ISSN 2348-1218 (print)
International Journal of Interdisciplinary Research and Innovations ISSN 2348-1226 (online)
Vol. 2, Issue 4, pp: (38-58), Month: October - December 2014, Available at: www.researchpublish.com

Pollutant Variation through Tigris River in Mosul City

[1]Naufal A. Al-Masri, [2]Mazin N. Fadhel

[1,2]College of Environmental Science & Technology, Mosul University, Iraq.

Abstract: **During the past three decades, wastewater production has increased tremendously due to the population increase and the continuous rural population resettlements in the cities seeking a presumed better standard of living .Global and regional climatic changes have contributed to the issue in addition to the exhaustion of the environment, including water ways and water bodies. The River Tigris receives it share of water quality deterioration and scarcity. Therefore, full scale environmental precautions have to be setup urgently in order to protect this magnificent and historic water resource. In the absence of sewage infrastructure services in Mosul city, most of the urban wastewaters (domestic, industrial and agricultural return flows) reach the river through natural canals passing through the city. In addition, the city solid waste services are managed improperly which causes further suffering of the environment. It is estimated that 5 to 6 m^3/s of mostly settled raw waste water is disposed of into the river as gray water. In order to investigate the most potent pollutants existing in the river water and their seasonal variation, this research work has been initiated in order to evaluate and model the variation of these pollutants with distance and time as the river passes through Mosul city, their environmental impact on the quality of river Tigris and to define their use status as compared with potable water quality criteria. The results of the study indicate that the concentration of some of the pollutants in the river water is affected by the highly polluted wastewater disposed into the reach under consideration which exceeds the permissible limits of potable water on some occasions. Pollutant variation as expressed by the derived models indicates that the pollutants flowing downstream vary considerably with the river flow rate and/or time of the year. A modified Water Quality Index (WQI) has been suggested and implemented over the reach under investigation. The water quality is classified as clean water or 17% polluted on the average. Suitable instantaneous and long run solutions are proposed in order to reduce and /or even eliminate (as a final goal) the decline in the water quality of the river Tigris while flowing through Mosul city. Since Mosul city is located at the river mouth upstream, thus any variation in its quality can certainly affect all the cities and /or downstream river water consumers including the capital Baghdad, the most heavily populated city in Iraq. As the pollutant loading is high in the mentioned reach, the dilution and self- purification process possessed by the river, especially in low flow periods might be inadequate to preserve and maintain a reliable and adequate water quality in the river Tigris. Environmental legislation and laws set up by the authorities involved in the regulations and protection of the environment have to be actuated and implemented over a national scale urgently and adequately.**

***Keywords*:** **River Tigris, Pollutant Variation in, Pollutant Modeling, Water Quality Index WQI.**

I. INTRODUCTION

The River Tigris has been and will always be one of the most significant rivers in the region in addition to its twin river the Euphrates. Since both rivers extend over a vast amount of land in the Middle East, therefore, they are considered as main sources of water in the region. In ancient times, the land area within the southern section of these rivers formed what was known as “Mesopotamia”, the former great civilizations of the Sumerians, Babylonians and Assyrians in southern, middle and northern Iraq. These nations discovered writing, established the first law and legislation of Hammurabi in addition to practicing irrigated agriculture for grain production of the first land cultivation in the world. The (twin) Tigris-Euphrates Rivers and their tributaries have always been the major fundamental reason for sustaining and developing the civilizations in their basins and territories. Among them is the largest, most famous city of Mosul. It is located in the upstream of the Tigris River including a basin of 235000 square kilometres shared by four neighboring countries, namely Turkey, Syria, Iraq and Iran (Al-Juboury, 2009).

The most significant value of the river in its upper reach of Iraq is its function as the major water supply for the Mosul dam, the northern agricultural Nineveh valley, Mosul city and the eastern- southern Al-Gazerah irrigation schemes for irrigated agriculture (Al-Naqib, and Mustafa, 2010). While flowing through Mosul city, the Tigris River supplies almost all of the population of Mosul with their water requirements. This means that the river receives almost all of the city's untreated gray water. As Mosul city is in the upstream of the Tigris in northern Iraq, so the pollution of the Tigris potable water caused by the city will certainly affect all the other cities downstream, among them is the capital Baghdad and also Basrah in the far southern part of Iraq. The total length of the river is about 1900 km, of which 1440 km is located within Iraqi territory. The yearly total water income has been reduced tremendously over the last three decades from 58 km^3 to about half of this quantity at present, mostly because of the huge Turkish Southeast Anatolia Project more commonly known by its Turkish initials as GAP. This reduction in the Tigris water flow has worsened the river water quality as well. With the absence of clear and internationally recognized agreements between Iraq, Syria and Turkey on the rights of water use of the river Tigris, it is hoped that the Iraqi national water resource security shall be recognized soon (Al-Masri and Al-Hadeethee, 2000).

The water quantity-quality deterioration in addition to global changes in the weather as more and more pollutants are being released into the environment will create more and/or even increased reduction in the per capita water availability (less than 1000 m^3 per year). Excessive water use, the absence of regulatory water use authorities, less availability of fresh water in the country and more polluted water disposed into the water bodies treated and /or mostly untreated, will involve all the environmental authorities in Iraq, the region and international agencies to take urgent and immediate action to with stand and overcome the scarcity of water resources. In addition to the above mentioned complicated and protracted water status issues on a national basis, Mosul city exerts even more serious problems because of the absence of infrastructure networks, the inadequate and obsolete drinking water networks and lakes of the solid waste collection system and sanitary land fill services. Consequently, as the Tigris River passes through the city, almost all of the 1 700 000 inhabitants of Mosul dispose of their gray untreated waste water through more than 20 natural wadies into the river. In the absence of a proper sewage network almost all the domestic sewage of the city is treated through septic tanks in local homes. These units are typically improperly operated since no cesspools are connected to them for the settled sewage to be disposed of.

Consequently, the shallow ground waters are contaminated and often interfere with the adjacent old deteriorating drinking water network and hence this affects the public health of the Mosul residents. In this situation, Mosul city is under serious threat from the polluted environment and at the same time it is contaminating the Tigris River water. Many researchers and the engaged authorities have executed many studies trying to investigate the problems concerning the polluted status of the river, but almost none of them have dealt with curing the reasons behind the pollution, nor suggest visible solutions to the problem.

This study has been initiated in order to investigate and produce a methodology for properly allocating the reasons for the Tigris water pollution, and to simulate the pollution variation along the river reach and/or time of the year. The following statements comprise the basic objectives of this study:

1. Investigate the reasons for the river Tigris water quality deterioration and its variation with both distance and time of the year as it passes through Mosul city.
2. Sorting and analyzing water quality for various uses and implementing an improved proper Water Quality Index (WQI) for the river.
3. Using water quality parameters (simulation) through modeling techniques, generation and verification.

II. METHODOLOGY

Samples of the River Tigris water were collected from seven sampling stations along the river reach under investigation at a frequency of twice a month that continued for two years ending in 2012. The sampling station numbering was kept the same as for comparison reasons. These stations are:-

1. Stations T1 and T2 located in Ninawa reservoir (not included in this research).
2. First station is (T3) which is at the Mosul Dam and it is 106.6 km from the Turkish border where the river enters Iraq.
3. Second station is (T4) located at the Hawee Al Chenesa region 177.9 km from the border.
4. The third station is station (T5) which is located near the Old Bridge (Alhadedi Bridge) 184.5 km away from the border.
5. The fourth station is (T6) located near the Al Huriah Bridge 188.8 km from the border.
6. The fifth station is (T7) near the Sugar Factory 196.0 km from the border.
7. The sixth station (T8) is positioned at the Wadi Al Daier outlet at the junction with the Tigris River. This station is 199.7 km from the border.
8. The seventh station (T9) is located near Hamam Alalell city 220 km away from the border.

The collected samples were analyzed at the MED laboratories for the following water quality parameters: SO_4, Mg, Cl, DO, Ca, EC, BOD_5, TH, Turbidity and TDS. The analyses of the collected samples were under taken and analyzed in accordance with the standard method procedures mentioned in the APHA, 2006.

III. RESULTS AND DISCUSSION

The results will be discussed over the following sections:-

A-Pollutant variation through distance:

The results of the study show a wide variation in the concentration of almost all measured parameters with distance (stations) and time of year as well.

However these variations are within the permissible limits of the potable surface water (WHO, 1996, and EPA, 1992) except for DO with some of its values dropping below the recommended minimum level of 5 mg/l specifically in the low flow periods. This finding is also confirmed by Al-Tayar et al., (1992).

Figure 1: demonstrates the SO_4 variation along the reach of the river starting from station (T3) at the Mosul dam with a concentration of about 64 mg/l. The river passes through the city till station (T9) where it reaches its maximum average value of about 77 mg/l.

The maximum increase in its average concentration is 17.1% at 93.1 km from Mosul dam measured at the Wadi Al Daier station. A decline in the SO_4 concentration in the river water is noticed after the old bridge station where the Al Kuoser little stream tips its water into the Tigris River

Figure 2: shows the Mg variation along the river reach where the maximum average increase in its concentration reached 19.7 mg/l or 20.3% near the old bridge station at 77.9 km from Mosul dam, Mg concentration after the old bridge station drops a little after the disposal of the Al Kouser stream into the river water

Figure 3: shows Cl concentration variation through the river reach where it fluctuate till reaching a limited increase of 4.9% after the city of Hamam Alalell 113.4 km away from the dam station.

This indicates that chloride presence in the disposed waters into the river is not significant to effect its variation in the river accept the little increase due to the disposal of Hawee AlChenesa stream into the river.

Figure 4: illustrates the dissolved oxygen variation through the river reach where its average concentration drops from 7.3 mg/l at the Hawee AlChenesa disposal point to 6.5 mg/l at Wadi AlDiaer station at the high flow period where the river water dilution is affecting the oxygen level. This finding is confirmed by Al – Taie (2012) as well.

Figure 5: represents Ca concentration variation through the river reach under consideration which appears to remains stable except with little fluctuation existed between the Hawee AlChenesa and Wadi AlDiaer station. However its concentration remains below the permissible level (Abawiand Hssan ,1990) .

Figure 6: shows the EC variation along the river reach where its highest level is observed near the old bridge site because of the high EC level contents in the Hawee AlChenesa water as it is disposed into the Tigris. Similar finding is observed by Al-Mashadani et al. (1989).

00The BOD_5 variation along the studied reach of river Tigris is shown in **Figure 7** .where its maximum average increase reached 64.7% near Hamam Alallel city 113.4 km away from Mosul dam as a reference point.

Mostly all wadies disposing into the Tigris contribute in adding more and more organic pollutants as detected by the BOD_5 as river flows downstream till exceeding the limits at Hamam Alallel city as mentioned by the WHO criteria 1999 .

Figure 8: demonstrates the TH variation along the river reach where it average values increased from 200 at Mosul dam site to reach its highest value of 213 after 77.9 km (corresponds to a 6.1% increase in percentage). This low variation level is due to the mixed effects of mixing and /or the dilution process between the river and waters of the wadies , although , these levels are within the WHO limits (1996) , and as described by the finding of Ali (1987).

