000 \qquad (4)$$

Where:

V= volume of H_2SO_4.

N= normality of H_2SO4.

M_W = the molecular weight of $CaCO_3$

V1= volume of water sample, ml.

7. Na^+ Test by Photometer (S6) Method

This method was done by using Atomic Absorption Spectrometry using Photometer (Model: WTW S6, Germany).This photometer allows measurement of convenient rapid tests by inserting the coded cuvette (Na^+) and read the result directly.

8. SO_4^- Test by Photometer (S6) Method

This method was done by using Atomic Absorption Spectrometry using Photometer (Model: WTW S6, Germany).This photometer allows measurement of convenient rapid tests by inserting the coded cuvette (SO_4^-) and read the result directly.

3-RESULTS

1- From the laboratory tests, the mean concentration of biological oxygen demand (BOD) at the point of entry (main discharging point 0km) was 280 mg/l (Fig.3) which is higher than the permissible value according to the Iraqi standards, this discharging adversely affects the quality of water and gradually ended up to the 8km where the BOD concentration becomes 30 mg/l which is lower than the permissible value (40 mg/l).

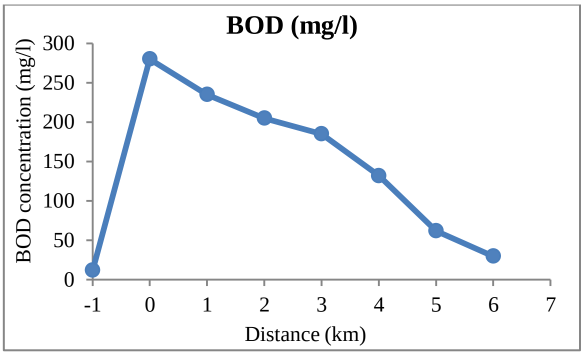

Figure (3) Variation of BOD concentration with distance

2-The COD concentration level increases at the main discharging of river at a point 0km by 265% of the permissible value (Fig.4). After 5km from the point of entry the COD concentration decreases to 95 mg/l which is an acceptable value.

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Table 1 Mean value of physical-chemical parameters

Parameter	Upstream -1km	Point of Entry 0km	1km	2km	3km	4km	5km	6km	Max permissible Iraqi Standard (mg/l)
COD (mg/l)	25	365	330	256	245	170	95	42	< 100
BOD (mg/l)	12	280	235	205	185	132	62	30	< 40
Dissolved Oxygen (mg/l)	9	1.2	1.8	3.5	4.1	5	6.5	7.2	-
Total Dissolved Solids (mg/l)	450	1200	1119	998	975	945	610	480	< 1000
SO_4	45	425	389	370	365	360	239	187	< 250
Total Hardness	398	877	832	765	720	578	454	400	< 500
Na^+	32	78	65	51	35	34	33	30	< 150
PH	8.4	7.1	7.3	7.5	7.8	8.1	8.2	8.2	6-9.5

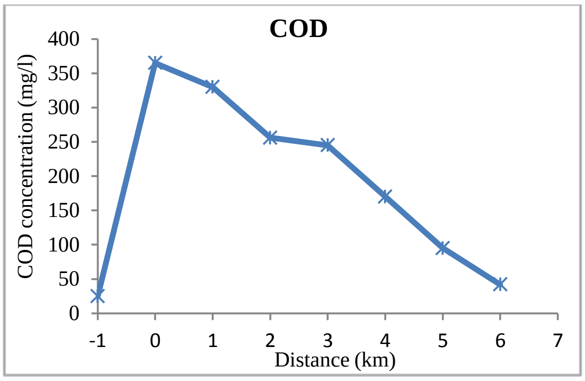

Figure (4) Variation of COD concentration with distance

3- The concerning the dissolved oxygen concentration, Fig (5) shows that the river was fully saturated with dissolved oxygen (1km upstream) which was 9 mg/l. Low dissolved oxygen and under saturation observed at the sewage outfall (0km) is due to increasing biochemical oxygen demand requiring oxygen to break down organic matter brought in by the sewage. After the first km beyond the point of entry the dissolved oxygen concentration increases gradually until it becomes 7.2mg/l at the station 6km downstream.

