American Journal of Earth and Environmental Sciences
2018; 1(1): 10-19
http://www.aascit.org/journal/ees

Evaluation of Water and Sediment Quality of the Tigris River, Baghdad City, Iraq

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Citation

Yasser Ahmed El-Amier, Oday Negm Al-Hadithy, Oday Gamal Kadhim, Muhammad Abd El-Hady El-Alfy. Evaluation of Water and Sediment Quality of the Tigris River, Baghdad City, Iraq. *American Journal of Earth and Environmental Sciences.* Vol. 1, No. 1, 2018, pp. 10-19.

Received: January 2, 2018; **Accepted**: January 16, 2018; **Published**: February 5, 2018

Abstract: Tigris River is one of the largest rivers in Iraq and is considered the main source of drinking water for Baghdad City. With the development of industry, agriculture and the growth of urban population, its pollution has become a serious problem. So it is an important target to evaluate water and sediment quality properties, in addition to analysis of trace metals (Fe^{+2}, Cu^{+2}, Zn^{+2}, Cr^{+3} and Co^{+2}). Ten representative locations were taken along the river within Baghdad city. It's noticeable that downstream of the river is more contaminated than locations at the upstream. From AWQI, it is an indicator of good water quality. Heavy metals in water are Nil. While the order of these metals in sediments are; $Fe^{+2} > Cu^{+2} > Cr^{+3} > Zn^{+2} > Co^{+2}$. All of the parameters are within the standard limits of WHO (2008) and Iraq standards for drinking water. Pollution load index of metals in sediments give an indication of low pollution level in river sediments. It's recommended to treat drainage water from point pollution sources along the river, in addition to prevention of discharging drainage water from the agricultural areas directly into the river.

Keywords: Water, Sediment, Heavy Metals, Tigris River, Iraq

1. Introduction

The aquatic environment with its water quality is considered the main factor controlling the state of health and disease in both cultured and wild fishes. Pollution of the aquatic environment by inorganic and organic chemicals is a major factor posing a serious threat to the survival of aquatic organisms including fish [1].

Increasing water pollution causes not only the deterioration of water quality but also threatens human health and the balance of aquatic ecosystems, economic development and social prosperity. So the water quality should be kept in acceptable standards to suit agricultural, human using, and industrial purposes. This requires set of procedures that based on scientific rules. The chemical processes used to treat water can affect water quality in a water distribution system [2-4].

Rivers in urban areas have been associated with water quality problems because of the practice of discharging of untreated domestic and small scale industries into the water bodies [5]. The Tigris River is one of the largest rivers in Iraq and is considered the main source of drinking water for Baghdad, which is the largest city in the country and the second largest city in the Arab world with a population estimated by 7.5 million. It is an important water source for the city, and it serves for irrigation, fishing, recreation and receiving wastewater. With the development of industry, agriculture and the growth of urban population, its pollution has become a serious problem. Pollution from domestic, industrial and agricultural activities has led to the deterioration of water quality [6, 7].

Salah *et al*. [8] stated that the increasing military activities in Iraq since 1980 resulted in establishing many military factories along the Euphrates and Tigris rivers. These factories led to an increase in environmental problems including water contamination and ecosystem degradation. Sediments have been reported to form the major repository of heavy metal in the aquatic system while both allochthonous and autochthonous influences could make the concentration of heavy metals in the water high enough to be of ecological significance [9]. Metal contamination is another problem in the aquatic bodies and has great concern because of its toxicity for the environment and human beings, non-degradable, persistence and ability to be accumulated in food chains [10]. The aim of our work is to evaluate the water and sediment quality and assess contamination of trace metals within Tigris River.

2. Materials and Methods

2.1. Study Area

Tigris is nearly 2000 Km long, of which 1360 Km runs through Iraq, rising in the Taurus Mountains of eastern Turkey and flowing in a generally southeasterly direction until it joins the Euphrates near in southern Iraq [11, 12]. The River enters Baghdad city at coordinates 44°24' E, 33°36' N and divides the city into two parts (Karkh & Risafa). The length of the river along Baghdad city is about 110 km [13]. In the present study, ten stations were chosen from Tigris River within Baghdad City (Figure 1).

Baghdad has a subtropical desert climate (Köppen climate classification) and is one of the hottest cities in the world [14]. In the summer from June to August, the average temperature 32.3 to 34°C. Winters boast mild days and chilly nights. From December to February, Baghdad has average temperature 9.65 to 12°C (Figure 2a). Annual rainfall, almost entirely confined to the period from November to March, the averages around 150 mm, but has been as high as 338 mm and as low as 37 mm. The average rainfall 3.3 mm/month in October to 27.2 mm/month in January. The humidity is typically very low due to Baghdad's distance from the marshy southern Iraq and the coasts of Persian Gulf (Figure 2b), and dust storms from the deserts to the west are a normal occurrence during the summer [15].