The turbidity variation as shown in **Figure 9** increases progressively as the river water flows downstream of Mosul dam such that its average concentration reached 6.3 mg/l at Hamam Alalel city (as corresponding to a 31% increase after 113.9 km from the dam site).On the other hand the maximum upper level reached 26 mg/l measured at the same site .This specific increase might be contributed by the disposal from the wadies and/or the non-point sources that enter into the river Tigris .The Turbidity level is still acceptable as indicated by the WHO (1996) requirements.

The TDS concentration increased by 9.8% at 77.8 km down from the dam site specifically near the old bridge site (see **Figure 10).** This reasonable increase indicates the effect of the disposal sites into the river Tigris water. However, the upper limits of the TDS are within the WHO level for potable and drinking waters of less than 500 mg/l (1996).

B-Pollutants Variation with Time:

Most of the measured variables show no trend of variation with time in general However to further investigate the time effects on the pollutant concentration of pollutant variation, Figure 11 is an example for demonstrating such effects for Ca. Figure shows the concentration of Ca variation with time for all stations .It can be seen that the Ca level increases with high river flow periods (spring time) and decreases at low flow periods (end of summer and beginning of fall/autumn). This fact applies fully for all other pollutants studied in this research indicating the more washouts of these constituents as surface and/or subsurface runoff increases with rainy seasons.

This phenomenon dose not applies for Cl which remained almost unchanged during the year and for organic pollutants (BOD_5 for example) which increased in low flow periods as the water in the main river decreased as compared with the increased polluted flow from the wadies that brings most of the gray city waters into the river(see figure 12).

The other reason which might also affects the BOD_5 increase in the low flow period is the temperature rise during this season (Al-Masri , 2010) .

0Figures 13 to 22 show the average concentrations variation of SO_4, Mg, Cl, DO, Ca, EC, BOD5, TH, Turbidity and TDS with time. An optimal statistical model of the drawn data is also derived and presented in these figures as well.

The derived models have week correlation coefficients except for DO, Ca and TH whose R values varied from 0.77 to 0.93.

In summary the figures conclude the type of relation of the constitute variation with time of year which is summarized in Table 1.0000

Table 1. Pollutants Variation Summary with Time of Year.

Parameter	Figure	Type of Relation	Concentration Variation
SO_4	13	Stable & Descending	Increases in Fall
TDS	14	Unstable& Descending	Increased in Spring
Cl	15	Almost Stable	Unchanged with Time
DO	16	Stable & Descending	Decreased in Fall
Ca	17	Stable & Descending	Increased in Spring
EC	18	Unstable& Descending	Increased in Spring
BOD_5	19	Vibrated & Ascending	Increased in Summer & Fall
TH	20	Stable & Descending	Increased in Spring
Turb	21	Unstable& Descending	Increased in Spring
Mg	22	Unstable	Increased in Spring

C-Minimal Water Quality Index:

The water Quality Index (WQI) is usually modified and/or adapted such that it can be suited for the environment and the regulations of the region to which it will be applied .One of the oldest and may be the still largely used index is the WQI established by the UK Royal Commission, UKRC, (EPA, 1992). Table 2 shows the WQI for rivers classifications using BOD_5 as the main classifier index.

Table 2 .River Water Classification according to UKRC* .

River Classification	BOD_5 (mg/l)
Very clean	Less than equal to 1
Clean	2
Medium Clean	3
Dutiful	4
Bad (Polluted)	Less than 10

* After EPA, 1992.

However the next WQI uses eight water quality classifiers was established by the Environmental Engineering for England and Wales (EEEW) starting with DO and ending with Zn .This WQI has 5 classification intervals, the best quality denoted by REI and the very worst quality denoted by RES (Martin, 2002) .The WQI for industrialized countries may not be fully for applicable for the developing countries or satisfy their environmental requirements. In this respect , Madhou (2002) modified an existing WQI to be used in the rivers in Mauritius and also Pesce and W underline modified a simplified WQI (2000) and they applied it to the Suquia River in Argentina sing three water quality classifiers namely DO in mg/l , TDS in mg/l and Turbidity in NTU .This WQI called the Minimal Water Quality Index (WQImin). WQImin includes 100 units of classifications starting with very bad quality (scale zero) to very good quality (scale 100) and is calculated according to the following equation:

$$\mathrm{WQImin} = \frac{(\mathrm{DO} + \mathrm{TDS} + \mathrm{Turb})}{3} \quad - - - - - - - - - - - - \quad (1)$$

Where each of DO , TDS & Turb represent the Normalized Unit Values for each constituents as indicated in Table 3.

Table (3) . Normalized Unit Values for Dissolved Oxygen , Total Dissolved Salts and Turbidity used to Calculate WQI_{min}

D.O Concentration mg/l	Total Dissolved salts Concentration mg/l	Turbidity NTU	Normalized Unit Values (C)	$BOD_5^{\#}$ mg/l
≥7.5	<100	<5	100	≤1
>7.0	<500	<10	90	<2
>6.5	<750	<15	80	<3
>6.0	<1000	<20	70	<4
>5.0	<1500	<25	60	<5
>4.0	<2000	<30	50	<6
>3.5	<3000	<40	40	<7
>3.0	<5000	<60	30	<8
>2.0	<10000	<80	20	<9
≥1.0	≤20000	≤100	10	<10
<1.0	>20000	>100	0	>10

Suggested by the Authors

To evaluate the water quality of river Tigris as it passes through Mosul city (the reach under consideration) during the period of study , the WQImin criteria as expressed by equation 1 was used and the results presented in Table 4. Figure 23 represents the average calculated WQImin for the stations included in the study .According to the results of WQImin using DO, TDS & Turb classification, the river water appears to have WQImin of 80% while the control station (Mosul dame station) showed WQImin of 83% .These results indicate a reduction of only 3% in the water quality of the river water as it passes

Mosul city .However, other results indicate the fact that the River Tigris water is partially polluted (17% as explained by the WQI) even upstream of the city .Because of

Table 4: WQImin calculation using equation 1

After Normalization				Before Normalization			
	T.D.S	Turb	D.O	T.D.S	Turb	D.O	
WQImin	**Avg**	**Avg**	**Avg**	**Avg**	**Avg**	**Avg**	Stations
83.4*	90	100	60	183	4.3	5.4	T3
80	90	90	60	192	5.4	5.4	T4
80	90	90	60	203	5.2	5.4	T5
80	90	90	60	196	5.2	5.5	T6
80	90	90	60	194	5.5	5.4	T7
80	90	90	60	198	5.19	5.4	T8
80	90	90	60	195	6.3	5.4	T9

* Normalized Unit Values drawn in Fig. 23

Much gray water disposed from the wadies into the river while passing through the city. In order to investigate the organic pollutants on water quality of the river as explained by WQImin another water quality classifier was suggested in this research and added to equation 1 and column 5 of Table 3 as a Normalized Units Values. The modified form is presented in equation 2 as follows:

$$\mathrm{WQImin} = \frac{(\mathrm{DO} + \mathrm{TDS} + \mathrm{Turb} + \mathrm{BOD})}{4} - - - - \quad - - - - - - (2)$$

The modified WQImin equation applied to the River Tigris water with four classifications is presented in Table 5 and drawn in figure 24 which indicates some improvement in the WQI. This is due to the low BOD values disposed into the river water via the gray water from the wadies.

During the study period the average river flow (as released from Mosul dam) was a little bet high and varied between 600 to 1100 m^3/s .This provide sufficient dilution of the river water (AL-Rawi,2005). The average modified WQImin increased to 82.5% at stations T4 to T9 as compared to 80% from the first equation.

Table 5. The calculated WQImin using equation 2 (the modified equation).

WQImin	T.D.S	Turbidity	BOD5	D.O	T.D.S	Turbidity	BOD_5	D.O	Station
	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	
87.5#	90	100	100	60	183	4.3	0.6	5.4	T3
85.5	90	90	100	60	192	5.4	0.9	5.4	T4
82.5	90	90	90	60	203	5.2	1.1	5.4	T5
85.5	90	90	100	60	196	5.2	0.9	5.5	T6
85.5	90	90	100	60	194	5.5	0.8	5.4	T7
82.5	90	90	90	60	198	5.19	1.1	5.4	T8
82.5	90	90	90	60	195	6.3	1.7	5.4	T9

Normalized Unit Values drawn in Fig. 24

IV. CONCLUSIONS

Under the limitation of the results of this study and for the Tigris river reach under consideration through Mosul city, the following conclusions were reached :-

1. The concentration of the water quality parameters studied were less than the allowable limits for potable water except for DO which drops below 5 mg/l (or the minimum limits)for the low flow period of the river.
2. The concentration of the water quality parameters measured increased in progresses order with the flow downstream the river through Mosul city .The percent increase in the concentrations of the parameters with distance as compared with the reference station (Mosul dam station) are summarized below :-
3. The water quality parameter concentrations increased in the high flow periods except for the organic pollutants indicators namely DO and BOD which increased in the low flow periods.
4. The following water quality parameters were modeled clearly in polynomial forms with correlation coefficients that varied from 77% for SO4 and higher for DO, Ca and ending with 93% for TH.

Table 6.

Km from Mosul Dam	At Station	Percent Increase	Parameter	No.
----	----------------	0.00	Ca	1
82.2	New Bridge	0.70	DO	2
113.4	Hamam Alalel	4.90	Cl	3
77.9	Old Bridge	6.10	TH	4
77.9	Old Bridge	9.80	TDS	5
77.9	Old Bridge	11.44	E.C	6
93.1	Wade Aldaier	17.10	SO_4	7
77.9	Old Bridg	20.30	Mg	8
113.4	Hamam Alalel	31.70	Turb	9
113.4	Hamam Alalel	64.70	BOD_5	10

5. QImin was applied to express the pollution status of the River Tigris water while passing through Mosul city giving an 80% index which is classified as good quality water.
6. A modified WQImin was suggested in this study by including the BOD classifier in addition to DO, Turbidity, and TDS. This suggested index gave an average value of 83% (good water quality) indicating that the self- purification process and/or the river water dilution is quite sufficient (at least for the time being) to purify the water of organic pollution.

RECOMMENDATIONS

The following recommendations are suggested for further research work and field investigation:-

1. Establishing Permanent Water Quality Monitoring Stations (PWQMSs) along the Tigris River and all other water streams, rivers and water bodies in Iraq as well.
2. Perform a routine water quality testing utilizing the SCADA system including GPS as well for the PWQMSs to check the disposal of gray and drainage waters from the wadies into the river.
3. Establish a data base in the MDE for collecting all water, wastewater, solid waste (also sanitary land fill), hazardous waste, noise and air pollution data in Mosul Provenceand across the whole of Iraq as well.
4. Perform more research work on the Tigris River to maintain and conserve its water quality such that it will continue to be a main source of water supply for now and the future.
5. Establish and complete all the infrastructure systems in Mosul city and the suburbs as well. These systems and networks will definitely reduce and control the river water pollution and maintain better environmental conditions for better living and /or public health of the Mosul and Iraq inhabitants.
6. Controlling the quality of the potable water shall definitely contribute in developing and maintaining the strategic national water resource conservation practices.
7. Improve the existing water sharing policies between Turkey, Syria Iran and Iraq such that every country can sustain and develop its national water resources in the best interest of all the people in the region.
8. Improve the connections and scientific communication between the national, regional and international environmental agencies for exchange and improving by all means the knowledge, experiences and environmental practices. These new technologies will introduce and help sustain the environment, combat desertification, enlarge the natural green belts and areas, improve and reduce the dusty weather conditions and even maintain better water quality.

