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Assessment of Water and Sediment Quality of the River Nile, Damietta Branch, Egypt.

Amany F. Hasaballah*, Talaat A. Hegazy, Mahmoud S. Ibrahim and Doaa A. El-Emam
Environmental Sciences Department, Faculty of Science, Damietta University, Egypt.
*Corresponding Author: dr_env_env@yahoo.com

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ABSTRACT

Water of Damietta Branch, River Nile is contaminated by different domestic and industrial wastes. It contains various inorganic, organic and biological pollutants which causes serious environmental impacts and significance. This study performed to assess the pollution degree in Damietta Branch - River Nile. Twelve different sampling points were selected along the study area, River Nile Damietta branch from its spring at Cairo to its estuaries at Ras ELbar-Damietta. The results revealed that Dissolved Oxygen concentrations in river water ranged from 2.7 to 9.2 mg/l; BOD values were in the range of 10.5 to 40.6 mg/l, whereas Chemical Oxygen Demand ranged from 30.6 to 92 mg/l. Total nitrogen ranged from 0.125 to 1.4 mg/l. Total phosphorus ranged from 1.1 to 2.8 mg/l. Also, a high concentration of dissolved and suspended salts as total salts ranged from 38.49 to 93.04 mg/l. These results also confirmed with sediment analysis. The concentrations of heavy metals in sediment samples, followed the order Fe> Zn> Pb> Co> Ni> Cu> Mg, while, in the water samples it followed the order Pb> Fe> Cu> Co> Cd> Ni. Through the results of water quality index (WQI) based on 10 critical parameters (pH, Temperature, DO, BOD, COD, TP, TN, Turbidity, TS and Salinity), it indicated that site 5 (Eladlia WQI= 49), site 8 (Bosat Kareem Eldein WQI=47), site 9 (Talkha WQI=45) and site 10 (Smnood WQI=45) were more polluted than the other sites along the river branch. Overall, the results of WQI indicated that the Nile water quality of the studied area classified as medium quality (WQI average 55). The concentrations of Fe, Zn and Cu in water samples were within the safe limits of Egyptian standard regularities of article 60 law No. 48/1982. By contrast, the concentrations of Cd and Pb in water samples were above safe limits.

INTRODUCTION

Water pollution is a serious worldwide environmental problem. This problem results from increased population growth, urbanization, and industrialization, (Wang and Choi, 2019). Where, agricultural, industrial and domestic activities discharged vast quantities of waste in rivers all over the world, (Badr *et al*., 2013). The River Nile is considered the fundamental source of freshwater in Egypt. Egypt depends on a very confined share of the surface water of the Nile River 55.5 BCM (billion cubic meters)/ year, (MWRI, 2010). The water quality of the River Nile is influenced by the agricultural, industrial, domestic and touristic activity along the banks of the River in many countries upstream to downstream, (JUBEK *et al*., 2019). Most of the pollution input to the water comes from drainage discharge. Self-purification and dilution concepts did contribute to the gradual improvement in water of the River Nile quality (Mostafa and Abdelazim, 2017). It is essential that environmental lawyers and policymakers work to define regulation to ensure that water is maintained at the appropriate quality for its identified use. Damietta Governorate is famous by intensive industry, where surrounding agricultural areas are affected by atmospheric deposition of heavy metals. Also, agricultural practice, e.g., application of sewage sludge or phosphate fertilizers, has led to increased metals concentration in soils. The quality of the plants and lands fertility affected negatively by the usage of domestic and industrial polluted sewage water without any treatment. Besides, the increase of heavy metals concentration up to highly toxic levels may also affect animals and the human body through the food chain to which they have thus access (Karatas *et al.*, 2006). Some of the metals are considered as essential metals such as iron, copper, zinc, and manganese play crucial roles in biological systems, while, mercury, lead, and cadmium, etc. are non-essential elements, (Sangun *et al.*, 2010). The non-essential metals are toxic even in trace amounts, while the essential minerals produce toxic effects when taken in extreme excess. Heavy metals have the same pathway of exposure; emissions from industry and traffic exhaust contain considerable air contaminants, which reach the food chain and then animals to finally deposit in the human body (Amany, 2013). State and concentration of the various nutrients present in the water and the specific physicochemical characteristics of it, is expressed as the water quality. Many studies were interested in measuring the water quality state of Rivers: (Oluyemi *et al.*, 2010; Shamrukh and Abdel-Wahab, 2009, 2011; Fawzy *et al.*, 2012; Badr *et al.*, 2013; Tyagi *et al.*, 2013; Mostafa and Peters, 2015; Abdalla and Shamrukh, 2016 and Mostafa and Abdelazim, 2017). This study investigated the water quality of the River Nile - Damietta Branch and used the water quality index to summarize large amounts of water quality data into simple terms (e.g., good, average, or poor) for reporting to treatment and management.