Figure 1. Location map of Tigris River and sampling sites.

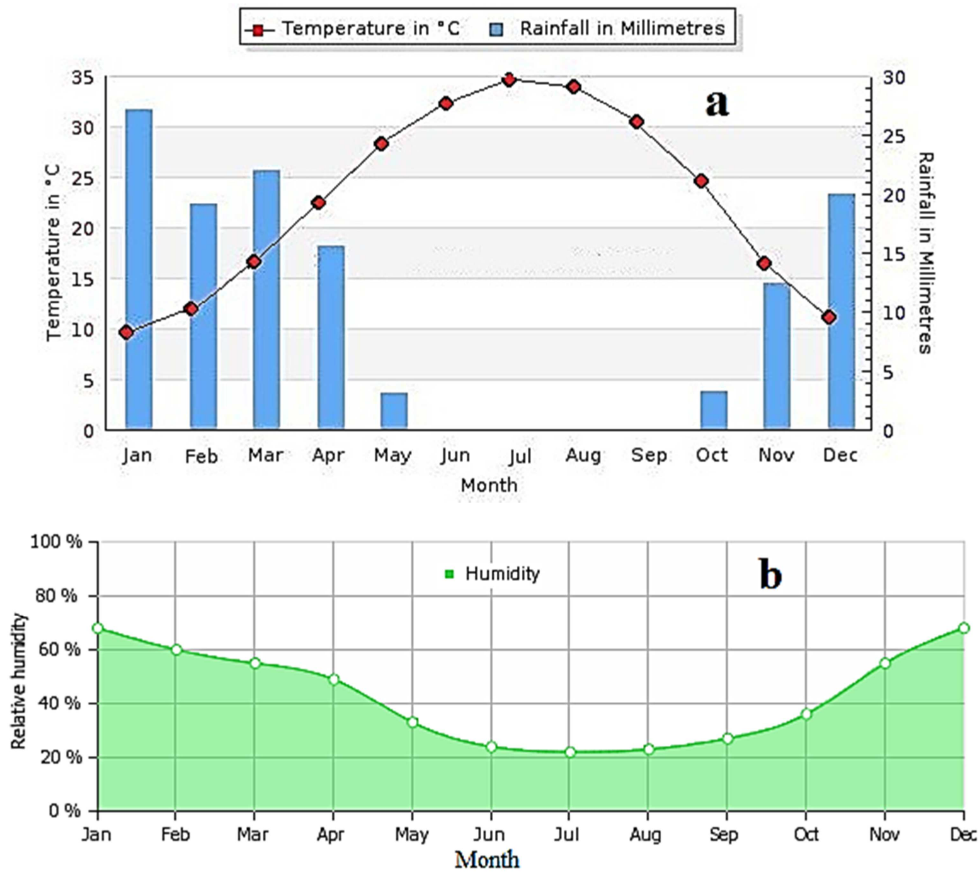

Figure 2. *Climate graph showing: a) average rainfall and temperatures and b) average relative humidity in Baghdad City, Iraq.*

2.2. Sampling and Analysis

Ten geo-referenced, representative water and sediment samples were collected from Tigris River distributed along with Baghdad City (Table 1). Surface water samples were collected and then stored in acid-washed polyethylene bottles for analyses. Then, these samples were filtered using 0.45 um membrane filters. Sediment samples were collected from the stations of the Tigris River. All samples were then carried to the laboratory in plastic bags shortly after collection. The samples were spread over sheets of paper, air dried, thoroughly mixed, passed through a 2 mm sieve to remove gravel and debris, then packed in plastic bags ready for physical and chemical analyses.