REFERENCES

[1] Abawi, S. and Mohamed, S. Hssan (1990),"Water Testing in Scientific Environmental Engineering", Dar Al-Hekma Pu. Mosul University (in Arabic).

[2] Al- Juboury, A. I. (2009) "Natural Pollution by Some Heavy Metals in the Tigris River, Northern Iraq", Int. Jou. Envi. Res.3(2):189-198. (in Arabic).

[3] Ali, L. H (1987),”Industrial Pollution”, Dar Al-Kutob Pu. Mosul University, Iraq.(in Arabic).

[4] AL-Naqib, S. Q. and M. H. Mustafa, (2010) “The Expected Impact of the Turkish Ilisu Dam under Construction upon Tigris River Water Quality”, Proceeding of the 7th Periodical Scientific Conference: 24-25 Nov. Investment of Water and Natural Resource towards Future Challenge.

[5] Al-Mashadani, Y. D, Abdul Aziz, T and Said, S, (1989),“Groundwater in Mosul to Bahsecha and its Suitability for Domestic and Agricultural uses”, Jou. of Education and Science (9): 11 – 20. (in Arabic).

[6] Al-Masri, Naufal and Esham AL-Hadeethee (2000) “Programming the Reuse of Saline Water for Irrigation”, The International Conference and Exposition of Energy and Water Desalination, June, Tripoli, Libya 20-21, June.

[7] Al-Masri Naufal (2010),“Water Balance Study for Misurata Region”, Al-Sattle, Jou. Of Misurata University, Libya.

[8] Al-Rawi, S.M. (2005),“Contribution of Man –Made Activities to the Pollution of the Tigris Within Mousl Area /Iraq”, Int. Jou. Environ. Res. Public Health, 2(2), 245-250.

[9] Al-Taie (2012),“A Study of Some Chemical Pollutant and Heavy Metals in Tigris River in Mosul City and its Environmental Impact”, M.Sc. Thesis in Soil Sciences and Water Resources.College of Agriculture, Mosul University.

[10] AI-Tayar, T. A., M. A. Musatfa and S. Q., Al-Naqib (1992) “Pollution of Tigris River Water by Natural Acidin Zanquba Area”, 18th WEDC Conference. Nepal, Water Engineering Management, pp. 51-54.

[11] APHA (1985),“Standard Method for the Examination of Water and Waste Water”, 16th Edition, AWWA, WPCF, New York.

[12] Environmental Protection Agency, EPA (1992),“Guidelines for Water Reuse”, 625, R-92/004, EPA. Washington, D.C.

[13] Martin, D (2002),“The River Ecosystem Classification System” Environmental Agency, Bristol: available at http://www.environmental-.gov.uk/co,onData/103599/River-eI.doc. (2002). Agency.

[14] Pesce, S. F and Wunderlin, D. A. (2000),“Use of Water Quality Indices to Verify the Impact of Cordoba City (Argentina) on Saquia River”, Water Research, Vol. 34, No. 11, pp 2915 -2926.

[15] WHO (1996),“Guidelines for Drinking Water Quality”. 2nd ed., Vol. 2. World Health Organization, Geneva.

[16] WHO (1999), “Surface Water Quality Guidelines for Use in Alberta”, Alberta Environmental, No: T/483.

APPENDIX -A: LIST OF FIGURES (1- 24)