METHOD AND MATERIAL

Study Area

Damietta Branch, as shown in Fig. 1, located at the eastern part of the Nile Delta. Its length is about 241 km, average width 280 m with an average depth 11 m and average elevation 2 m. It includes five governorates of the Nile Delta: Damietta, Eldakhlia, El-Gharbia, El-Menofyia, Qaliubiah. The study area divided into twelve sites as shown in Fig. 1.

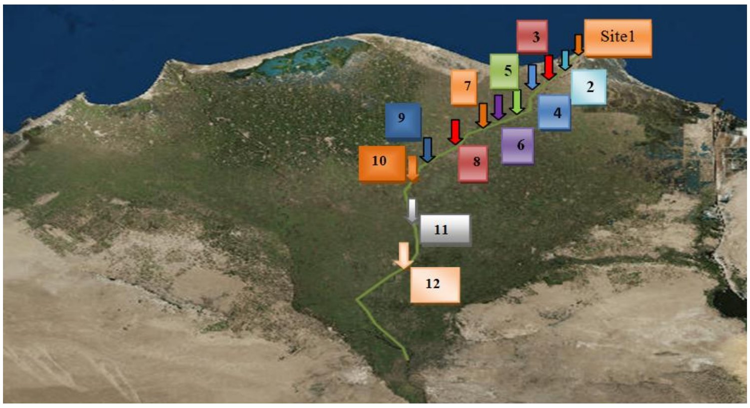

Fig. 1: Geographic Map of the Nile Delta showing the study area (Damietta Branch), different 12 ecological sites.

Field Analysis

Water samples were collected seasonally for a year, starting from spring 2017 to winter 2018 from River Nile- Damietta Branch, Egypt**.** Twelve different sampling points were selected along the whole course of the River Nile Damietta Branch from its spring at Cairo to its estuaries at Ras ELbar-Damietta. Water samples were collected in high-density polyethylene (HDPE) bottles that were routinely acid-treated with a solution (0.5 N HCl) and well rinsed with de-ionized water before use, dried, and stored with the caps on to prevent contamination. The samples of water collected from the central area of each site at a depth of 20-30 cm. Sediments also were taken from the same points of water samples as a grab sample and then analyzed separately. A Global Positioning System (GPS) used for recording geographical location of samples.

Physicochemical analysis of water samples

In the present study, the collected water samples were analyzed for both physical and chemical parameters which include: pH, Turbidity, Dissolved Oxygen (DO) Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Phosphorus (TP), Total Dissolved Solids (TDS), Nitrite, Total Nitrogen (TN), Electrical conductivity (E.C), Total suspended solids (TSS), and salinity have been determined according to Standard Method (APHA, 2010). Samples of water were collected examined within 2- 6 hours of collection. Temperature and pH determined in the field. Chemical addition, pH control, refrigeration, and freezing used as preservation methods, (EPA, 2009). Heavy Metals Analysis of Drinking Water Samples (Fe, Zn, Pb, Cu, Ni, Cd, and Co) was carried out according to (Yasser *et al.*, 2015).The Inductively Coupled Plasma-Mass Spectrometry (ICP-OES 7000) was used for heavy metal analysis with ultrasonic instrument is Perkin Elmer Optima 3000, USA.

Sediment Analysis

Total dissolved solids (TDS), Salinity, Electrical Conductivity (EC) measured by digital meter (Digital Portable TDS/ Conductivity meter Model. 8033 HANNA, USA). The texture of sediment samples, organic carbon and chlorides were determined according to Pipe (1947). Calcium carbonate content, Electric pH-meter, Carbonates and bicarbonates, total phosphorus, and total nitrogen have been determined according to Standard Method (APHA, 2010). Heavy metals concentrations (Fe, Mn, Zn, Pb, Cu, Ni, Cd, and Co) were carried out according to (Yasser *et al.*, 2015).