Table 1. *Sites description in Tigris River.*

No	Latitude (N)	Longitude (E)	Description
1	24.133323	36.104420	Gherai´at
2	39.113321	21.264422	Adamiyah
3	35.203320	48.374422	Bab Al Moatham Bridge
4	53.293319	41.294423	Al Salhiah (Sink Bridge)
5	42.943318	58.864424	Abu Nuwas
6	42.993317	59.814423	Aa'mah Bridge
7	08.713316	07.084422	Jadriyah
8	28.863317	08.594426	Karada-Masbah St
9	16.363317	50.674426	Dora, Agricultural Activities
10	01.273314	14.524427	Bo'aitha, Oil Industry, Agricultural Area

2.3. Sediment Analysis

The texture of sediment samples, water-holding capacity, organic matter and chlorides was determined according to Piper [16]. Electric pH-meter was used to determine the soil reaction. Electrical conductivity was measured by YSI Incorporated Model 33 conductivity meter. Carbonates and bicarbonates were determined according to [17]. Sulphates were estimated gravimetrically and the available phosphorus was determined by direct stannous chloride method [18], while the available nitrogen was determined by the micro-Kjeldahl method according to Allen *et al.* [19]. The method of different elements extraction (Na^+, K^+, Ca^{+2} and Mg^{+2}) and heavy metals (Fe^{+2}, Zn^{+2}, Pb^{+2}, Cu^{+2}, Cr^{+3}, Cd^{+2} and Co^{+2}) were carried out according to Allen *et al*. [20].

2.4. Water Analysis

Electrical conductivity was measured directly using conductivity meter (Model Corning, NY 14831 USA), the pH value of surface water was measured in situ by using Electrical-pH meter (Model Lutron YK-2001pH meter). The BOD_5, COD, chloride and total phosphorus according to APHA [18]. Calcium carbonate content was determined according to Welch [21]. Sulphate content was estimated gravimetrically according to Jackson [22]. Water-soluble carbonates and bicarbonates were determined according to Baruah and Barthakur [23]. The total nitrogen was determined by the micro-Kjeldahl method according to Allen *et al*. [19]. Determination of phosphate and nitrate in water samples was carried out according to the methods described by Grasshoff [24]. The method of extraction of different elements (Na^+, K^+, Ca^{+2} and Mg^{+2}) and heavy metals (Fe^{+2}, Zn^{+2}, Pb^{+2}, Cu^{+2}, Cr^{+3}, Cd^{+2} and Co^{+2}) was described by Allen *et al*. [20].

2.5. Water Quality Index (WQI)

WQI is a mathematical way of summarizing multiple properties into a single value. Typically, WQI ranges between 0 –100, with higher numbers indicating lower quality water. WQI is useful for comparing differences in water quality across a region, or for monitoring changes in water quality over time. In the present study, WQI was calculated using the equation developed by Tiwari and Manzoor [22]. The quality rating qi, for the water quality parameter can be obtained by the following relation:

$$q_i = 100(\frac{V_i}{S_i})$$

Where V_i is the observed value of the parameter at a given sampling site and S_i is the stream water quality standard. Equation (1) ensures that q_i = 100 if the observed value is just equal to its standard value. Thus, the larger value of q I revealed polluted the water. To calculate WQI, the quality rating qi corresponding to the parameter can be determined using equation (2). The overall WQI was:

$$WQI = \sum_{i=1}^{n} q_i$$

The average water quality index (AWQI) for n parameters was calculated using the following equation (3):

$$AWQI = \sum_{i=1}^{n} q_i / n$$

Where n = number of parameters. AWQI was classified into 4 categories: good (0.0 – 100), medium (100 – 150), bad (150 – 200) and very bad (over 200).

3. Results and Discussion

3.1. Assessment of Physical and Chemical Parameters in Sediments

Sediment quality is a good indicator of pollution in water column, where it tends to concentrate the heavy metals and other organic pollutants [26]. Physical and chemical parameters of sediments were as shown in Table 2. The texture of soil analysis characterized to clayey loam at site 1 and site 2, loamy at sites (3, 7 and 8) and silt loam at other sites. The organic matter (OM) of the study area ranged from 1.18 in site 6 to 1.75 in site 4 with a mean value of 1.43%. While the OM attributed to the nature of sediments like clay minerals [27]. Organic matter showed the low difference between stations. There is no significant difference in electrical conductivity between locations. While it increased towards the end of the river as it ranges between (1.65 to 1.93) with a mean value of 1.81 ds/m. For cations, there is a significant difference among different stations for Na^+ and K^+, moderate for Ca^{+2} and low for Mg^{+2}. They were take the following sequence; Ca^{+2} > Na^+> Mg^{+2}> K^+ with mean values 48.15, 41.21, 18.46 and 14.65 mg/l respectively. While Ca^{+2} is moreover Mg^{+2} in sediments of freshwater [28].