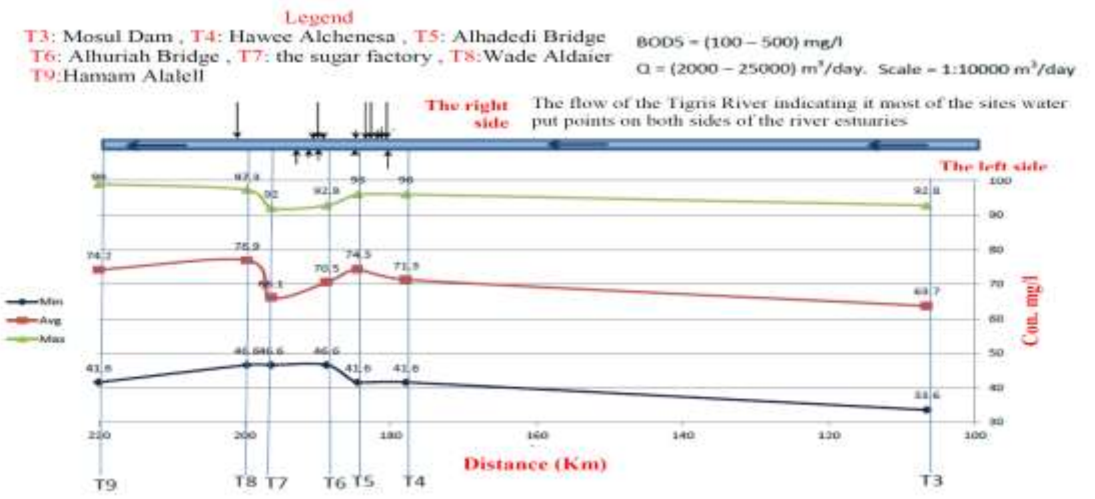


Figure 1. Demonstrates SO_4 concentration variation along the the river

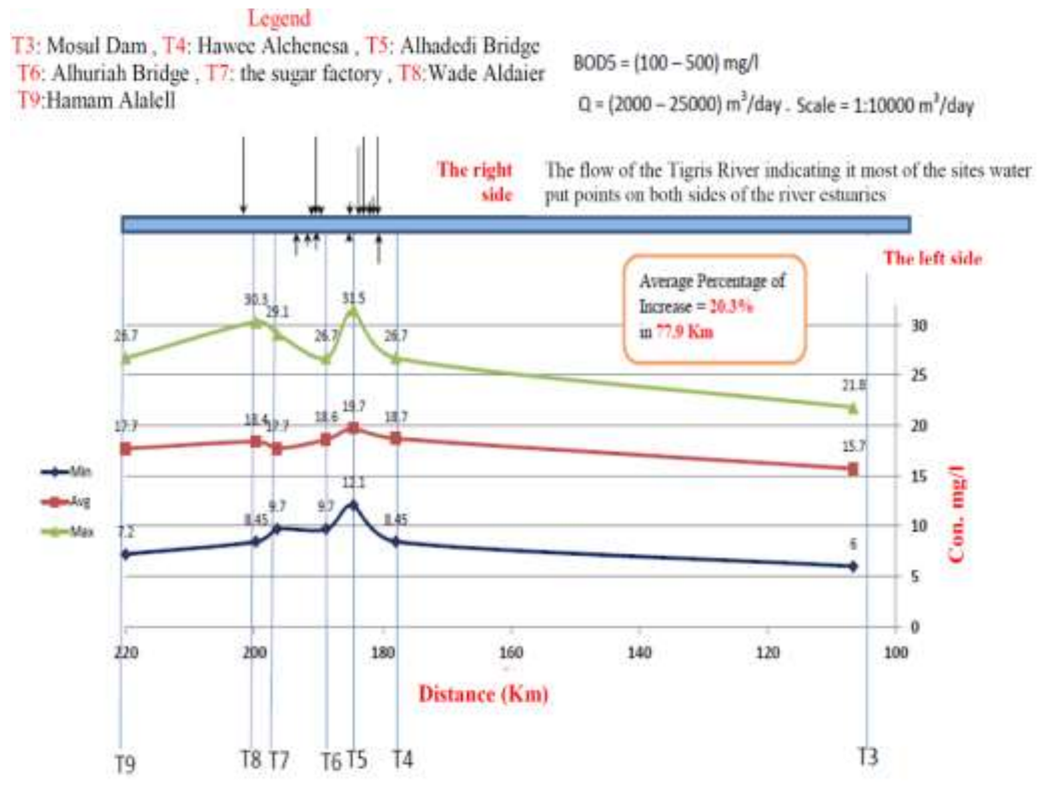


Figure 2. Shows the Mg concentration variation along the river

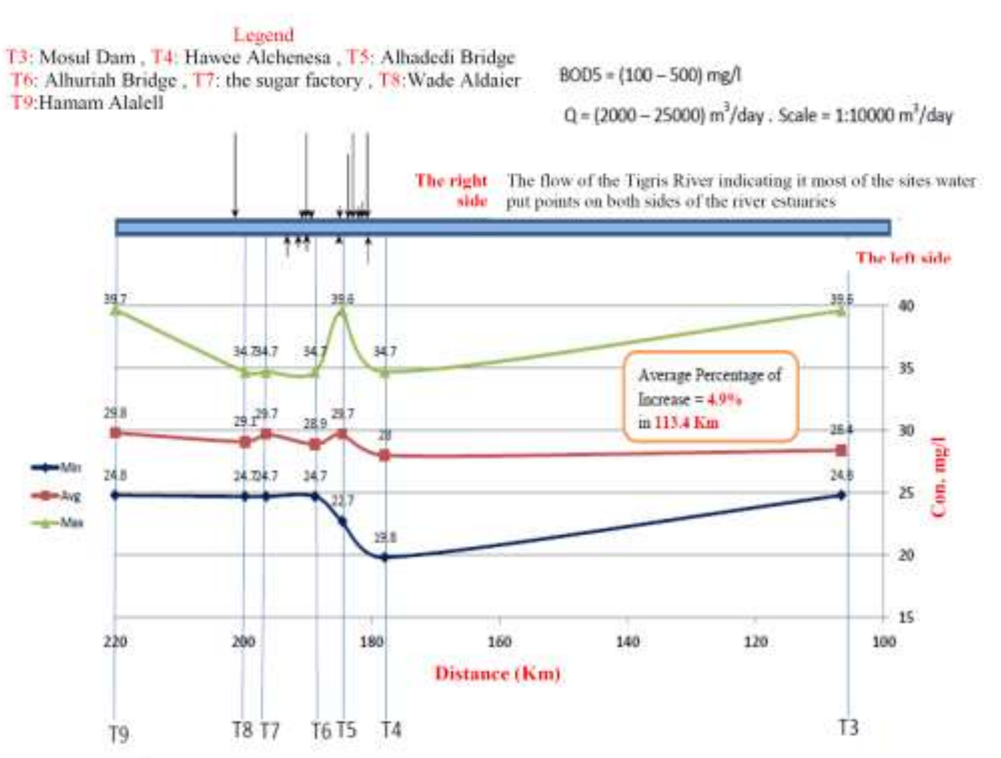


Figure 3. Shows Cl concentration variation through the river

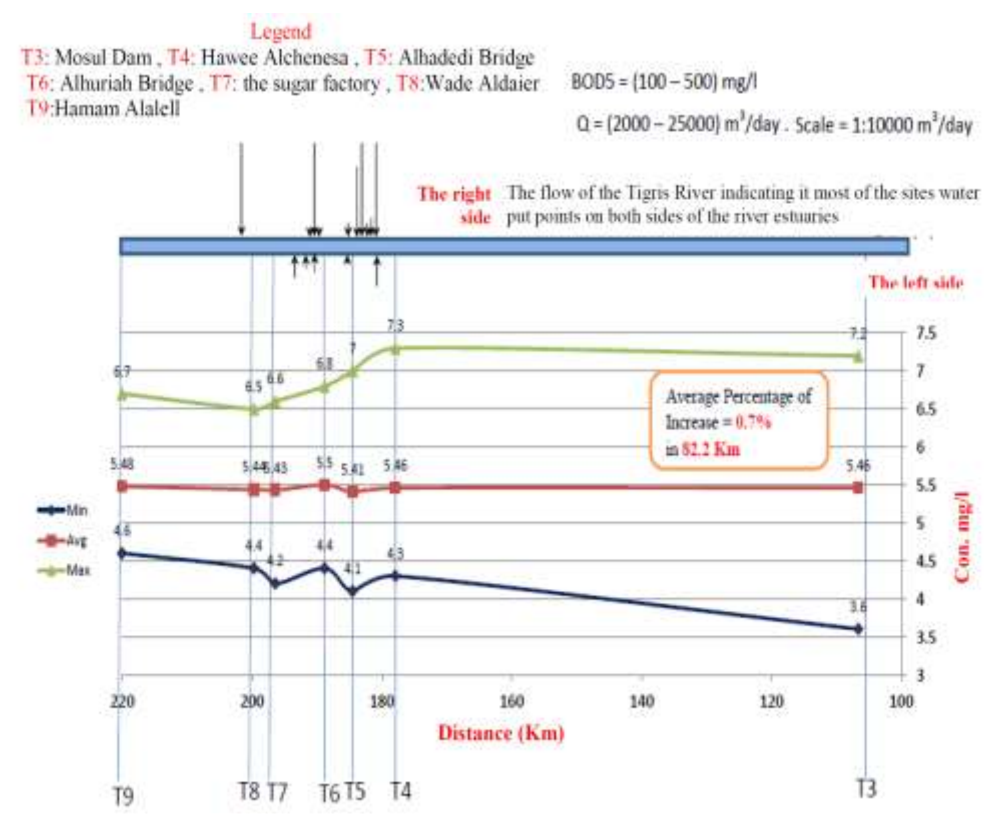


Figure 4. Explains dissolved oxygen variation through the river

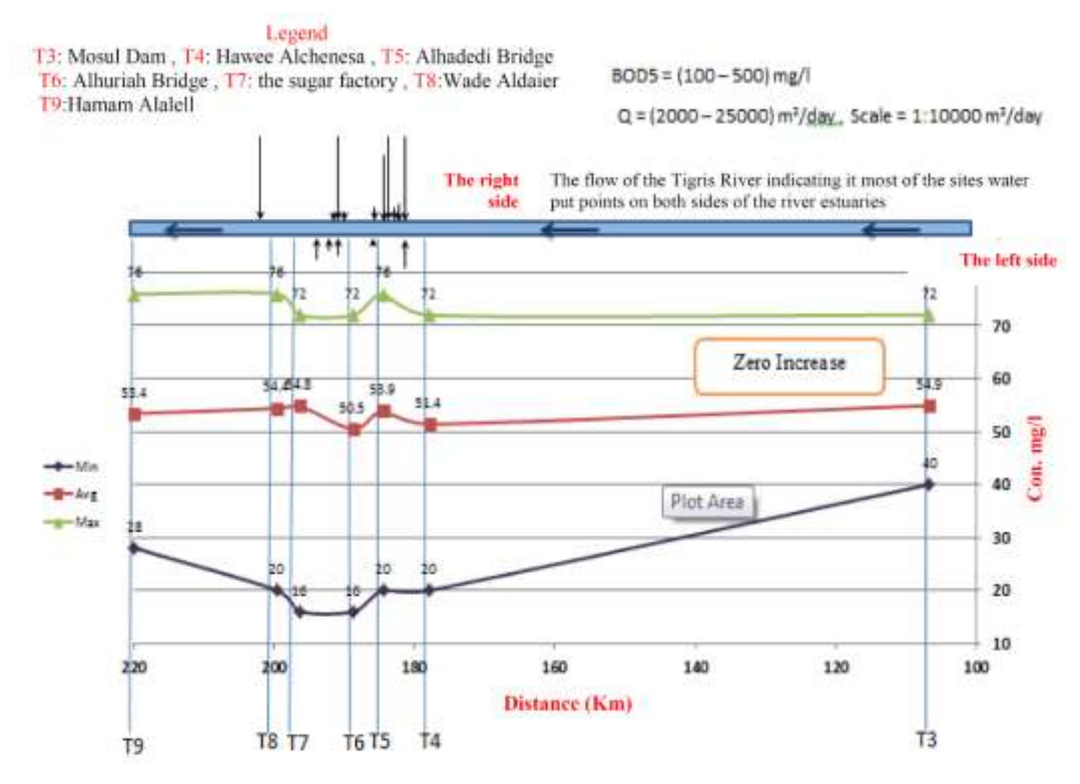


Figure 5. Represents Ca concentration variation through the river

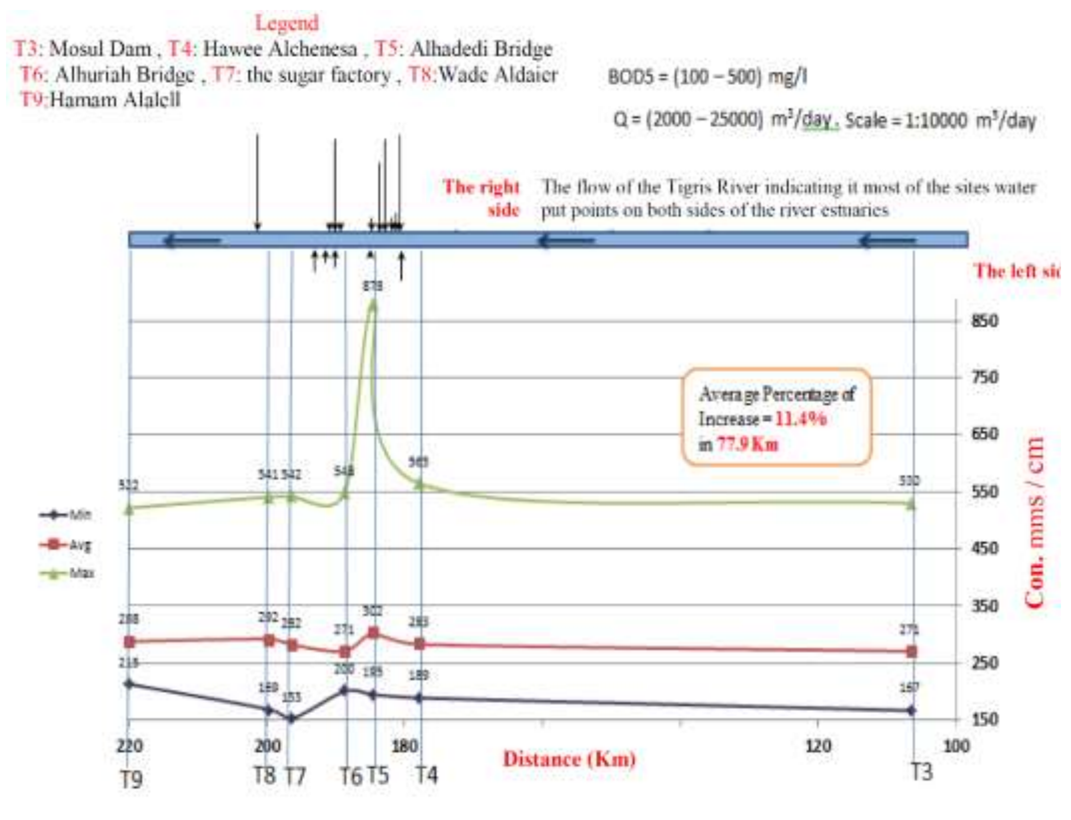


Figure 6 .Shows the EC variation along the river

