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POLLUTION INVESTIGATION ON TIGRIS RIVER WITHIN MOSUL AREA, IRAQ

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Abstract

Limnological study of Tigris river was conducted within Mosul area. It was found that not less than 24 sources of sewerage loaded with all types of pollutants were drained to the river. The effluents may contain an annual weight of ≥ 240000ton as total solids, of them are ≥ 80 ton of both NO_3^- and PO_4^{-3}. Oxygen demand need for organic load cracking was ≥ 340000 ton. Chlorophyll a, b and c concentrations were found in a range between ≥ (0. 13- 1. 86) mg/L, (0. 12-1. 84) mg/L and (0. 16-5.43) mg/L. this situation accelerates the eutrophication phenomena, reflected by algal total count which ranged between (414-21081) cell/L. Class Diatom exhibited obvious dominance over the other species in all locations and during study period, then Chlorophyta and finally Cyanophyta. Whereas twelve genera of Bacillariophyta, eight of Chlorophyta and two genera of Cyanophyta were identified in this study. Salinity as RSC is also increased in terms of Cl^- and SO_4-^{2} ions concentrations from 0.7672 to 2.9126 within 30 years only.
Keywords: nutrient status, water basin shape, fresh water, algae, Tigris river, Mosul City, eutrophication and salinity.

Introduction

Water pollution could be considered as an increase in certain constituents and/or a foreign matter found in water make it inconvenient for certain use. Wastewater discharges loaded with organic load, nitrogen and phosphorous drained to water course will cause eutrophication in an ecosystem, (Ittekkot *et al.* 2000). Ecology of algae in a river depends upon the following:

1. Descending stream accelerates mostly eutrophication, where the nature of upstream is out to acquire the characters of silted downstream river.
2. The growth of algae and their dynamics will differ in shape, size and structure assemblage but it will vary continuously downstream river and differ among species and locations.
3. The proposed mechanism of hydraulic retention and growth enhancement in no flowing storage zones is separated from the main flow by boundary zones across which fluid is exchanged.

Eutrophication may take place very slowly, but is directly proportional with nutrients loads, (Golterman, 1975) and (Massoud and Samir, 1978).

Algae are composed by their majority production in almost aquatic environment; therefore, algae are considered as the base of food chain in the aquatic system, (Jin *et al.* 1994).

Tigris river pollution problem becomes more complicated as the river appears to be polluted even before flowing into Mosul city, by many points and non-point source pollution beside impoundment in Mosul lake, (Mustafa, 2005).

Sources of Tigris river may receive all types of pollutants, 2. Zakho town wastewater drained to Tigris river via Al- Khabour river at Deraboon, 3. Drainage of many valleys to Mosul lake is responsible of eutrophication, mainly, Dohouk city after its dramatic growing, 4. Al-Mur tributary discharges, "drainage system of Northern Al-Jazzerah Irrigation Project", 5. Sulfur springs discharge of 300 m^3/hr, at Badoosh dam project, 6. Hazardous waste of some industry, at Al- Naorah village, 7. Buffalo solid waste of at least (10 ton/day on dry base) at Badoosh, 8. Raw construction material quarrying activity between Sheikh Mohammad and Mosul city, 9. Car maintenance and washing, also cattle washing and treatment applications found on both river banks. These facts had been changed Tigris river water quality by means of; hardness, salinity, nutrients, organic loads, algal growth…etc. (Mustafa, 2002) and (Mustafa, 2005).

Actually, the river Tigris water is used for all purposes. in the meantime, it is also used as an ultimate sink for all types of wastewater transporting via many estuaries arising from manmade activities. Within Mosul city, it is believed that not less than (24) sources drain their effluents to the river from both banks (Mustafa and Jankeer, 2007). Recent estimation of these wastewaters is around 500000 m^3/day where Mosul city population are 1700000 citizens. Such wastewater may contain all types of pollutants serve to degrade the river water quality.