Table 2. *Sediments analysis of different stations in the study area. WHC: water holding capacity, Av. Water: available water, EC: electrical conductivity, TDS: total dissolved solids, OM: Organic matter, Av. N: total nitrogen, Av.P: total phosphorus, Av. K: available potassium, Values are significant at *P ≤ 0.05, ** P ≤ 0.01, *** P ≤ 0.001.*

Soil variables		Units	Stations										Mean	P-value
			1	2	3	4	5	6	7	8	9	10		
Physical characteristics	Sand	%	22.00	23.00	30.50	27.00	26.00	25.00	32.00	31.00	28.50	23.50	26.85	0.000***
	Silt		45.00	40.00	46.50	51.00	53.00	52.00	41.00	44.00	51.50	52.50	47.65	0.000***
	Clay		33.00	37.00	23.00	22.00	21.00	23.00	27.00	25.00	20.00	24.00	25.50	0.000***
	WHC		48.70	46.50	40.20	44.70	45.30	44.50	38.50	41.50	43.60	45.00	43.85	0.02*
	Av. Water		9.70	10.70	8.30	8.80	10.80	9.50	8.50	8.50	10.40	9.50	9.47	0.03*
Chemical characteristics	pH		7.72	7.65	7.78	7.69	7.85	7.81	7.76	7.58	7.62	7.54	7.70	0.1^{ns}
	EC	ds/m	1.65	1.76	1.70	1.81	1.84	1.78	1.85	1.89	1.93	1.90	1.81	0.267^{ns}
	TDS	%	0.21	0.23	0.22	0.23	0.24	0.23	0.24	0.24	0.25	0.24	0.23	0.99^{ns}
	OM		1.29	1.45	1.32	1.75	1.53	1.18	1.50	1.25	1.64	1.36	1.43	0.0014**
	SO_4^{-2}		0.039	0.040	0.038	0.041	0.041	0.040	0.041	0.045	0.046	0.045	0.04	0.89^{ns}
	Cl^-		0.046	0.048	0.048	0.050	0.052	0.049	0.049	0.049	0.050	0.050	0.05	0.79^{ns}
	HCO_3^-		0.017	0.019	0.018	0.018	0.018	0.018	0.018	0.018	0.019	0.018	0.02	0.99^{ns}
	CO_3^{-2}		2.10	18.90	20.60	25.10	23.50	21.30	19.60	22.80	24.80	23.90	20.26	0.000***
	Av. N		3.18	4.93	4.55	6.56	5.27	2.54	5.63	3.8	5.98	4.78	4.72	0.000***
	Av. P		1.35	2.01	1.70	2.63	2.25	0.98	2.19	1.24	2.30	1.98	1.86	0.000***
	Av. K		13.60	14.60	14.30	17.80	16.00	11.30	15.40	12.80	16.80	13.90	14.65	0.000***
	Na^+	Mg+2/100g dry soil	37.50	38.90	39.10	37.90	41.00	39.60	41.80	44.10	46.80	45.40	41.21	0.000***
	Ca^{+2}		45.30	47.90	46.00	49.10	48.80	48.40	48.50	49.00	49.60	48.90	48.15	0.01**
	Mg^{+2}		18.00	19.30	17.60	18.80	18.30	19.10	18.10	18.70	18.50	18.20	18.46	0.03*

Available nitrogen and phosphorus showed a significant difference between stations. The lowest mean value of nitrogen and phosphorus were recorded at site 6. The highest mean values of available nitrogen and phosphorus were recorded in site 4, may attributed to anthropogenic activities. Elnaggar and El-Alfy [29] observed high concentrations of available nitrogen and phosphorus in sediments of Manzala Lake nearby sites impacted by agricultural and domestic wastes. Struyf *et al.* [30] stated that the increase in N and P content observed between impacted and un-impacted sites likely reflect the effect of human-induced nutrient enrichment.

3.2. Assessment of Heavy Metals Concentrations in Sediments

As shown in Table 3, the range of trace metals in mg/kg are as follow: Fe^{+2} (61.67-64.01), Cu^{+2} (0.70-0.89), Zn^{+2} (0.53-60), Cr^{+3} (0.60-0.71) and Co^{+2} (0.36-0.41). So the order of these metals in sediments are; Fe^{+2} > Cu^{+2} > Cr^{+3} > Zn^{+2} > Co^{+2}, from statistical analysis, it's obvious that there is a significant difference between different stations for Fe *(P<0.001)*, no significance for Cu^{+2}, Zn^{+2} and Cr^{+3}. While there is a little significant variation for Co^{+2}. The highest values for Fe^{+2} and Cu^{+2} were recorded at site 6 may attributed to the texture of sediments and organic content [31]. When the organic matter is abundant, it increases the chance of increasing of heavy metals concentrations [32]. The concentrations of metals are within the European Union Standards [33] and within EPA [34] except for Fe^{+2}.