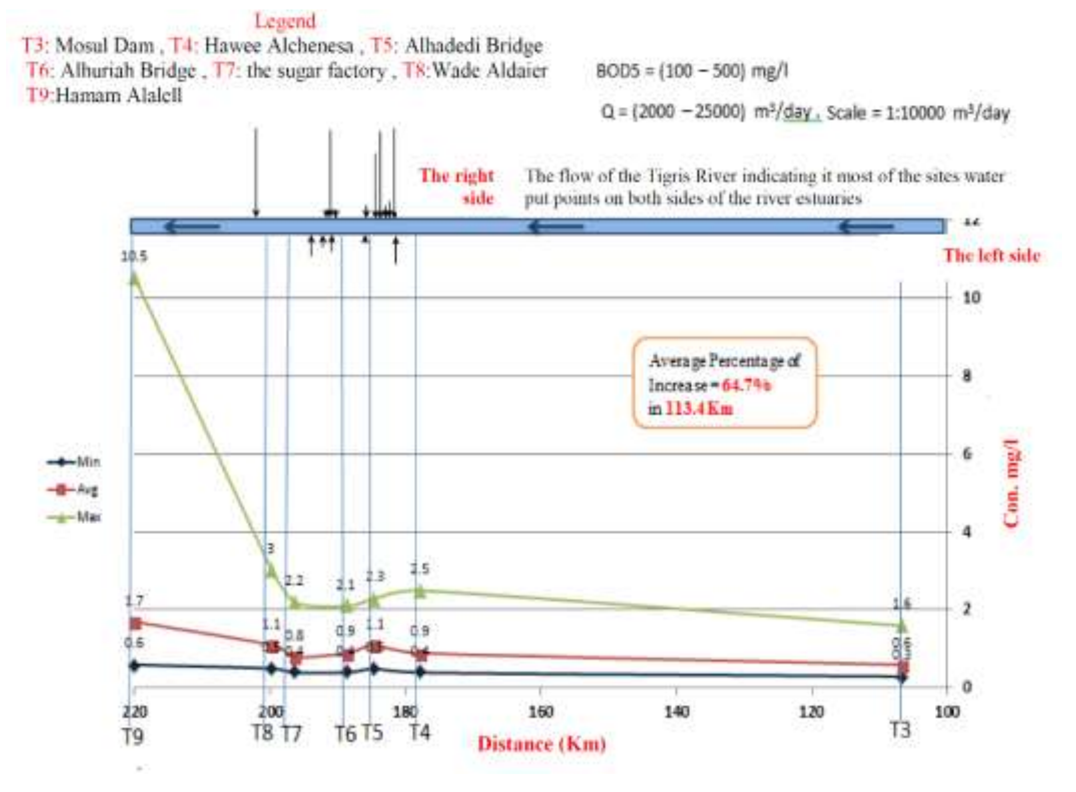


Figure 7 .Shows The BOD5 variation along the river

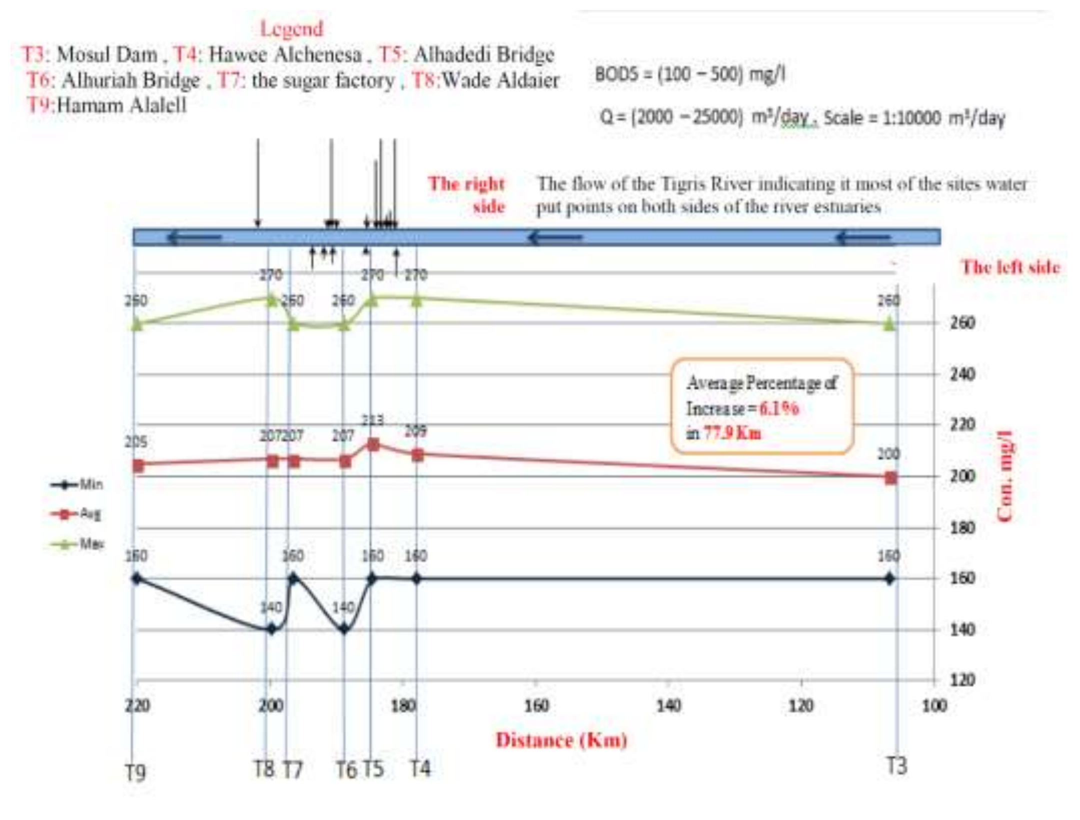


Figure 8. Demonstrates the TH variation along the river

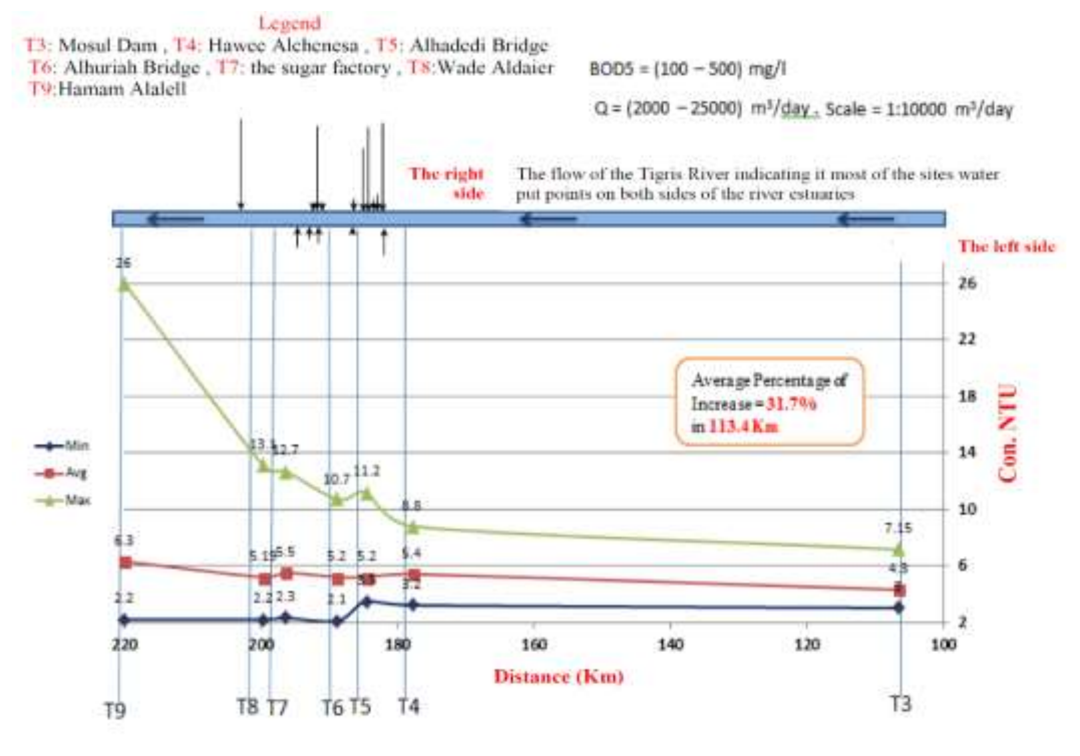


Figure 9. Shows Turbidity variation along the river

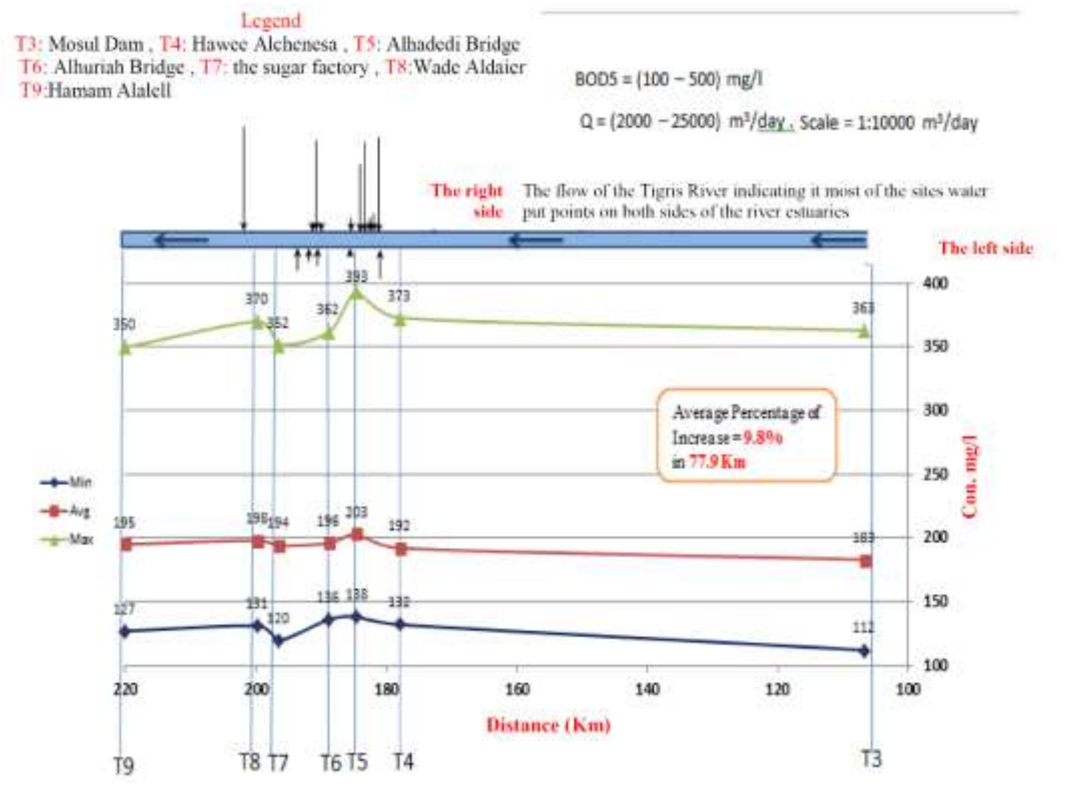


Figure 10. Shows TDS concentration along the river

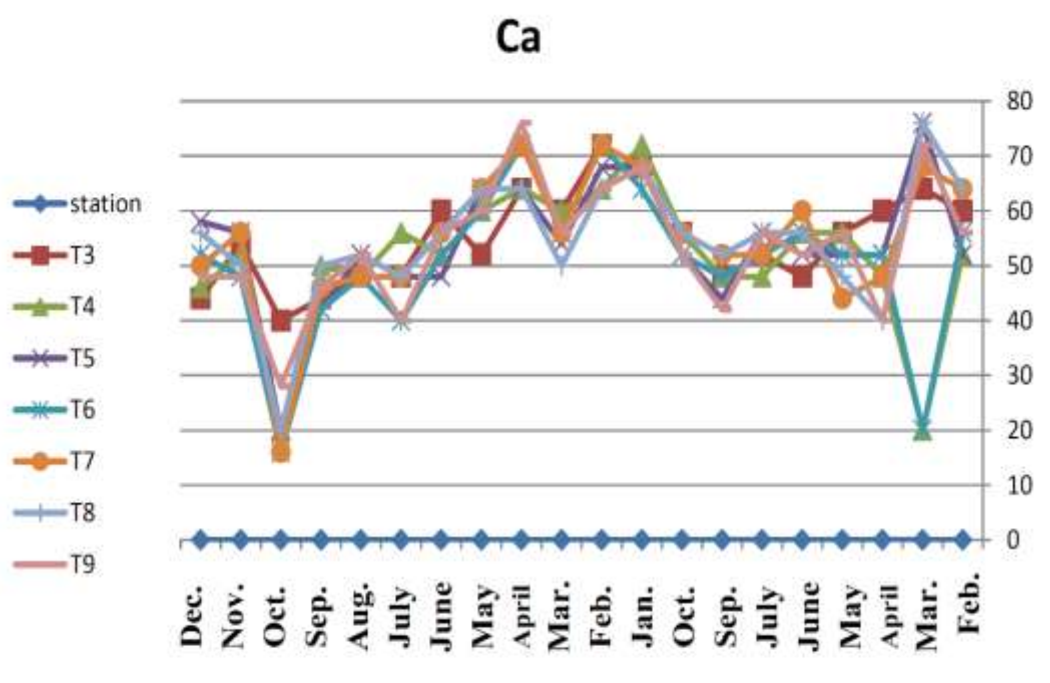


Figure 11. Represents a change in (Ca) concentration with time for all stations in the river section

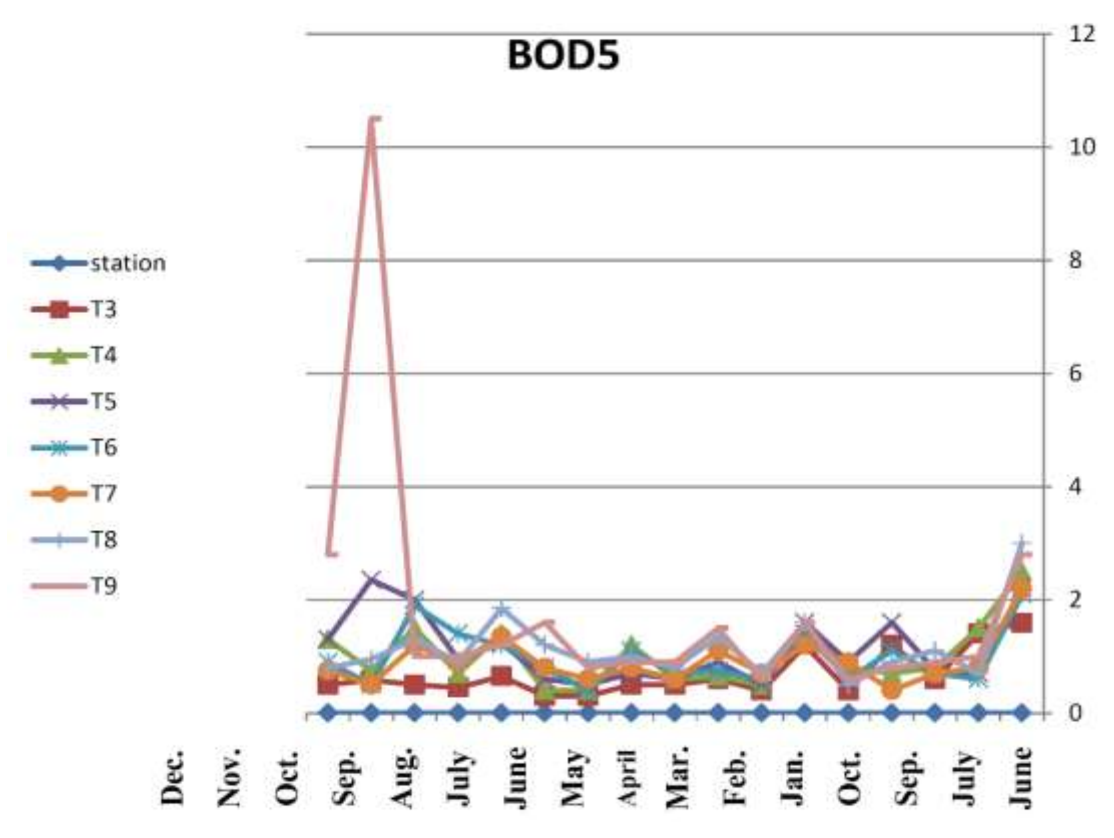


Figure 12. Represents a change in BOD_5 concentration with time for all stations in the river section