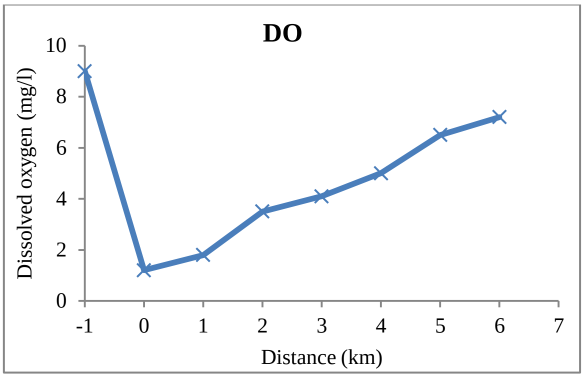

Figure (5) Variation of DO concentration with distance

4-The pH values decrease at the discharge point, Fig (6) and increase at the other stations downstream. All the values of pH at the ten stations were at an acceptable range of Iraqi standards.

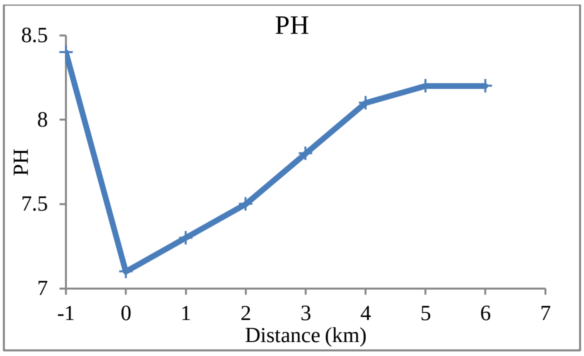

Figure (6) Variation of pH concentration with distance

5-The phosphates concentrations were higher in the vicinity of sewage outfalls (425 mg/l) which is about 170% higher than the permissible value according to the Iraqi standards. There was a slow dissipation of phosphates from a higher concentration at the pollution source to near the station at 4km. The lowest concentration was recorded at the station 6km about 187 mg/l.

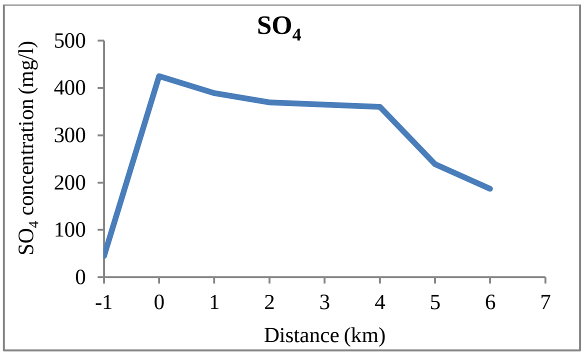

Figure (7) Variation of SO_4 concentration with distance

6- The total dissolved solid (TDS) concentrations varied between 480 - 1200 mg/L (Fig. 8) in all the study sites beyond the point of entry, and ranged from a minimum of 480 mg/L at the station 6km to a maximum of 1200 mg/L at the station 0km as an average. The high dissolved solids recorded in could be because of domestic effluent discharges and surface run-off from the cultivated fields which might have increased the concentration of ions. The observed high concentration of dissolved solids in the surface water is a pointer to the fact that there are intense anthropogenic activities along the course of the river and run-off with high suspended matter content.

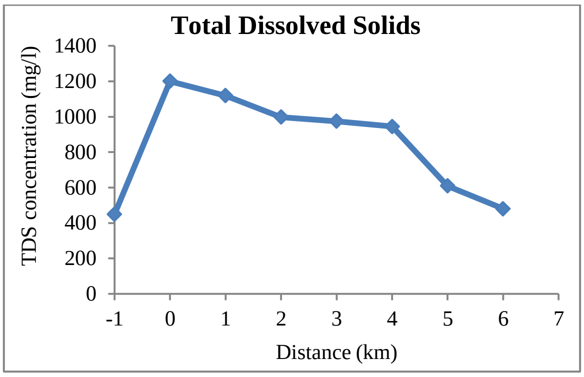

Figure (8) Variation of TDS concentration with distance

7- In spite of the maximum value of sodium ions concentration at the point of entry (Fig. 9), the concentrations conserve within the permissible values of Iraqi standards.