Tigris river pollution is clearly reflected on the high growth of aquatic hydrophytes, mainly algae. These types of plants and algae will cause many difficulties, of them are:

1. Clogging in power stations and water treatment plant intakes.
2. Odor, taste, and color are mainly due to its decay.

Salinity is also rising as a problem due to dramatic increase in its constituents Cl^- and SO_4^{-2} ions.

This work aims of evaluation Tigris river water quality status within Mosul city, regarding eutrophication and salinity indications phenomena.

Materials and Methods

An upstream and downstream Mosul city location on Tigris river had been chosen to clarify the impact of Mosul wastewater discharges between 2002 and 2012. Samples were collected by using polyethylene bottles. Analyses had been run for samples through seasons involved some selective physical, chemical and biological aspects according to (APHA, AWWA and WPCF, 1998). Also, evaluation and considering of some studies, covering the whole year seasons to show Tigris water quality variation and reflecting the algal quality and quantity, chlorophyll concentrations, in addition to salinity. Whereas, the concentration of chlorophyll pigments had been measured according to (Al- Taai, 2000). Regarding algal quality, it was run according to (Macnab, 1960) using (0.45) mm Millipore filter paper. Filtered samples were tested under the microscope to identify algal species according to (Prescott, 1980; APHA, AWWA and WPCF, 1998).

Result and Discussion

Pollutants load estimated by the difference between up and downstream Mosul city, considering that Tigris river annual discharges (250- 300) m^3/sec. Parameters investigation tabulated in Table (1-5) are the following:

1. Temperature; water temperature was (11.9- 20.0) °C. these values are less than that of Tigris river before Mosul dam construction where it was in a range of (10.5- 29.8) °C. The drop in water temperature is due to water discharges from the bottom outlet of the lake, (Mustafa 1982) and (Mustafa, 2000 a).

2. pH; the influence of various factors was reflected on pH values along the river, the level was fluctuated within definite pattern, but sustained in alkaline side at all stations (never below pH 7.0). Actually, Tigris river water has high buffering capacity due to carbon dioxide- bicarbonate balance, this agrees with the general water properties of Iraqi inland waters (Liere *et al.* 1991).

3. Turbidity; on dry weather the turbidity of Tigris river is mainly from organic origin, it seems to be very low (≤ 10). Its constituents are mainly colloidal and semi colloidal organic materials, in addition to algae, while most of in organic suspended solids has been settled in Mosul lake. Both turbidity and suspended solids form inorganic origin are found high through rainy seasons, mainly the first heavy rain after dry weather period. Actually, low turbidity is difficult to remove in the local conventional water treatment plants which are not designed for that, (Mustafa, 2000 a) and (Mustafa, 2000 b).

4. Dissolved Oxygen; it is affected by all types of wastewater discharges drainage to the river between Turkish border and Mosul city and within it. Consumption of dissolved oxygen by microorganism for organic compounds cracking, in addition of oxidizing some reduced inorganic elements will drop its concentration to ≤ 7.0, (Mustafa and Jankeer, 2007).

5. Electrical conductivity; the recorded values of electrical conductivity are 2680560- 6821381μhos/cm. the values increased along the path of the river due to wastewater discharges (Talee'a, 1983), and (Al-Shahwani, 2001), and within Mosul city it rises by 126144- 151376μhos/cm.

6. Solids; total solids and total dissolved solids increase in Tigris river due to the discharges drained to the river via many estuaries, between Turkish border down to Mosul city (Mustafa and Jankeer, 2007). Mosul dam construction had reduced Tigris river catchment area from 55000Km^2 to < 5000Km^2. Consequently, suspended solids had been reduced from ≥ 3000 to ≤ 100mg/L due to the impoundment in Mosul lake (Al- Hamdani 1997). The nature of the solid's sources had been changed from inorganic to organic, mainly due to sanitary wastewater discharges. This reflected by the increase of the organic load's concentration, (Mahmoud, *et al*. 2002) and (Mustafa & Jankeer, 2007). In the present work load of solids ranges between ≥ 3153600- 7095750 ton/ year, and it increases within Mosul city by 236520- 283830 ton/ year.