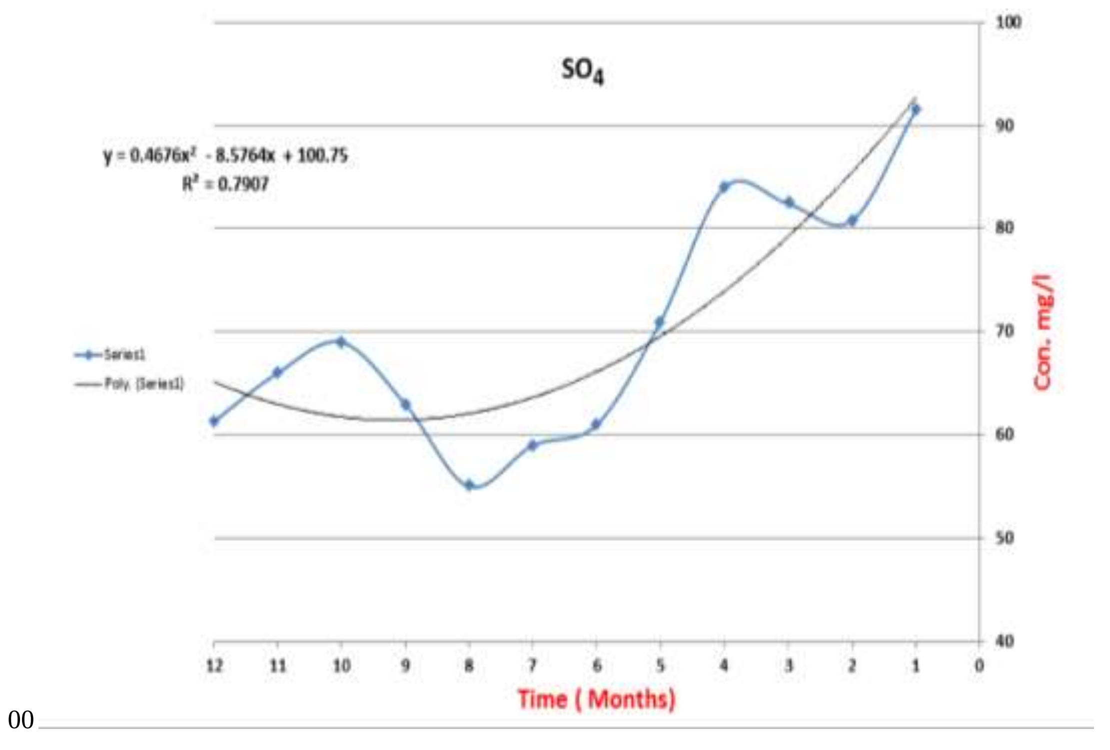
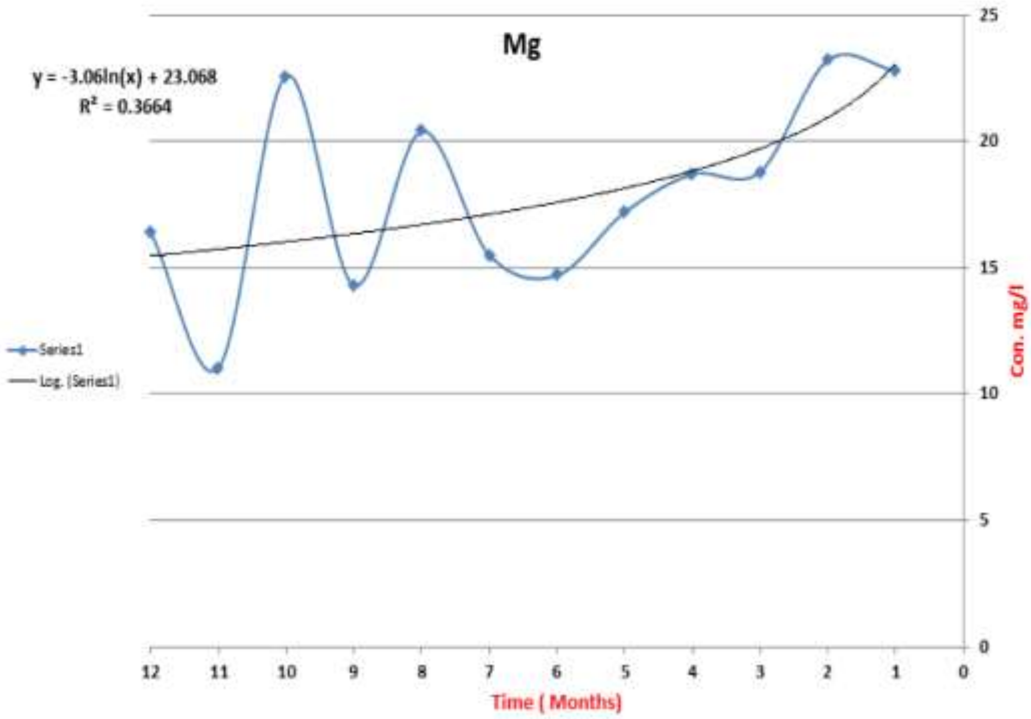


Figure 13. Represents a change in SO_4 concentration with time for all stations in the river section



00

Figure 14. Represents a change in Mg concentration with time for all stations in the river section

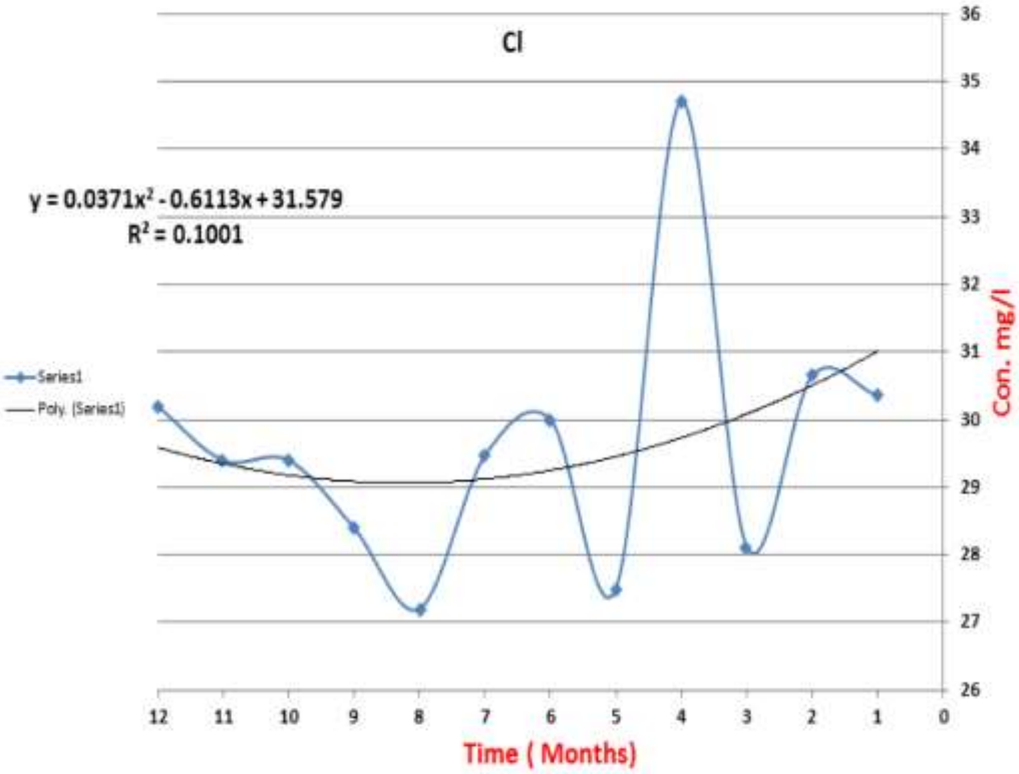


Figure 15. Represents a change in Cl concentration with time for all stations in the river section

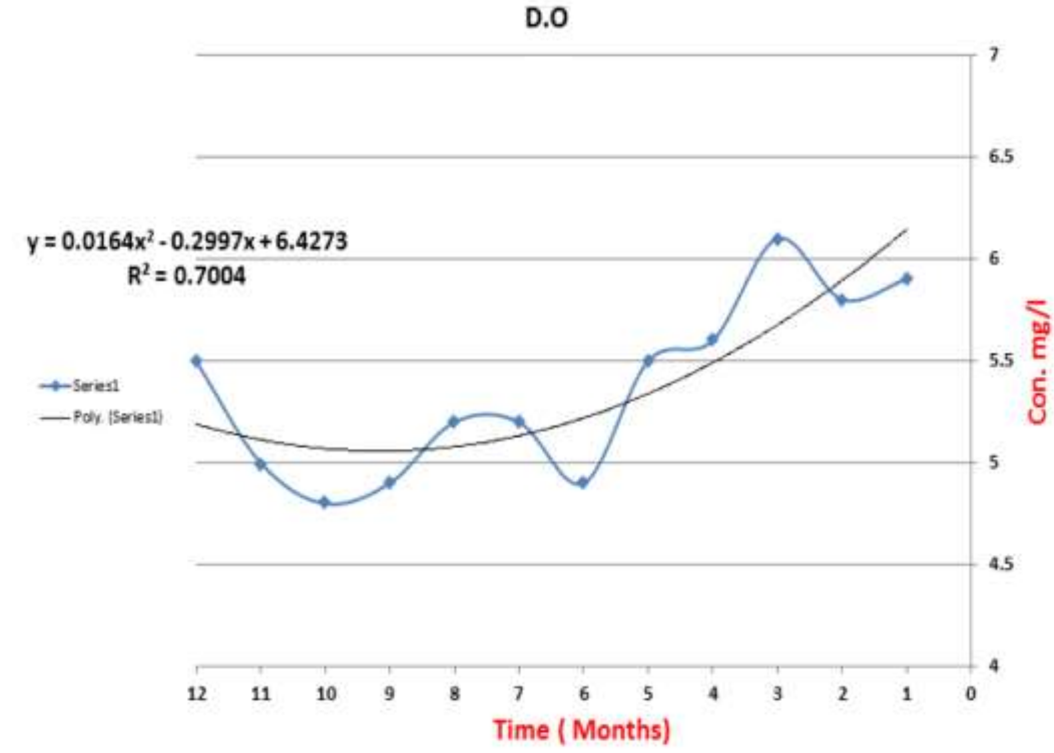


Figure 16. Represents a change in DO concentration with time for all stations in the river section