Table 3. *Concentrations of metals in sediment samples.*

Metal	Stations										*Mean*	*P-value*	*EU (2002)*	*EPA (2002)*
	1	2	3	4	5	6	7	8	9	10				
Fe^{+2}	63.15	62.11	63.21	61.67	62.23	64.01	63.53	63.83	63.78	63.40	63.09	0.000^{***}	-	15
Cu^{+2}	0.83	0.73	0.85	0.70	0.73	0.89	0.76	0.83	0.87	0.85	0.80	0.64^{ns}	140	25
Zn^{+2}	0.59	0.59	0.60	0.53	0.56	0.59	0.56	0.58	0.59	0.54	0.57	0.96^{ns}	300	300
Cr^{+3}	0.65	0.60	0.70	0.63	0.64	0.70	0.62	0.71	0.71	0.70	0.67	0.92^{ns}	150	150
Co^{+2}	0.39	0.38	0.39	0.37	0.36	0.39	0.37	0.40	0.40	0.41	0.39	0.04^{*}	-	-

*Cd and Pb are nil in all sediment samples

The highest concentrations of Zn^{+2} was recorded at site 3 (commercial areas) may be attributed to drainage water thrown on this site especially, industrial wastes and or from anthropogenic activities i.e. the discharge of industrial wastes especially electroplating and synthetic fiber production [35, 36]. The highest concentration of Cr^{+3} was obtained in the downstream of river nearby stations 8 and 9 which characterized by many activities i.e. agricultural; and industrial activities. Large quantities of chromium may be released from pulp and paper mills, cement and fertilizer plants, textile mills, power plants, chlor-alkali plants, and petrochemical industries. Urban runoff and industrial storm waters can be important contributors for Cr^{+3} to the aquatic environment [37]. For Co^{+2}, the highest mean value was recorded at the downstream (station 10), may attributed to industrial and/or agricultural wastes as fertilizers especially triple super phosphate that is a rich source of nephrotoxic metals including Co^{+2} and other metals [38].

3.3. Metal Pollution Indices in Sediments

3.3.1. Enrichment Factor (EF)

The ranges of enrichment factor of metals in sediments were as follow: Cu^{+2} (11.91-14.58), Zn^{+2} (4.23-4.64), Cr^{+3} (5.07-5.84) and Co^{+2} (14.37-16.07) (Table 4, Figure 3). It's obvious that EF values > 2 and it likely to be from anthropogenic activities nearby the river bank. Co^{+2} is recorded the highest enrichment between other metals especially in site 10 at the downstream also this station characterized by industrial and agricultural activities, may attributed to the impurities that exist in superphosphate fertilizers [36].

Table 4. *Enrichment factor of heavy metals in sediment samples.*

Station	EF			
	Cu	Zn	Cr	Co
1	13.79	4.64	5.40	15.34
2	12.33	4.72	5.07	15.20
3	14.10	4.72	5.81	15.33
4	11.91	4.27	5.36	14.90
5	12.30	4.47	5.39	14.37
6	14.58	4.58	5.74	15.14
7	12.55	4.38	5.12	14.47
8	13.64	4.51	5.83	15.57
9	14.31	4.60	5.84	15.58
10	14.06	4.23	5.79	16.07

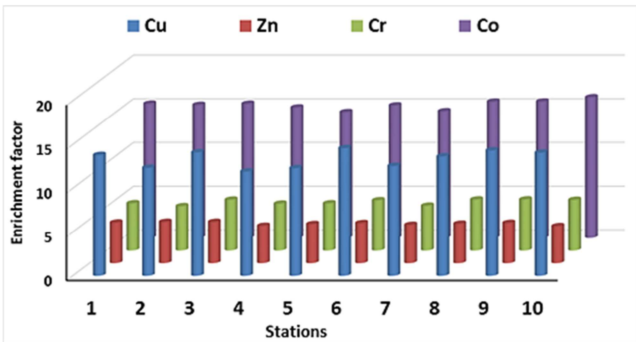

Figure 3. *Enrichment factor of metals in sediments of Tigris River.*

3.3.2. Contamination Factor (CF), PLI and DC

As shown in Table 5 the calculation of CF for metals in sediment samples, its ranges were; Fe^{+2} 0.0013 in all sites except for sites 6, 8, 9, were they characterized by industrial and agricultural activities. For Cu^{+2}, it varied between 0.0162 at sites 2, 5 to 0.0198 at site 6. For Zn^{+2} it varied from 0.056 at site 4 to 0.063. While CF for Cr^{+3}, it ranged between 0.0069 to 0.0079 in sites 8 & 9. For Co^{+2}, CF varied from 0.0189 at site 5 to 0.0216 at site 10. From the previous results, it indicated that CF for all metals showed low contamination factor (Figure 4). From PLI results, values were lower than 1 so indication to low pollution level. Also DC was a low category in all stations (Figure 5).