7. Total hardness; the impoundment of Tigris river water may increase permanent hardness due to gypsum dissolving in Mosul lake (Al-Hamdani 1997). In addition to other manmade activities. While temporary hardness was increased due the huge quantity of carbon dioxide liberated from organic loads cracking by microorganisms. This can convert limestone to bicarbonate, according to the following equations;

$$CO_2 + H_2O \rightarrow H_2CO_2 + CaCO_3 \rightarrow Ca\,(HCO_3)_2$$

Actually, temporary hardness is outweighed the permanent one due to the above-mentioned factors, (Mahmoud *et al*., 2002) and (Mustafa and Jankeer, 2007). Load of total hardness ranges between 2128682- 4257450 ton/ year, and it increases by 102492- 122993 ton/ year within Mosul city.

8. Alkalinity; in addition to the information listed in TH article, alkalinity is directly proportional with temporary hardness formation according to above factor. It gives an indication of water PH ≥ 7.0. Load of alkalinity ranges between 1103760-1712441 ton/ year, and it increases by 102492- 122993 ton/ year within Mosul city, recently it decreases due to its dramatic consumption by aquatic hydrophytes (macro algae and weeds), in the bed of the river Tigris.

9. Sulfate; sulfate is increased by different factors of them are; gypsum rock dissolving due to the impoundment of Tigris river water in Mosul lake, as it had been mentioned before. Many industrial activities may produce this ion too. At the present time, wet battery repairing using sulfuric acid could be assumed as the main sources of sulfate ion (Mustafa and Jankeer, 2007). Concentration of sulfate is increased 2.5–3.4 times since 40 years where it was only ≤ 77mg/L, (Mustafa 1982), while recently its average is 195 and maximum result is 259 mg/L (A- Taie, 2012). which is above the standards. Sulfate ion load is ranging between 607068-1267774 ton/ year, about 42574- 51089 ton/ year is added to the river within Mosul city.

10. Chloride; sources of chloride ion reach Tigris river water may not easily count, through 30 to 40 years it increased five times, where it was only 13mg/L, downstream Mosul city, now it is up to 70mg/L (Mustafa, 1982) and (Al- Taie, 2012). It simply increases with time due to population growth and their different activities. Presence of sulfate and chloride are more or less affected by the same industrial factors also both ions are an indication of salinity, (Mustafa, et al., 2002) and (Mustafa and Jankerre, 2007). Load of chlorides ranges between 312206- 747419 ton/ year, and it increases with 788-946 ton/ year within Mosul city.

11. Nutrients; nitrate and phosphate are closely existed along the river, their values recorded between (0.01- 0.08) *mg/L* with a mean average equal of (0.07) *mg/L,* whereas, the nutrients are found to be available for algal growth. Phosphate is regarded as a limited factor of algal growth. The available orthophosphate form is existent due to the extensive uses of detergent of highly phosphate builders. Microorganisms capable to convert polyphosphate to orthophosphate, same as most types of nitrogen compounds mainly amino acids which may convert to nitrate types of nitrogen compounds mainly amino acids which may convert to nitrate (Smith et al., 1999). weight of both nitrate and phosphate are ranged between 79-757 ton/year, an increase in their loads within Mosul city may reach 79-95 ton/ year.

12. Organic Loads; both COD and/ or BOD_5 reflect the majority of organic loads presence which increase dramatically in the river water recently. Its concentration is beyond the maximum permissible level of assuming the Tigris river water as a raw water, where both BOD5 and COD are ranged (5.4-48.4) mg/L and (54-97) mg/L respectively, (Mustafa and Jankeer, 2007). Organic load as COD was 323244- 1277235 ton/year, while its BOD5 was 17345- 744581 ton/ year. Both parameters were increased with 339012- 406823 ton/ year, within Mosul city.

