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Evaluation of Water Quality of the Surface Water of the Damietta Nile Branch, Damietta Governorate, Egypt

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Abstract—Water quality and heavy metals pollution of the Damietta Nile Branch at Damietta governorate were investigated in the current work. Fourteen different sampling points were selected along the Damietta Nile branch from Ras EL-Bar (sample 1) to Sheremsah (sample 14). Physical and chemical parameters and the concentrations of Cd, Cr, Cu, Ni, Fe, Al, Hg, Pb and Zn were investigated for water quality assessment of Damietta Nile Branch at Damietta Governorate. Most of the samples show that the water is suitable for drinking and irrigation purposes. All locations of samples near the sea are unsuitable water but the samples in the south direction away from the sea are suitable or good water for drinking and irrigation.

Keywords—Water quality indices, Damietta Governorate, Nile River, pollution.

I. Introduction

It is known that the 1959's Nile water agreement with Sudan, allocates 55.5 BCM (billion cubic meters)/year to Egypt [1]. Water of Nile River has been used in many of purposes such as drinking (domestic) water supply, irrigation, industrial, fisheries, recreation. Water requirements in Egypt are continuously increasing due to the high rates of growing population, increasing urbanization, industrialization and the rapid agricultural growth. Demands for the agricultural sector represent the largest component (about 80%) of the total water demand in Egypt [1]. According to [1], the actual release from the High Aswan Dam shows very little yearly variation. Annual variation of the release of water from the High Aswan Dam depends mainly on irrigation needs. The release from the high Aswan Dam ranges from approximately 800 m^3/s during the (winter) closure period to approximately 2760 m^3/s during the summer months. In the Nile Valley and Nile Delta, groundwater resource use account for approximately 4.4 billion m^3/yr, mainly being recharged from the Nile and seepage of irrigated agriculture [1]. Rainfalls play a minor role in Egypt's water resources, with average rainfall rates declining from 200 million m^3/yr at the Mediterranean Coast to 20 mm^3/yr in Cairo and almost zero in Upper Egypt [1].

In the 1993/94 hydrological season, gross water consumption of irrigated agriculture amounted to approximately 54.5 B. (billion) m^3/yr (of which almost 30 B. m^3/yr occurred in the Delta). Other water uses, such as municipal and domestic drinking water, industry and others consumed approximately 8.8 B. m^3/yr., and an estimated 2.0 B. m^3/yr was lost through evaporation and about 14.0 B. m^3/yr was discharged to the Mediterranean Sea (Table I) [1]. In recent years, the amount discharged to the Mediterranean Sea directly from the River Nile system, declined sharply, specially, the agricultural and drinking water supply use (approximately 2.3 B. m^3 discharged in 1990 compared with approximately 1.2 B. m^3) [1].

Deterioration of Egyptian water is due to increasing discharges of polluted domestic and industrial effluents into its waterways such as River Nile and Canals. Also, the pollution of water occurred due to the excessive uses of pesticides and fertilizers in agriculture. Deterioration in water quality occurs when the Nile divided into Damietta and Rosetta Branches d*ue* to the disposal of the municipal and industrial effluents and agricultural drainage with decreasing flows [2].

Water quality is a term used to express the suitability of water to various purposes [3]. The quality of water may be described in terms of the concentration and state the organic and inorganic material present in the water, together with certain physical characteristics of the water [4].

According to [1], Egyptian industry uses 638 M. m^3/yr of water, of which 549 M. m^3/yr is discharged to the drainage system. Industrial activities in the Greater Cairo and Alexandria regions use 40% of the total. The River Nile supplies 65% of the industrial water needs and receives more than 57% of its effluents. More detailed information about water consumption, wastewater discharge and point sources of pollution and loads from different industrial sectors are provided (Table II).

The natural and anthropogenic effects changed the geo-environmental status of Nile Delta in the last few decades. The Nile Delta has ecological and economic values and it is considered as a major centre of population and agriculture [5]. Water quality has been changed by human intervention [4]. These effects are the polluting activities, such as the discharge of domestic, industrial, urban and other wastewaters into the watercourse (whether intentional or accidental) [6].

According to [7] and [8], 124 pollution points discharge the wastewater to the Nile River from Aswan to Delta Barrage, of which 67 are agricultural drains and the remainder is industrial and domestic sources. Industry purpose in Egypt uses 7.6 B m^3/yr of water. In the Delta region, the amount of agricultural drainage water reuse officially was estimated to be around 4.27 BCM/year, in addition to about 0.3 BCM/year lifted to surface water (Rossetta branch) from west delta drains.