Table 5. *Contamination factors (CF), pollution load index (PLI) and contamination degree (DC) of heavy metals.*

Station	CF					PLI	DC
	Fe^{+2}	Cu^{+2}	Zn^{+2}	Cr^{+3}	Co^{+2}		
1	0.0013	0.0184	0.0062	0.0072	0.0205	0.0074	0.0537
2	0.0013	0.0162	0.0062	0.0067	0.0200	0.0071	0.0504
3	0.0013	0.0189	0.0063	0.0078	0.0205	0.0076	0.0548
4	0.0013	0.0156	0.0056	0.0070	0.0195	0.0069	0.0489
5	0.0013	0.0162	0.0059	0.0071	0.0189	0.0070	0.0495
6	0.0014	0.0198	0.0062	0.0078	0.0205	0.0077	0.0556
7	0.0013	0.0169	0.0059	0.0069	0.0195	0.0071	0.0505
8	0.0014	0.0184	0.0061	0.0079	0.0211	0.0076	0.0548
9	0.0014	0.0193	0.0062	0.0079	0.0211	0.0077	0.0558
10	0.0013	0.0189	0.0057	0.0078	0.0216	0.0075	0.0553

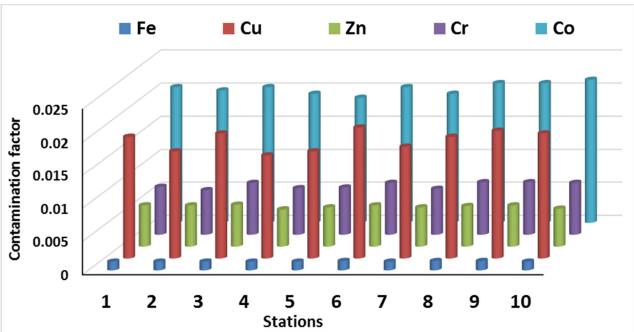

Figure 4. *Contamination factors of metals in sediments of Tigris River.*

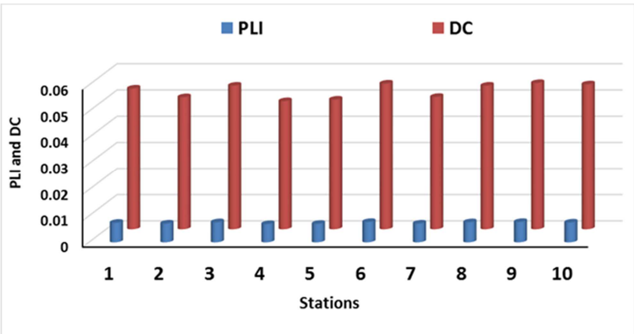

Figure 5. *PLI and Dc of metals in sediments of Tigris River.*

3.3.3. Geo-Accumulation Index (Igeo)

The I*geo* for all metals attains unpolluted degree for in all stations (Table 6, Figure 6). Rabee *et al.* [12] showed pollution of Tigris river sediments with Pb^{+2} and Cd^{+2}. The decrease in values of PLI and Dc indicate that dilution and dispersion of metal content with increasing distance from source areas occur [39].

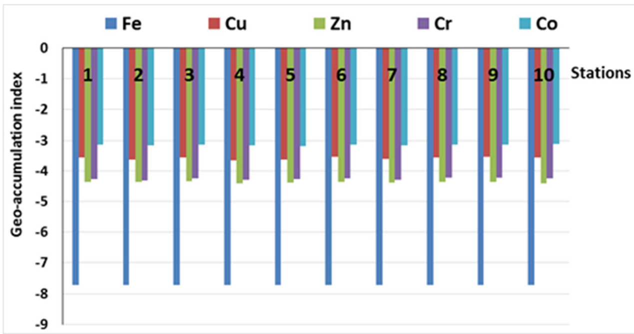

Figure 6. *Geo-accumulation index of metals in sediments of Tigris River.*

Table 6. *Geo-accumulation index of heavy metals.*

Station	Fe^{+2}	Cu^{+2}	Zn^{+2}	Cr^{+3}	Co^{+2}
1	-7.72	-3.56	-4.36	-4.27	-3.14
2	-7.73	-3.62	-4.36	-4.31	-3.15
3	-7.72	-3.55	-4.35	-4.24	-3.14
4	-7.73	-3.64	-4.41	-4.29	-3.17
5	-7.73	-3.62	-4.38	-4.28	-3.18
6	-7.72	-3.53	-4.36	-4.24	-3.14
7	-7.72	-3.60	-4.38	-4.29	-3.17
8	-7.72	-3.56	-4.37	-4.23	-3.13
9	-7.72	-3.54	-4.36	-4.23	-3.13
10	-7.72	-3.55	-4.40	-4.24	-3.12