13. Algal count and Chlorophyll; the chlorophyll concentration is in parallel with the algal total cunt which ranged between (4147-21081) cell/L, whereas the values of chlorophyll a, b and c ranged between (0.13- 1.86) mg/L, (0. 12-184) mg/L and (0.16-5.43) mg/L respectively. Out of 20 species were identified throughout the present work, Table (3), these species related to three taxa cyanophyta (9.0) %, chlorophyta (34. 4%) and Bacillariophyta (54.5%). The Bacillariophyta made up the majority of the population qualitatively and quantitatively which is followed by green algae then blue greens. Similar results were found into the related studies (Mustafa and Fadhl, 2008) . The total number of species showed a general increase trend from the upper location in comparison with downwards. Finally, it is worthy to mention that Tigris river bed seems to be as a forest of aquatic hydrophytes (macro algae and weeds), Table (2), Figures (1-8) even in a location very close to Mosul dam (Mustafa and Fadhl, 2008) and (Al- Taie, 2012).

14. Salinity; concerning this parameter, (Mahmoud *et al.* 2002), stated that a doubling of salinity levels in Tigris is a result of upstream irrigation in Turkey, according to(Governmental Iraqi Technical Report, 2002) . While (Al-Naqib et., 2012) shows that increasing in the parameters T.D.S, TH, Ca^{+2}, HCO_3^-, Cl^-, and SO_4^{-2}, Table (5) salinity levels are between 250 and 500mg/L. this in spite of Tigris river discharges fluctuation, where during April the discharges are around 1433m^3/sec, while through September it is dropped to 113m^3/sec. Table (4), shows clearly the increase in T.D.S, TH, Ca, HCO_3^-, Cl and SO_4^{-2}. Dealing with salinity, it is also worthy to consider the figures in table (5). Information in Table (4) reveals some fluctuation in some figures; this could be due to dilution factor, while a significant increase is easily noticed in the parameters of, Cl^-, SO_4^{-2} and RSC. Figures 1-6 shows clearly this idea. In this regards it also worthy to mention that most of sparingly soluble cations as for example Ca^{+2} ions can be consuming by aquatic hydrophytes and/ or precipitate as calcium carbonate, consequently T.D. S and TH are reduced. In addition to that alkalinity as a source of carbon is used for algae reproduction which shows a significant decrease in its concentration. In the meantime, completely soluble ions like Cl^- and SO_4^{-2} and RSC Figures 1-6 shows clearly this idea. In this regards it also worthy to mention that most of sparingly soluble cations as for example Ca^{+2} ions can be consuming by aquatic hydrophytes and/ or precipitate as calcium carbonate, consequently T.D.S and TH are reduced. In addition to that alkalinity as a source of carbon is used for algae reproduction which shows significant decrease in its concentration. in the meantime completely soluble ions like Cl^- and SO_4^{-2} and in spite of the chance of their consumption by weeds, but their increase were so clear during the past 3decates, this was reflected by the rising of salinity factor (R.SC) from 0.7 to 20.9 i. e 4times during the above period.

Table 1 : Tigris River Water Quality Differences between Upstream and Downstream Locations within Mosul City.

Parameters	Upstream Position	Downstream Position	Differences	Weight of Pollutant's comes from Mosul City tons/Year
	Range/Average	Range/Average		
Water Temp. C°	9.8-21.0 15.9	10.2-21.5 16.1	0.2	-
pH nuit	7.4-8.2 7.9	7.0-7.7 7.2	0.7	-
Turbidity (N.T.U)	4-12 9.2	3-16 9.9	0.7	-
D.O	5.8- 7.6 7.2	5.5- 7.1 6.6	-0.6	-4730-(-5677)
E.Cμhos/cm	340-655 464	345-721 480	16	126144-151376
T.S	400-7400 525	440- 750 555	30	236520-283830
T.D.S	360-595 470	400-605 490	20	157680-189220
S.S	25-100 65	25-110 75	10	78840-94610
TH	270-450 337	280-450 350	13	102492-122993
Al AlK.	140-175 155	165-181 178	13	102492-122993
$SO4^{-2}$	77-123 94.6	83-134 100	5.4	42574-51084
Cl^-	39.6-64.5 53.6	43-79 53.7	0.1	788-946