Water Quality Index (WQI)

Water Quality Index (WQI) was used to summarize results from different physicochemical measurements using computer program created by the National Sanitation Foundation, USA. The used parameters are pH, temperature, DO, BOD, TN, and TP. This index reduces vast amounts of data to a single number thus ranking water into one of five categories: very bad water (0 - 25), bad (25 - 50), medium (50 - 70), good (70 - 90) and excellent quality of the sampled water (90 - 100). It can be calculated as the following equation to evaluate water quality (Badr *et al.,* 2013).

$$WQI = K \frac{\sum_i C_i W_i}{\sum_i W_i} \qquad (1)$$

Where: K is a subjective constant representing the visual impression of river water quality. WQI ranges from 0.25 (highly polluted water) to a maximum value of 1.0 (good quality water), Ci is the value assigned to each measured parameter after normalization on a scale from 0 to 100, where; Zero indicates water that is not suitable for the intended use without further treatment and 100 represents perfect water quality.

W*i* is the relative weight assigned to each parameter; maximum weight of 4 was assigned to relative importance parameters for life, (Yasser *et al*., 2015).

Statistical Analysis

One and Two-way ANOVA compared the data of the different study sites. The one-way ANOVA and correlation analyses were conducted using SPSS 22 for Windows.

RESULTS AND DISCUSSION

Water Characteristics

Physicochemical parameters of water samples from twelve ecological sites of the River Nile are shown in Table 2. Water temperatures varied between 19 and 21°C as a mean value of analysis. Water samples varied from neutral to slightly alkaline in the pH values, with an average of 8.04 ±0.56. These variations may be due to point source pollution which is a common cause that can increase or decrease pH depending on the chemicals involved according to (EPA, 2012). These chemicals can come from agricultural runoff, wastewater/domestic discharge or industrial runoff. Wastewater discharge that contains detergents and soap-based products can cause a water source to become too basic (WHO, 2015), and this appeared clearly in Eladlia, Elsero/Elzarqa, Bosat Kareem Eldein/ Sherbein, Talkha and Smnood regions ($F = 2.125$, $p < 0.05$; Table 2). The results revealed a significant positive correlation between pH and the other parameters except DO, TSS and Cl (Table 3). Results showed that EC had a significant positive correlation with TDS, Cl and turbidity ($r = 0.952$, $r = 0.638$ and $r = 0.588$ respectively, $p < 0.05$; Table 3). As EC is the measurement of the materials which dissolved in an aqueous solution, the higher the EC of material the higher dissolved materials will be founded in a water or soil sample, (Perlman, 2014). TDS, TSS and TS, the lowest mean values were recorded in site six, 24.3, 14.19 and 38.49, respectively. The highest mean value of salinity was recorded in site 1 (41.7 mg/l), while the lowest one was recorded in site 6 (23 mg/l), and this agreed with (El-Sayed, 2016). Turbidity is a parameter which depends on total suspended solids in water and is often using as an indicator of water quality, (Aniyikaiye *et al*., 2019). The increase in turbidity can often indicate a decrease in water quality, not just potential pollution, (Wood, 2014). It was found that, a significant positive correlation between turbidity and all measured parameter except DO which had a significant negative correlation ($r = -0.256$, $p < 0.01$) for the whole dataset Table 3. It was significantly higher during spring and winter relative to summer and autumn ($F = 3.72$, $p < 0.05$; Table 2). According to Ali *et al.* (2011), the average value of DO in the study area was 6.53±2.006 mg/l. Temperature, salinity, and pressure considered the main factors affecting the actual amount of dissolved oxygen. Remarkably higher values of DO were observed during autumn and winter as compared with spring and summer ($F = 0.007$, $p < 0.05$; Table 2). The results revealed a weak, and a significant negative correlation between DO and salinity ($r = -0.128$, $p < 0.05$, Table 3). In contrast with DO, the results indicated a significant decrease in both BOD and COD values during autumn and winter as compared with spring and summer ($F = 64.03$, $F = 174.9$, respectively $p < 0.05$). Significant positive correlation also founded between salinity and BOD ($r = 0.05$, $p < 0.05$). The higher BOD and COD values adversely affect water quality and reflect the relatively high loads of organic matter (El-Ezaby *et al.*, 2010). After biological wastewater treatment, Nitrogen mainly occurs as oxidized nitrite, (Ragaa *et al.*, 2016). TP and TN in water samples took the same distribution as their lowest mean values were recorded in site 1, 1.1 and 0.125 mg/l, respectively, and the highest mean values were 2.8 and 1.4 mg/l which were recorded in site 9 for TP and TN, respectively. These are likely due to various anthropogenic inputs from industrial wastewater as one of the principal uses of nitrate is as fertilizer, (Ogrinc *et al*., 2019). Results significantly appeared this fact in TP and TN distribution along the Damietta branch especially in Talkha district, ($F = 20.52$, $F = 0.72$, respectively, $p < 0.05$). Chloride is an important parameter that provides information on physical processes especially evaporation occurring during recharge and time-dependent flow, (Ma *et al*., 2019). Chlorides concentration decreased along the branch to the lowest value at site 12 with a concentration of 1.45 gm/l. This decrease thought to be due to seawater intrusion. The initial evaluation of the obtained results has been carried out via the comparison of data of the current study with the World Health Organization Guidelines (WHO, 2011), U.S. Environmental Protection Agency (EPA, 2018) and Egyptian standard Regulations Law No. 48 of 1982 Table 1.