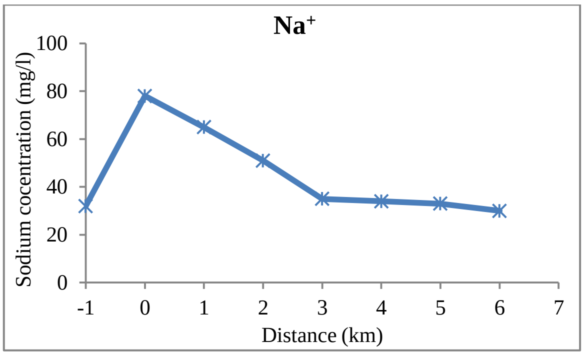

Figure (9) Variation of Na^+ concentration with distance

8- Total hardness mainly depends upon the dissolved salts present in the water. The water is classified as very hard if the values exceed 180 mg/l, therefore water of the river can be considered as hard. Hard water also forms deposits that clog plumbing. These deposits, called "scale", are composed mainly of calcium carbonate ($CaCO_3$), magnesium hydroxide $Mg(OH)_2$, and calcium sulphates ($CaSO_4$). The following equilibrium reaction describes the dissolving/formation of calcium carbonate scales [11]:

$$CaCO_3 + CO_2 + H_2O \leftrightharpoons Ca^{2+} + 2HCO_3 \qquad (5)$$

As water moves through the soil and the rock, it dissolves very small amounts of minerals and holds them in solution. Calcium and magnesium dissolved in water are the two most common minerals that make water "hard." Calcium and magnesium ions can be removed by water softeners. In the present study, it has been found that the total hardness ranges from 400-877 mg/l at the stations 6km and 0km respectively (Fig. 10). This is due to discharge of domestic sewage, washing clothes, and animals in the river.

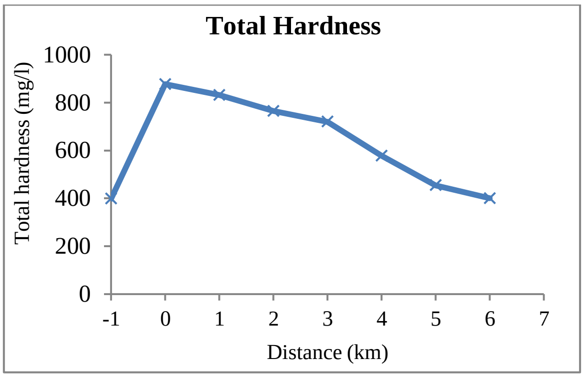

Figure (10) Variation of total hardness concentration with distance

4- DISCUSSION

The major sources of water pollution can be classified as municipal, industrial, and agricultural. Municipal water pollution consists of wastewater from homes and commercial establishments. For many years, the main goal of treating municipal wastewater was simply to reduce its content of suspended solids, oxygen-demanding materials, dissolved inorganic compounds, and harmful bacteria. In recent years, however, more stress has been placed on improving means of disposal of the solid residues from the municipal treatment processes. The basic methods of treating municipal wastewater fall into three stages: primary treatment, including grit removal, screening, grinding, and sedimentation; secondary treatment, which entails oxidation of dissolved organic matter by means of using biologically active sludge, which is then filtered off; and tertiary treatment, in which advanced biological methods of nitrogen removal and chemical and physical methods such as granular filtration and activated carbon absorption are employed.

The impact of domestic discharges depends not only on their collective characteristics, such as biochemical oxygen demand and the amount of suspended solids, but also on their content of specific inorganic and organic substances. Three options are available in controlling domestic wastewater. Control can takes place at the point of generation in the Chinese residential camp; wastewater can be pretreated for discharge to municipal treatment sources; or wastewater can be treated completely at the WTPP project and either reused or discharged directly into receiving waters.

The chemical composition of sewage varies from day-to-day or even from hour. Sewage water contains inorganic waste, which creates a problem of disposal, but apart from inorganic waste, undesirable organic matters, which are offensive and dangerous, are also present. Inorganic compounds of sewage water support the growth of harmful bacteria and other microorganisms, which sometimes lead to the epidemics among the human beings. Health standards are dependent upon efficient waste disposal. It has been observed that numbers of the serious diseases are transmitted through sewages. Gastrointestinal, typhoid fever, paratyphoid fever, cholera, and dysentery certain nematode infection, etc.

Tigris is an important river of the central part of Iraq supplies water to a large command area of Wasit province. The present investigation was aimed at assessment of water quality and thereby an estimation of pollution loads on the river just close to its origin. The study reveals that the water quality is poor and pollutants of both organic and inorganic origin are entering into the river, thereby deteriorating its water quality. The high concentration of BOD and COD are due to high concentration of decomposable organic matter in the domestic wastewater flowing from the Chinese residential camp. The increased concentration of TDS depicts high concentration of dissolved inorganic solids. It is evident from the study that the Chinese residential camp (during the construction phase of WTPP project) near the Tigris river are polluting it by discharge of wastewater. The severely pollution of water of Tigris river has rendered its water unfit for human consumption especially there are many villages downstream about 1km away from the project. Treatment of wastewater before discharge in the river is the only means by which the problem of water pollution could be mitigated. During the present investigation, the water quality of Tigris river in the upstream was observed quite well in comparison to downstream of the river, which was found to be highly polluted due to discharge of municipal sewage through surface drains.