3.4. Assessment of Physical and Chemical Parameters in Water

The physiochemical properties of water samples are as shown in Table 7. The pH values obtained in water showed little variation from one station to another. The pH values of the river water ranged between 7.37 and 7.62; the high pH value can be attributed to different activities nearby this location (i.e. domestic or industrial activities) [40]. Values of pH are within standard limits in water samples (Table 7).

Table 7. *Water variables of different stations in the study area. EC: electrical conductivity, TDS: total dissolved solids, BOD: biological oxygen demand, COD: chemical oxygen demand, T.N: total nitrogen, T.P: total phosphorus. Values are significant at* $*P \leq 0.05$, $** P \leq 0.01$, $*** P \leq 0.001$.

Water variables		Stations										*Mean*	*P-value*	WHO (2008)	Iraqi Standards
		1	2	3	4	5	6	7	8	9	10				
pH		7.39	7.54	7.42	7.52	7.48	7.45	7.37	7.55	7.62	7.58	7.49	0.21^{ns}	6.5-8.5	6.5-8.5
EC ds.m^{-1}		0.87	0.862	0.879	0.251	0.883	0.889	0.892	0.9	0.915	0.959	0.83	0.0002^{***}	2.5	2
TDS		557	551	563	544	565	569	570	576	585	581	566.10	0.000^{***}	1000	1000
SO_4^{-2}		110	106	113	102	112	115	113	116	119	117	112.30	0.01^{**}	250	250
Cl^-		95	93	98	89	98	94	92	98	90	88	93.50	0.01^{**}	250	200
HCO_3^-		41	45	38	35	40	39	41	47	116	43	48.50	0.000^{***}	-	-
NO_3^-		2.5	2	3.1	2.3	3.5	3.4	2.8	3.5	3.8	2.7	2.96	0.01^{**}	50	50
PO_4^{-3}		0.018	0.019	0.017	0.02	0.021	0.019	0.022	0.021	0.023	0.017	0.02	0.1^{ns}	0.5	0.5
TN	mg/l	17.5	18	18.7	19.3	19.9	18.8	18.2	17.7	12.6	19	17.97	0.000^{***}	-	-
TP		0.25	0.31	0.28	0.22	0.33	0.35	0.27	0.29	0.32	0.36	0.30	0.83^{ns}	-	-
BOD		3.4	3	3.75	3.65	4.15	3.5	4.3	4	3.95	3.8	3.75	0.000^{***}	-	-
COD		88	92	96	95	89	93	103	95	106	97	95.40	0.000^{***}	-	-
Na^+		89	93	98	87	98	95	97	101	104	102	96.40	0.000^{***}	-	-
K^+		4.7	2.5	3	3.4	3.5	4	4.2	50	42	45	16.23	0.000^{***}	-	-
Ca^{+2}		110	112	157	153	159	113	111	115	118	116	126.40	0.000^{***}	200	150
Mg^{+2}		46	41	51	37	48	50	40	46	49	51	45.90	0.000^{***}	150	150

Electrical conductivity is a considerable indicator of ionized substances in the water [41]. The highest value of EC was recorded at the downstream of the river (0.959 ds/m) but lower than that recorded by Salman *et al.* [4] at Euphrates River. Total dissolved solids in water, representing soluble inorganic substances originate from natural sources, sewage, urban runoff, industrial wastewater and chemicals used in the water treatment processes [42, 43]. The highest mean value of TDS was obtained in site 9 where there are agricultural activities increasing runoff of particulates in drainage water. TDS and EC values in all stations are within the WHO [44] and Iraq standards [45].

Sulphates varied from 102 in site 4 to 119 mg/l with a mean value of 117 mg/l. the highest mean value of sulphates was recorded at site 9 (agricultural wastes), where Sulphates in water mostly arise from anthropogenic additions in the form of sulphate fertilizers in the catchment area and from domestic and industrial wastes [46, 43]. The values of SO_4^{-2} are within standard limits of drinking water (250 mg/l).