NO_3^-	0.01-0.07 0.03	0.01-0.08 0.04	0.01	79-95
PO_4^{-3}	0.0-0.07 0.03	0.0-0.08 0.04	0.01	79-95
COD	41-62 54	75-135 97	43	339012-406823
BOD_5	2.2-6.8 5.4	35.1-78.7 48.4	43	339012-406823
Chl. A	0.13-1.01 0.47	0.22-1.86 0.52	0.05	394-473
Chl. B	0.12-1.59 0.38	0.23-1.84 0.62	0.24	1892-2271
Chl. C	0.16-3.32 1.09	0.29-5.43 1.10	0.01	79-95
Algal Count cell/L	4147-14169 8381	6566-21081 9987	1606	1.3×10^{16}- 1.5×10^{16}cell/year

All parameter are in mg/L, unless it is mentioned, actual Tigris river discharge is 250- 300, 3/sec.

Table 2 : Hydrophytes and Macro algae Identified Within the Study Area

Hydrophyte	Macro Algae
Potamogeton pusillus	*Hydrodictyon reticulatum*
Potamogeton nodosus	*Cladophora glomerata*
Ceratophllum demersus	*Nitella* sp.
Phragmites australis	*Compsopogon* sp.
Phragmites sp.	----------------------------

Table 3 : Algae Identified in the Two Locations.

Taxa		
Bacillariophyta	Chlorophyta	Cyanophyta
Amphora sp.	*Chlorella sp.*	*Anabaena sp.*
Cocoueis sp.	*Cladophora sp.*	*Oscillatoria sp.*
Cymbella sp.	*Oedogonium sp.*	
Cyclotella sp.	*Nitella sp.*	
Diatoma vulgare	*Spirogyra sp.*	
Fragilaria sp.	*Pandorina sp.*	
Gyrosigma sp.	*Ulothrix sp.*	
Navicula sp.	*Zygnema sp.*	
Nitzschia sp.		
Rhoicosphenia curvata		
Synedra ulna		
Tabellaria sp.		

Table 4 : Differences in the major parameters between upstream and downstream Mosul city, in different periods.

Parameters	1996	2009	2010[+]	2012
T.D.S	16	20	6.7	54
TH	19	13	7.8	29
Ca^{+2}	3	-	2	5.2
HCO_3^{-1}	5	13	2.3	(-54)[++]
Cl^-	7.5	0.1	2.1	18.5
SO_4^{-2}	19.8	5.4	16	128.5

[+]This study had been covered the period between 1973- 2009, i.e before and after Mosul dam construction.[++]
The drop in alkalinity reflect the consumption of CO_2 content by aquatic hydrophytes, which is now covers most of the river Tigris bed.

Table 5 : Maximum concentration of the main common parameters.

Parameters	1982	1996	2007	2010	2012
TDS	250	263	490	400	320
TH	200	249	350	350	195
Ca^{+2}	74	57.3	74	90	52
HCO_3^-	120	126	178	200	74
Cl^-	13	24.3	53.7	30	67.4
SO_4^{-2}	77	82	100	150	194
RSC	0.7672	1.1115	2.0335	1.6264	2.9126

Conclusions

1. Direct discharges of non- treated wastewater giving no chance for self- purification of Tigris river.
2. Nutrients and salinity loads are found fair enough for all types of aquatic hydrophytes growth and reproduction through Tigris river path.
3. Growth of hydrophytes and algae affect the intakes of water treatment plants by all means of them is the clogging its pumps, mainly through Tigris river discharges fluctuations.
4. Organic loads and decay of aquatic plants causes odor, color and taste also it may cause strong bad taste in the presence of phenols, in addition to the chance of carcinogenic compounds formation in the presence of certain organic compounds, if the chlorination of raw water is applied as a first step.
5. There are very clear increases in salinity constituents in Tigris river water in comparison with the last forty years.

Recommendations

1. A treatment of wastewater should be done before discharging to Tigris river.
2. A natural remediation should be applied for all valleys and rivers drained to Tigris River, in order to remove both organic and salinity constituents loads.
3. Buffalo at Badoosh should be migrated to downstream Mosul city due to their bad impact on Tigris river water quality.
4. Treated wastewater discharged to the river must have minimum salinity by all means, i.e artificially and/ or naturally under control.

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