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Additional unofficial reuse done by farmers themselves has been estimated to be around 2.8 BCM/year. The remaining drainage water is discharged to the sea and the northern lakes via drainage pump stations. The total amount of drainage water that was pumped to the sea has been estimated to be 12.41 BCM/year [8]. The changes in water quality are primarily due to a combination of land and water use, as well as water management interventions such as; (a) different hydrodynamic regimes regulated by the Nile barrages, (b) agricultural return flows, and (c) domestic and industrial waste discharges including oil and wastes from passenger and riverboats [7].

TABLE I
WATER BUDGET CALCULATION OF THE RIVER NILE SYSTEM [1]

Resources	Billion m^3/yr.	Water Diversions/ Intakes	Billion m^3/yr.
Release from Lake Naser	55.470	Agricultural Intake	54.410
Groundwater Extraction	4.400	Drinking Water Supply	2.910
Irrigation Excess Water Return	16.910	Industrial Water Supply	5.890
Industrial Wastewater Return	5.480	Nile Flow to the Med. Sea	1.160
Domestic Wastewater Return	1.400	Drainage Outflow	12.890
Total	**83.660**	Evaporation from System	2.000
		Groundwater Recharge	4.400
		Total	**83.660**

TABLE II
INDUSTRIAL WASTEWATER DISCHARGE TO THE RIVER NILE SYSTEM DISTRICT [1]

District	Ultimate Sink (M.m^3/yr.)				Total
	Nile	Canals	Drains	Lakes	
Upper Egypt	192	5	2	5	204
Greater Cairo	80	21	20	7	128
Delta	27	85	13	1	126
Alexandria	13	7	33	35	88
Others	0	0	3	1	4
Total	**312**	**118**	**71**	**49**	**550**

The situation of water pollution is probably getting worse with time, as the discharge of wastes is increasing. Heavy metals contamination in river is one of the major quality issues in many fast growing cities, because maintenance of water quality and sanitation infrastructure did not increase along with population and urbanization growth, especially for the developing countries [9]-[11]. Heavy metals contamination is important due to their potential toxicity for the environment and human beings [12]-[15]. Some of the metals such as Cu, Fe, Mn, Ni and Zn are essential as micronutrients for the life processes in animals and plants while many other metals such as Cd, Cr, Pb and Co have no known physiological activities [16], [17]. Damietta branch is about 242 km length, with average width and depth 200 and 12 meter respectively. It is the main source of drinking and irrigation waters for many of Governorates such as El-Qalubia, El-Gharbyia, El-Dakahlyia and Damietta [18]. Faraskour Dam divides the Damietta Nile branch in Damietta Governorate at the inlet of Damietta City about 20 km south of Mediterranean Sea to cut off the flow of the Nile water to the Mediterranean Sea. The water characteristics after the dam (saline water) is completely different compared with the water before the dam (fresh water) [19]. Damietta branch receives several pollutant types. Talkha fertilizer factory is considered the main source of industrial pollution, recooling waters of Talkha and Kafr Saad electric power stations. Domestic and sewage effluents at El-Serw City represent another source of pollution [20].

Damietta Nile Branch at Damietta Governorate has been suffered from intensive pollution. Damietta Nile Branch receives the water of a number of agricultural drains, which are heavily polluted by industrial and domestic sewage. The Damietta Branch receives polluted water of a number of agricultural drains, The Fertilizer Company is considered as the major point source of industrial pollution at Damietta branch. Many of villages on each banks of Damietta Nile branch without sanitation services, thus the river receive many wastewater resulted from industrial and domestic activities.

Damietta Governorate with area of about 910 km^2 north of the Nile Delta and contains about 1.3 million people living within its four administrative centers. These centers are Kafr Saad, Faraskour, El-Zarka and Damietta center. It was the Egyptian gate along the Mediterranean Sea before the construction of Alexandria about 300 years BC. The long of the Damietta Nile Branch in the Damietta Governorate about 40 km from Ras EL-Bar (north) to Sheremsah Village (south). The landuse/cover map of Damietta Governorate was shown in Fig. 1. It consists of water, barren land, agriculture and urban [21]. About 14 water samples were taken from the Damietta Nile Branch from Ras EL-Bar to Sheremsah Village (Table III) to study the water quality in the Nile Water of Damietta Governorate.