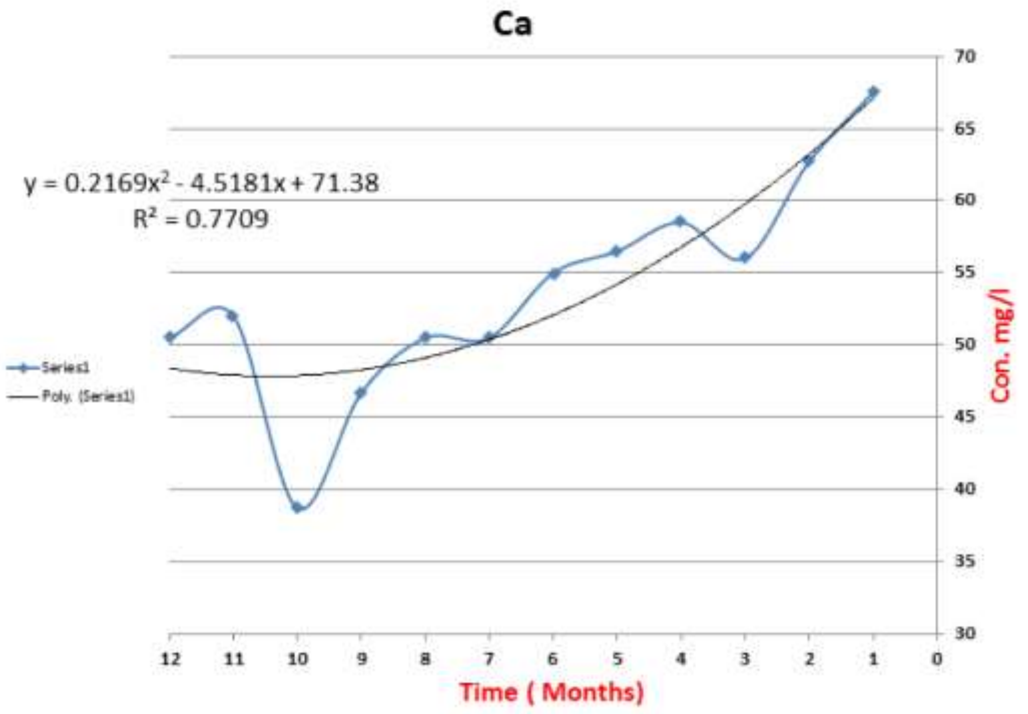


Figure 17. Represents a change in Ca concentration with time for all stations in the river section

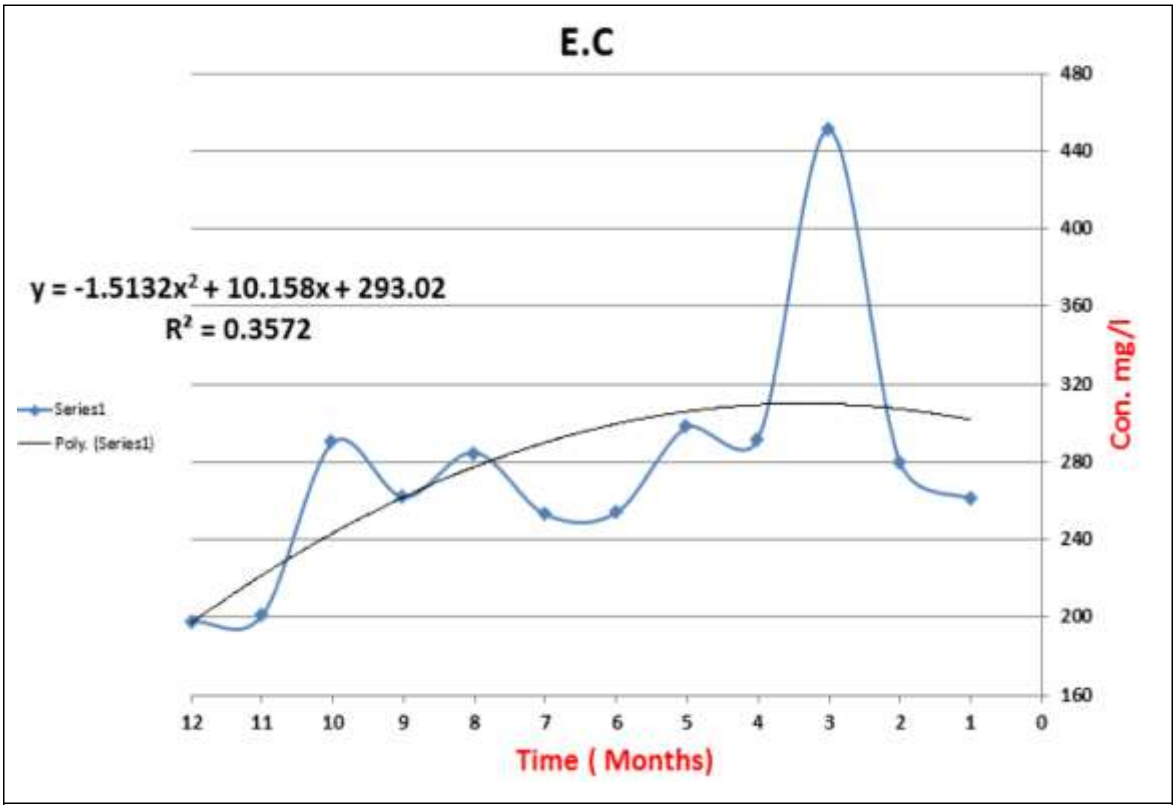


Figure 18. Represents a change in E.C concentration with time for all stations in the river section

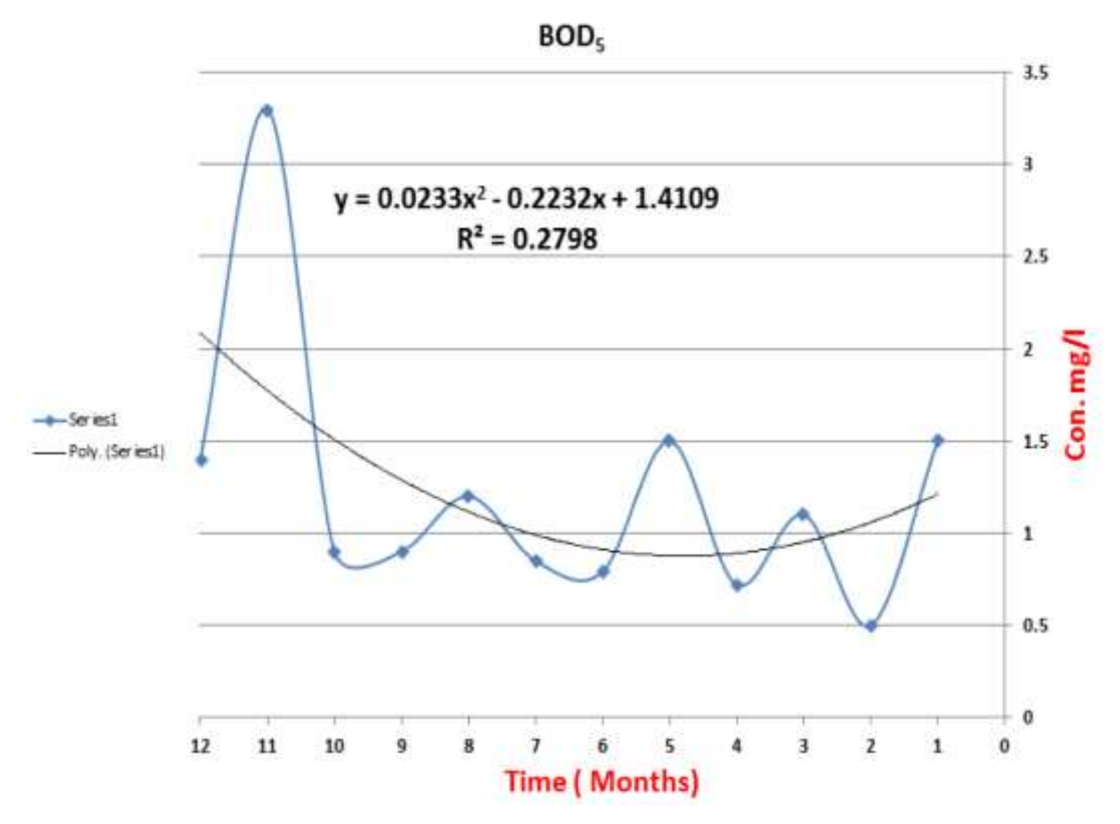


Figure 19. Represents a change in BOD_5 concentration with time for all stations in the river section

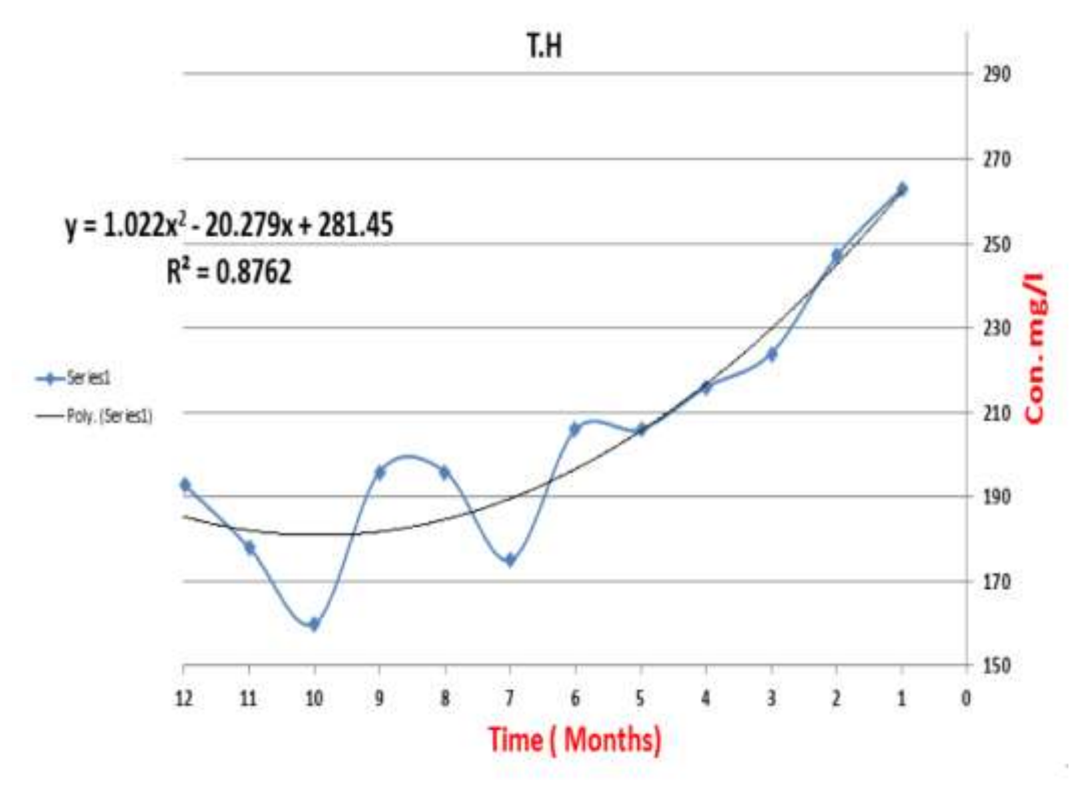


Figure 20. Represents a change in T.H concentration with time for all stations in the river section