However, the obtained results from this study for all the parameters were much higher than the previously reported values [13], in spite of the fact that the range of values published in these literature were observed for a station located before distillery and downstream of point where untreated sewage from Bağıvar settlement.

Ali (1978) concluded that Tigris River in Baghdad area is highly polluted comparing with Euphrates and Abu- Graib stream. Al-Masri and Ali (1985) confirmed that discharging treated and untreated wastewater into river limited the use of water for different uses as it flows down stream. For evaluating water quality parameters Al-Masri and Ali (1985) were studied some water parameters such as: sulfate, Alkalinity, chloride, calcium, hardness, and magnesium in Tigris River through Baghdad city. The results of study have indicated that concentrations of hardness, sulfate, and calcium exceeded the allowable limits established by the Iraqi drinking water standards. Ghadban (1993), concluded that after the war on Iraq in 1991, most water intakes of treatment plants, were heavily polluted by sewage discharges causing ecological damage and public health hazards. Abd-Ali (1993), also concluded that war on Iraq in 1991, affected the bacteriological quality of the Tigris river in Baghdad especially down river at Dora site, as a result of discharging the material sewage to the river.

5- REFERENCES

[1] WHO (2003). “The World Health Report: Shaping the Future: World Health Organization 1211 Geneva 27, Switzerland.

[2] Vivan EL, Bashiru D, Adamu CI (2012). An Appraisal of Water Supply and Sanitation Situation in Some Selected Areas of Kaduna Metropolis. Published in GURARA J. Vocational Technol. Sch. Agric. Technol. NuhuBamalli Polytechnic, Zaria.

[3] Dahr ,J.,(2004), " Pollution Chokes The Tigris; A Main Source of Baghdad's Drinking Water.

[4] William, O. Maddous, (2001), “Water Resources Planning ", First Edition, p.98.

[5] World Bank (1988). Pollution study on clean up river Kaduna. Part Creport. KEPA/ABUCONS.

[6] APHA, AWWA, WPCF (1995). “Standard Methods for the Examination of Water and Wastewater.”American Public Health Association, Washington, DC.

[7] Young, J.C., G.N. ,Mcdermott &.Jenkins,(1981), Alterations in BOD Procedure for The 15th Edition of Standard Methods for The Examination of Water and Wastewater," J. Water Pollution Control.

[8] Kadlec, R. H. and Knight, R.L. (1996). Treatment Wetlands. Lewis Publishers, CRC Press, Inc. Boca Raton, Fla.

[9] Clesceri, L.S.,(1998), " Flow Injection Analysis for The Orthophosphate", Standard Methods for The Examination of Water and Wastewater, 20th Edition.

[10] Rand and Greenburg, (1978), "Standard Methods for The Examination of Water and Wastewater", 4th Edition., Raven Press , New York . 619

[11] Onwughara, I. N., Ajiwe, V. I. , Alaekwe, I. O. 2011, Impact Assessment Of Total Hardness On Borehole Waters In Umuahia North MUAHIA NORTH Local Government Area Of Abia State, Nigeria. VSRD-TNTJ, Vol. 2 (8), 2011, 358-369

[12] Clesceri, L.S., A.E., Greenberg and A.E. Eaton, 1998, Turbidity Nephelo metric Methods’ Standard methods for the Examination of Water and Wastewater, 20th Edition.

[13] Varola, M., Gökotb, B., & Bekleyenb, A. (2010), Assesment of Water Pollution in the Tigris River in Diyarbakır, Turkey. Water Practice & Technology Vol. 5 No 1.

[14] Abd-Ali. A.H. ,1993, "A Statistical Study on Some Effects of the Aggressive War upon the Quality of Water in the City Baghdad", M.Sc. Thesis, Build. And Const. Dept. University of Technology.

[15] Ali, A.I. ,1978,"Study the Bacterial Quality of Water in Iraq", M.Sc. Thesis, Agr. College, University of Baghdad.

[16] Al-Masri N.A. and Ali A.A. ,1985, "Effect of Domestic and Industrial Wastewater Discharge on Pollutant Variation in River Tigris", Proceeding of Iraq Conference on Engineering,IDE,pp.467-474.

[17] Ghadban, F.D. 1993, "Evaluation of Some Environmental Effects in Iraq (Water and Wastewater Treatment Plants)", M.Sc. Thesis, College of Eng., University of Baghdad.