Table 1: World Health Organization Guidelines, U.S. Environmental Protection Agency and Egyptian standard regularities of article 60 law No. 48/1982 regarding minimum standards for the water quality of the Nile River.

Parameter	**Egyptian Regulation (mg/l)**	**WHO 2011 (mg/l)**	**EPA 2018**
pH	7.0-8.5	8.2 – 8.8	6.5 – 8.5
TDS	500	-	500
DO	<= 5	-	-
BOD	6	-	-
COD	10	-	-
Nitrate	45	50	10
Ammonium	0.5	-	30
Iron	1	0.1	0.3
Manganese	0.5	0.05	0.05
Copper	1	2	1
Zinc	1	3	5
Cadmium	0.01	0.003	0.005
Lead	0.05	0.01	0

EC= Electrical Conductivity, DO= Dissolved Oxygen, BOD= Biological Oxygen Demand, COD= Chemical Oxygen Demand, TP= Total Phosphorus, OC = Organic Carbon, OP= Orthophosphate, TN =Total Nitrogen, WQI: Water Quality Index .Non-significant ($P > 0.05$), * = low significant ($P \leq 0.05$), ** = intermediate significant ($P \leq 0.01$) and *** = highly significant ($P \leq 0.001$).

Table 2: The physical and chemical parameters of water samples along Damietta Branch of River Nile.

Parameters					***ANOVA***	
	Mean	***SD***	***Min***	***Max***	***F-Value***	***P-value***
pH	8.04	0.56	7.10	9.10	2.12	0.15^{oo}
TDS g/l	28.78	8.94	12.40	40.30	59.40	1.08^{oo}
TSS g/l	27.13	14.94	4.80	53.60	19.89	$1*10^{-4}$***
TS g/l	56.13	18.46	38.49	93.04	76.40	1.31^{oo}
Salinity ‰	33.55	5.90	23.00	41.70	171.87	7.13^{oo}
E C mg/cm	35.62	9.83	16.38	46.90	85.88	4.73^{oo}
Turbidity NTu	4.15	2.09	2.40	7.80	3.72	0.05*
DO mg/l	6.53	2.00	2.70	9.20	$7*10^{-4}$	0.97^{oo}
BOD mg/l	23.37	9.41	10.50	40.60	64.03	5.87^{oo}
COD mg/l	62.55	15.51	30.60	92.00	174.90	6.01^{oo}
OP mg/l	0.54	0.16	0.36	0.92	32.66	$9*10^{-5}$***
TP mg/l	1.73	0.48	1.10	2.80	20.52	$1*10^{-4}$***
Nitrite mg/l	0.49	0.26	0.08	0.98	0.72	0.40^{oo}
TN mg/l	0.74	0.36	0.12	1.40	30.66	$1.44*10^{-5}$***
CL g/l	6.09	5.04	1.45	5.40	0.05	0.81^{oo}
WQI	55	3.09	53	45		
	med					

Table 3: Correlations matrix for the measured parameters in water samples collected from the Nile River Damietta Branch.