Chlorides ranged from 89 in site 4 to 98 with a mean value of 93.5 mg/l. Values of Cl^- between different sites showed moderate significant variation. The highest mean value was observed at sites 3, 5, 8 might be due to natural processes like the passage of water through natural salt or as result of pollution from domestic wastes in these sites [47]. Values of Cl^- are lower than the limits of WHO and Iraq standard limits. All cations showed significant difference among these stations. They take the following sequence; $Ca^{+2} > Na^+ > Mg^{+2} > K^+$. The values of Ca^{+2} and Mg^{+2} are within the limits for drinking water standards of WHO [44] and standards of Iraq [45].

Biological oxygen demand (BOD_5) clearly indicated pollution which may be attributed to the maximum biological activity [46]. It ranges between 3 at site 2 to 4.3 mg/l at site 7 which may attribute to sewage wastes. The values of BOD_5 showed a significant difference between different stations. The BOD_5 levels recorded in the river water and in are within the EU guidelines of 3.0 to 6.0 mg/l for the protection of the aquatic life [47].

The chemical oxygen demand (COD) test is commonly used to measure the amount of organic and inorganic oxydizable compounds in water. High COD will stress aquatic organisms and can lead to their death [48]. The lowest value of COD (88 mg/l) was recorded at site 1, while the highest value (106 mg/l) was recorded at site 9 which characterized by different agricultural and followed by station 10 with industrial activities in these locations.

Nitrates varied from 2 at site 2 to 3.8 mg/l at site 9 may due to agricultural wastes, it showed the moderate significant difference between different stations. Nitrate in high concentrations has been implicated in a number of currently inconclusive health outcomes as hypertension [49]. While phosphate showed the non-significant difference, but its highest value was obtained in site 9 may due to agricultural wastes. Mean values of 2.96 mg/l for nitrates are higher than recorded by [13] but for phosphate is 0.02 mg/l which lower than the mean value of the same study. PO_4^{-3} considered an important nutrient in a water body and one of most significant limiting factor, and is the only form of soluble inorganic phosphorus directly utilized by aquatic biota [41]. Those values of both nitrates and phosphate in water samples from different stations are within the standard limits of WHO [44] and Iraqi standards [45].

Total nitrogen and total phosphorus were related to the agricultural wastes dumped into the water. Low TN levels could protect aquatic animals against the toxicity of inorganic nitrogenous compounds [50]. TN ranged from 12.6 to 19.9 mg/l with a mean value of 17.97 mg/l. Total phosphorus ranged between 0.17 to 0.34 mg/l at site 10 may due to runoff agricultural drainage water [51].

Good water quality is important for a healthy river and ecosystem. There are several basic conditions that must be met for aquatic life to thrive in river waters. If these conditions are not met, aquatic species become stressed and can even die. The health of a river is generally measured from WQI [52]. The WQI and AWQI values were as shown in Table 8. The values of AWQI indicated good water quality of Tigris River. WQI results are showed a good state when compared with those obtained by El-Amier *et al*. [53] on Rosetta Branch (Nile River) in Egypt.

Table 8. *Mean (Vi) standard values (S_i) and quality rating (q_i) value of some parameters in water.*

Parameter	V_i	S_i	q_i
pH	7.49	6.5-8.5	99.87
EC	0.83	2	41.50
TDS	566.10	1000	56.61
SO_4^{-2}	112.30	250	44.92
Cl^-	93.50	200	46.75
NO_3^-	2.96	50	5.92
PO_4^{-3}	0.02	0.50	4.00
Ca^{+2}	126.40	150	84.27
Mg^{+2}	45.90	150	30.60
WQI		414.43	
AWQI		46.05	

4. Conclusion

It could be concluded that the stations nearby pollutant point sources like wastes from commercial, anthropogenic activities, distributed along the Tigris River were exposed to different types of pollutants especially those expressed as increasing in COD and BOD_5 values. The downstream part of River as in stations 9 and 10 obtained high values of nutrients as a result of runoff agricultural drainage water from point and non-point sources. From the results of AWQI calculations, it's obvious that the water of Tigris river is suitable for different uses in different fields either irrigation or as a source of drinking water. Metals were nil in water samples. Co^{+2} is recorded the highest enrichment between other metals. The I*geo* for all metals n sediments attains unpolluted degree for in all stations. So we recommended that wastewaters from different activities distributed along the river must be treated.

List of Abbreviations

BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
OM	Organic Matter
WQI	Water Quality Index
AWQI	Average Water Quality Index
S_i	Standard Value
Q_i	Quality rating
EU	European Union Standards
EPA	Environmental Protection Agency
WHO	World Health Organization

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