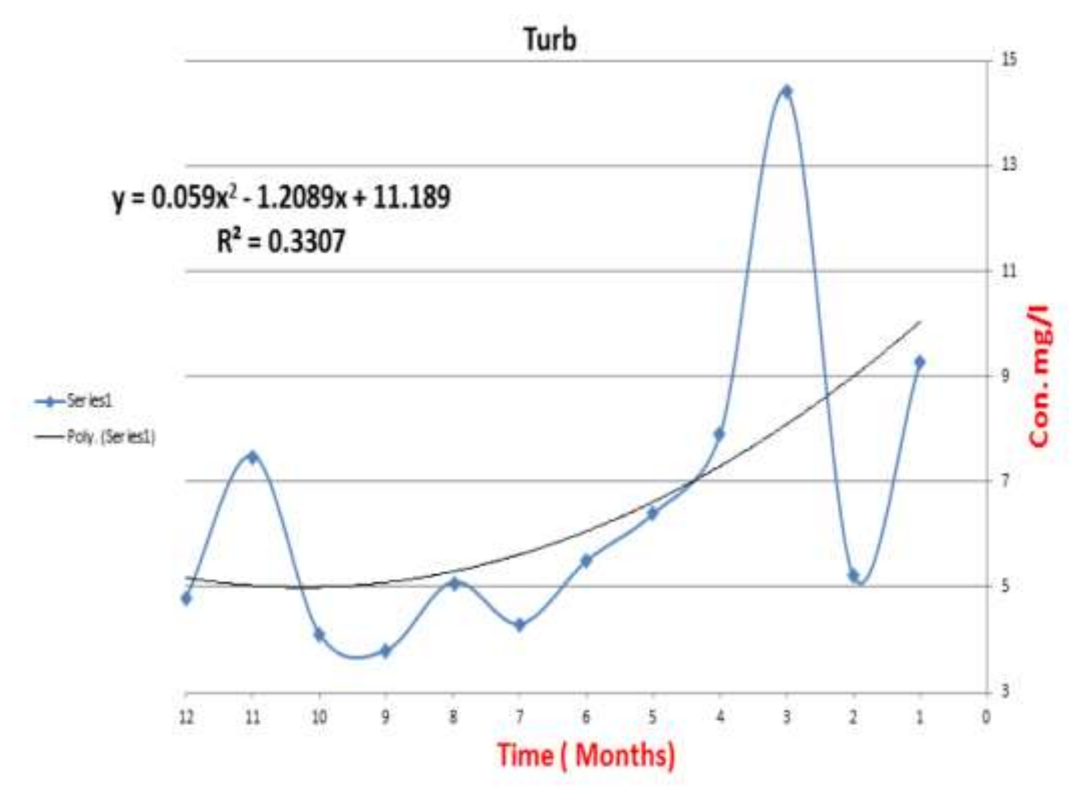


Figure 21. Represents a change in Turb. concentration with time for all stations in the river section

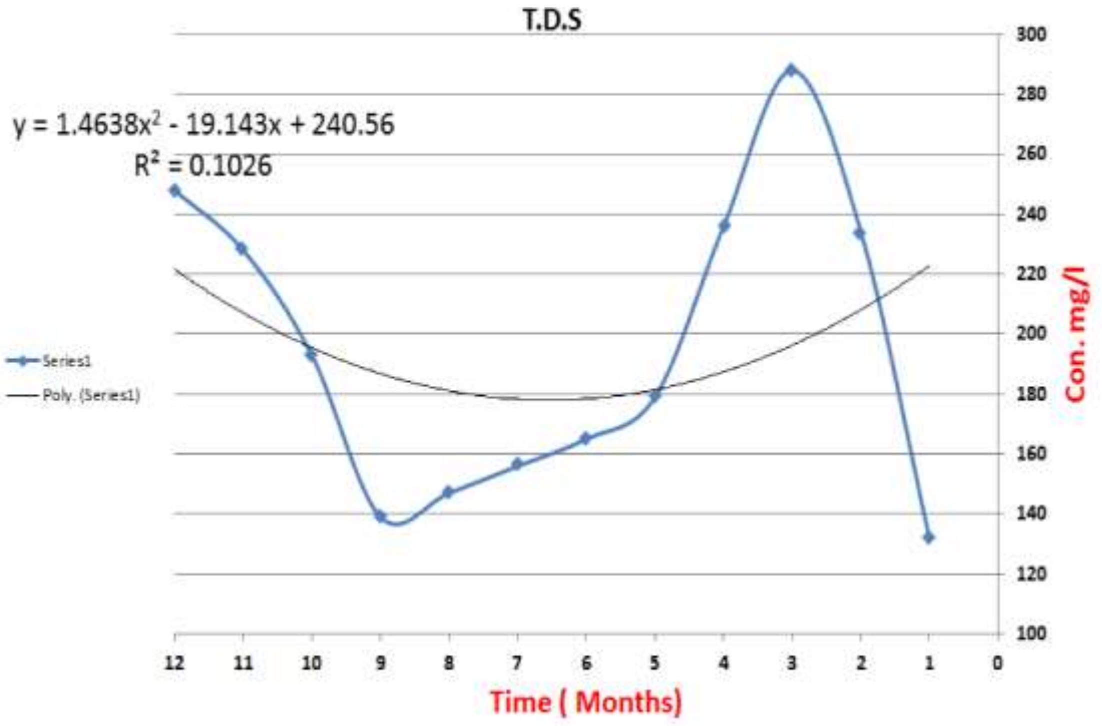


Figure 22. represents the change in TDS concentration with time for all stations in the river section.

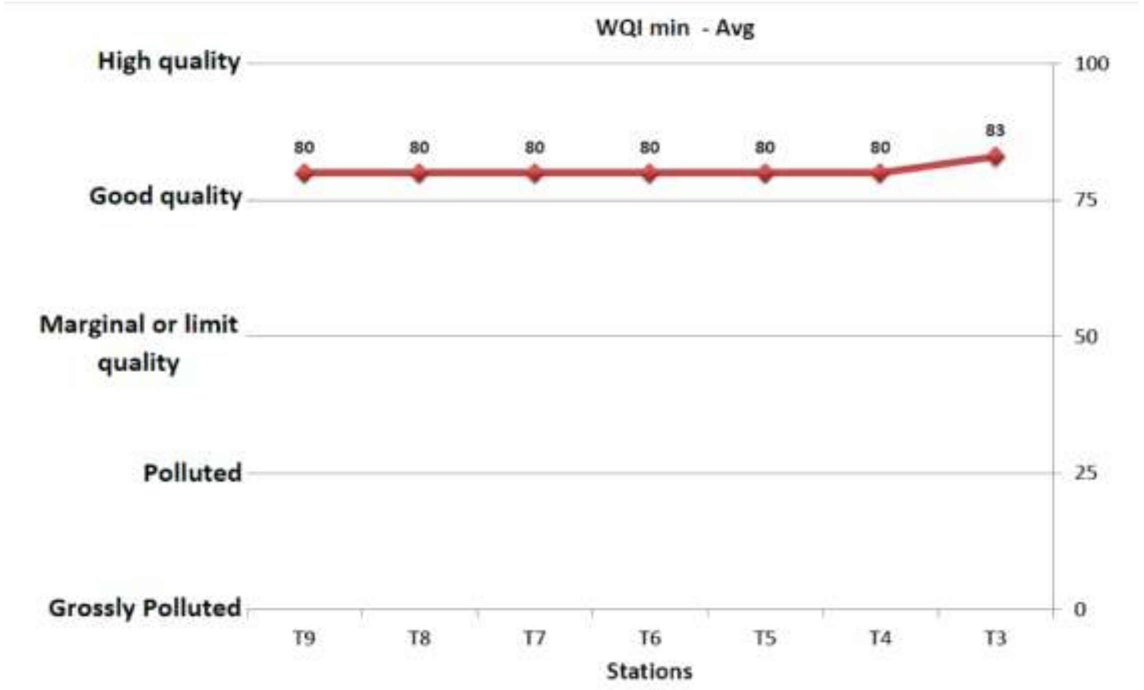


Figure 23. Results of the WQImin calculation for the water of the Tigris River using equation 1 (equation of Pesce and Wunderline ,2000).

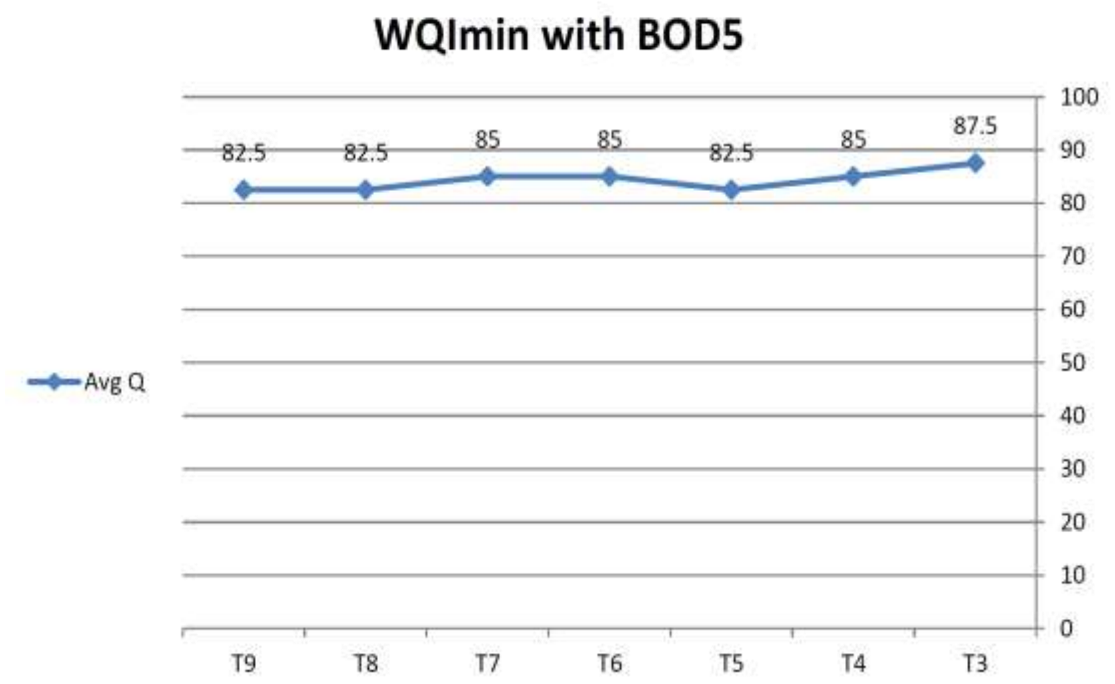


Figure 24. Results of the WQImin calculation of the water of the Tigris River by equation 2 (the equation developed by the authors of this research work).