	pH	**TDS**	**TSS**	**TS**	**Salinity**	**E C**	**Turbidity**	**DO**	**BOD**	**COD**	**O.P**	**TP**	**Nitrite**	**TN**	**Cl**
pH	1	0.14	-0.24	-0.24	0.36	0.29	0.45	-0.72	0.86	0.70	0.82	0.77	0.84	0.84	-0.35
TDS		1	0.17	0.59	0.73	0.95	0.32	0.28	-0.25	-0.29	-0.01	-0.22	-0.10	0.02	0.72
TSS			1	0.89	0.50	0.20	0.37	0.24	-0.38	-0.46	-0.45	-0.39	-0.56	-0.47	0.74
TS				1	0.74	0.60	0.44	0.32	-0.43	-0.51	-0.37	-0.42	-0.51	-0.40	0.91
Salinity					1	0.78	0.58	-0.12	0.05	-0.04	0.17	0.08	0.05	0.23	0.59
E C						1	0.50	0.14	-0.09	-0.17	0.10	-0.07	0.01	0.14	0.63
Turbidity							1	-0.25	0.30	0.13	0.35	0.33	0.21	0.14	0.10
DO								1	-0.93	-0.92	-0.87	-0.94	-0.87	-0.87	0.73
BOD									1	0.92	0.91	0.95	0.94	0.93	-0.74
COD										1	0.86	0.91	0.92	0.92	-0.78
O.P											1	0.97	0.94	0.93	-0.61
TP												1	0.93	0.92	-0.73
Nitrite													1	0.99	-0.70
TN														1	-0.64
Cl-															1

Sediment Characteristics

Sediments of freshwater considered the endpoints for trace metals emitted from the anthropogenic sources in freshwater and provide a good archive for studying trace metal pollution history, (El-Amier *et al*., 2015). In Table 4, the pH of the soil is an important physicochemical property that shows the bottom decomposition condition of the aquatic ecosystem, (Reeves and Liebig 2016). The pH values ranged between neutral to slight alkaline along this branch sites.

Table 4: The physical and chemical parameters of sediment samples along the Damietta Branch of River Nile.

					ANOVA	
Parameters	***Mean***	***SD***	***Min***	***Max***	***F-Value***	***P-value***
pH	7.68	0.529	7.10	8.90	5.05	0.03*
Sand %	78.60	11.78	49.55	87.28	327.15	$5.4*10^{-13}$***
Silt %	6.13	4.00	2.10	13.60	0.14	0.70^{oo}
Clay %	15.16	8.12	9.90	36.85	11.33	$3*10^{-3}$***
TDS mg/gm	1.90	0.51	1.22	2.89	13.65	$1*10^{-3}$***
Salinity ‰	2.03	0.67	1.20	3.35	12.41	$2*10^{-3}$***
E C mg/cm	3.46	0.85	2.32	5.26	4.15	0.05*
OC %	9.09	2.22	3.78	9.09	1.40	0.25^{oo}
CL mg/gm	1.38	0.48	0.85	2.60	17.96	$4*10^{-4}$***
CO_3^{2-} mg/gm	0.69	0.43	0.43	1.30	27.09	$5*10^{-5}$***
HCO_3^- mg/gm	0.97	0.49	0.13	2.11	21.71	$1*10^{-4}$***
$CaCO_3$ mg/gm	3.97	2.35	1.09	8.12	1.51	0.23^{oo}
TP mg/gm	1.88	0.65	0.93	2.92	13.59	$1*10^{-3}$***
TN mg/gm	0.76	0.32	0.32	1.35	24.96	$1*10^{-4}$***

EC= Electrical Conductivity, DO= Dissolved Oxygen, BOD= Biological Oxygen Demand, COD= Chemical Oxygen Demand, TP= Total Phosphorus, OC = Organic Carbon, OP= Orthophosphate, TN =Total Nitrogen, WQI: Water Quality Index .Non-significant ($P > 0.05$), * = low significant ($P \leq 0.05$), ** = intermediate significant ($P \leq 0.01$) and *** = highly significant ($P \leq 0.001$).

The majority of grain size of the Damietta Branch sediments is fine sand and type of soil classified as sandy loam. Sand % ranged from 49.55 % (site 12) to 87.28 % (site 3) as increased toward the shoreline, while clay % ranged from 9.9 % (site 3) to 36.85% (site 12) and silt also had small percent between them (2.1% in site 3 to 13.6% site 12). TDS, Salinity and EC, showed high mean concentrations, decreased along the branch to the lowest value with a concentration of 1.22 gm/l, 1.2 ‰ and 2.32 mg/cm, respectively. This distribution of the previous parameter may be due to the strong effect of Mediterranean Sea water mixing with Damietta branch water (the phenomenon of seawater intrusion), (Mostafa and Abdelazim, 2017), which appeared after the construction of Faraskour dam, which acts as an artificial barrier preventing natural equilibrium between the Damietta Branch and the Mediterranean Sea (Elkhatat *et al.*, 2013). On the other hand, Organic Carbon % ranged between 3.78 % in site 7 (the lowest value) and 9.09 % in site 9 (the highest value). In the present study, the highest organic carbon contents were found in site 8, 9 and 3, respectively. Results showed that OC had a significant positive correlation with TP and TN (r = 0.828, and r = 0.617, respectively, $p < 0.05$; Table 5). Carbonate was not detected at all investigated sites as it was absent in site 7,8,10 and12 although its highest value detected in site 4 (1.305 mg/l), that is due to a high amount of organic matter accessible to bacterial decomposition by increasing the sewage and agricultural effluents.

Table 5: Correlations matrix for the measured parameters in sediment samples collected from the Nile River Damietta Branch

	pH	**Sand**	**Silt**	**Clay**	**TDS**	**Salinity**	**EC**	**OC**	**CL**	**CO_3^{2-}**	**HCO_3^-**	**$CaCO_3$**	**TP**	**TN**
pH	1	-0.48	0.28	0.57	-0.46	-0.28	-0.49	-0.34	-0.18	0.009	-0.42	-0.27	0.05	-0.11
Sand		1	-0.94	-0.98	0.73	0.64	0.70	0.01	0.50	0.16	-0.02	0.48	-0.21	0.03
Silt			1	0.89	-0.80	-0.70	-0.76	0.14	-0.59	-0.04	0.19	-0.42	0.35	0.17
Clay				1	-0.67	-0.59	-0.65	-0.08	-0.45	-0.26	-0.06	-0.51	0.14	-0.12
TDS					1	0.78	0.94	-0.13	0.66	0.40	0.09	0.34	-0.56	-0.42
Salinity						1	0.81	-0.51	0.71	0.15	0.002	0.37	-0.44	-0.24
E C							1	-0.08	0.61	0.15	0.02	0.36	-0.38	-0.29
OC								1	-0.12	0.83	0.51	0.57	0.82	0.61
CL									1	0.03	-0.07	0.69	-0.58	-0.48
CO32-										1	0.78	0.77	0.11	0.27
HCO3-											1	0.31	0.27	0.41
CaCO3												1	0.08	0.20
TP													1	0.92
TN														1

Heavy metals in water and sediment samples

The results in Tables 6 and 7 show that the concentrations of heavy metals (Fe, Cu, Ni, Cd Pb, Co, and Zn,) of the sediment and water recorded highest significant correlations ($P < 0.05$) among the ecological sites in sediment and water. The concentrations of heavy metals in sediment samples, followed the order Fe> Zn> Pb> Co> Ni> Cu> Mg Fig. 2. While, in water samples followed the order Pb> Fe> Cu> Co> Cd> Ni Fig. 3.

Table 6: Correlations matrix for the measured heavy metals in Sediment samples collected from the Nile River Damietta Branch

	Zn	**Co**	**Pb**	**Cd**	**Ni**	**Cu**	**Fe**
Fe	0.37	0.15	0.43	0.06	0.31	0.23	1
Cu	0.29	-0.85	-0.29	0.37	0.90	1	
Ni	0.03	-0.16	-0.02	-0.15	1		
Cd	-0.15	-0.02	-0.10	1			
Pb	0.52	0.86	1				
Co	0.64	1					
Zn	1						

Table 7: Correlations matrix for the measured heavy metals in water samples collected from the Nile River Damietta Branch

	Zn	**Co**	**Pb**	**Cd**	**Ni**	**Cu**	**Fe**
Fe	0.40	0.25	0.08	0.002	0.31	0.08	1
Cu	0.64	-0.16	0.38	-0.01	0.79	1	
Ni	0.03	0.36	0.71	0.05	1		
Cd	-0.15	-0.02	0.007	1			
Pb	0.22	0.75	1				
Co	0.64	1					
Zn	1						

Accumulation of heavy metals, including Pb, Zn, Mn, Cd, and Cu, in a certain area arise from the exhausts of vehicle, discharges of different industries, oil lubricants, automobile parts, corrosion of building materials, and atmospheric deposition, (Du *et al.*, 2013). Heavy metals accumilate in water by different sources, industrial and consumer waste, or even from soils which breaked down by rain and releasing heavy metals into streams, lakes, rivers, and groundwater. Iron founded with high concentrations naturally whereas soil pollution, emissions of vehicle and industry, and crust re-suspension increased the concentrations of other heavy metals (Hasballah and

Beheary, 2016). The concentrations of Fe, Zn, and Cu in water samples were within the safe limits of Egyptian Standard regularities of article 60 law No. 48/1982. By contrast, the concentrations of Cd and Pb in water samples were above safe limits and constitutes.

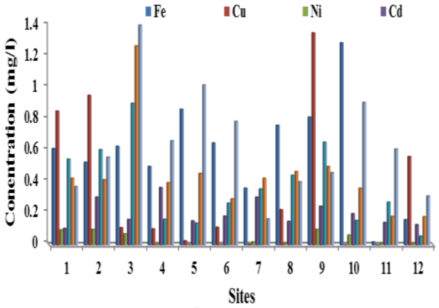

Fig. 2: Heavy metals concentrations (mg/l) in sediment samples along the Damietta Branch of River Nile

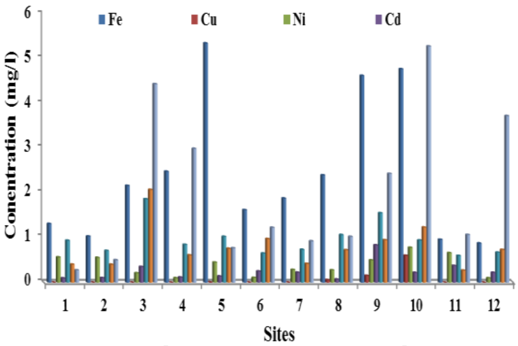

Fig. 3: Heavy metals concentrations (mg/l) in water samples along the Damietta Branch of River Nile

Water Quality Index (WQI)

The use of WQI can give a considerable indication of the quality of Nile water and keep path of any changes over time according to (Sanchez *et al.*, 2007). WQI is classified in four categories as follows: 100-91 (excellent), 90 - 71 (good), 70 - 51 (medium), 50 - 26 (bad) and finally 25 - 0 (very bad). Figure 4 shows, the water quality index calculated using equation 1. Normalized factors are described in Table 1.

WQI indicates better water quality of the Nile water at Ras Elbr Damietta district (WQI ranges 52 - 53) than water quality of the Nile at Dakahlia district (WQI ranges 45-51). The lowest values of WQI were detected at sites 9and 10 (WQI = 45). Comprehensively, the results of WQI indicate that the water quality of the studied area classified as medium (WQI average 55).

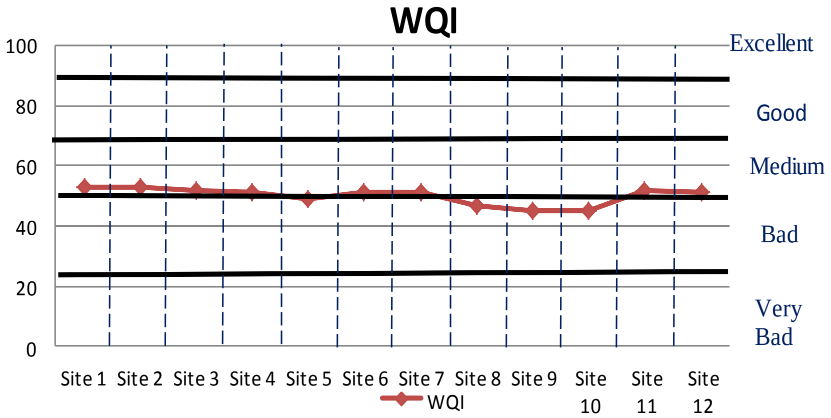

Fig. 2: Water quality index (WQI) in water samples collected from different ecological sites along the Damietta Branch-Nile River

CONCLUSION

Based on WQI results, the water quality status of the Damietta Branch varies from medium to bad. This study showed a progressive ecological degradation occurred along Damietta Branch at its estuaries. So, there should be regular and continuous monitoring for developing ecosystems of the River Nile system. It is essential to confirm urgent plans for the management of Damietta branch water quality to maintain pollution levels within the permissible values. Environmental law should be developed and enforced to prevent the discharge of wastewater such as agricultural, domestic, industrial, or other sources to the Nile River system.

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