II. MATERIALS AND METHODS

Water samples were collected from the Damietta Nile branch at Damietta governorate from March to May 2015 and tested for physical qualities and chemical contents. The samples were collected from 14 sampling stations along the main flow of the Damietta Nile branch (Fig. 2, Table III) starting from upstream near Sheremsah Village (sample 14) to downstream (outlet) at Ras El-Bar City (sample 1). Location of samples has been recorded using global positioning system (GPS). Water samples were collected from the central area of each site at depth of 10-30 cm.

Water samples were collected and kept into a one-litre polyethylene bottle in ice box and analyzed in the laboratory. Some of the physicochemical parameters including the electrical conductivity of the water samples ($mS \cdot cm^{-1}$), pH, and water temperature (°C) were measured in the field by using water checker U-10 Horiba Ltd. The other water parameters were measured according to the traditional manual methods of the American Public Health Association [22]; [23]. Total Pb, Ni, Al, Cu, Cr, Mn, Zn, Hg, Fe, Cd were measured after digestion using spectrophotometry.

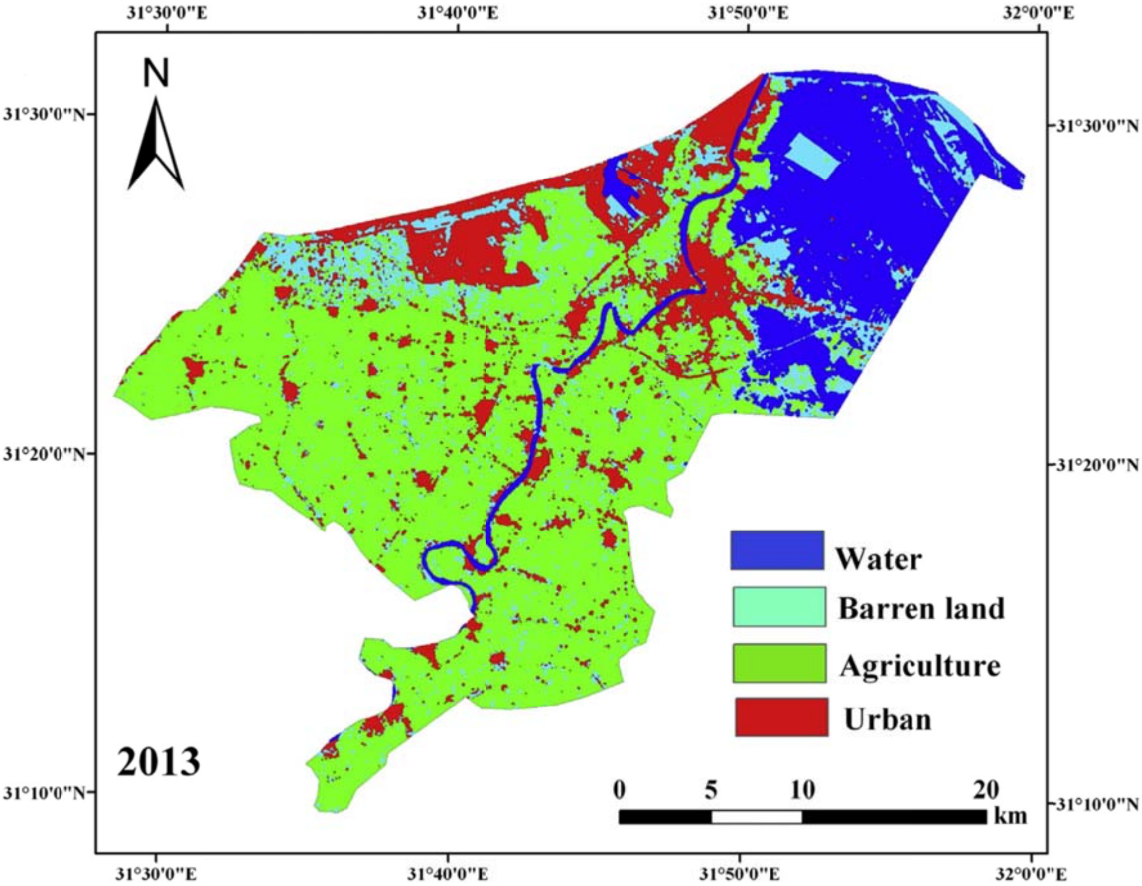

Fig. 1 The land use/cover map of Damietta Governorate as obtained from the Landsat-8 OLI image classification [21]

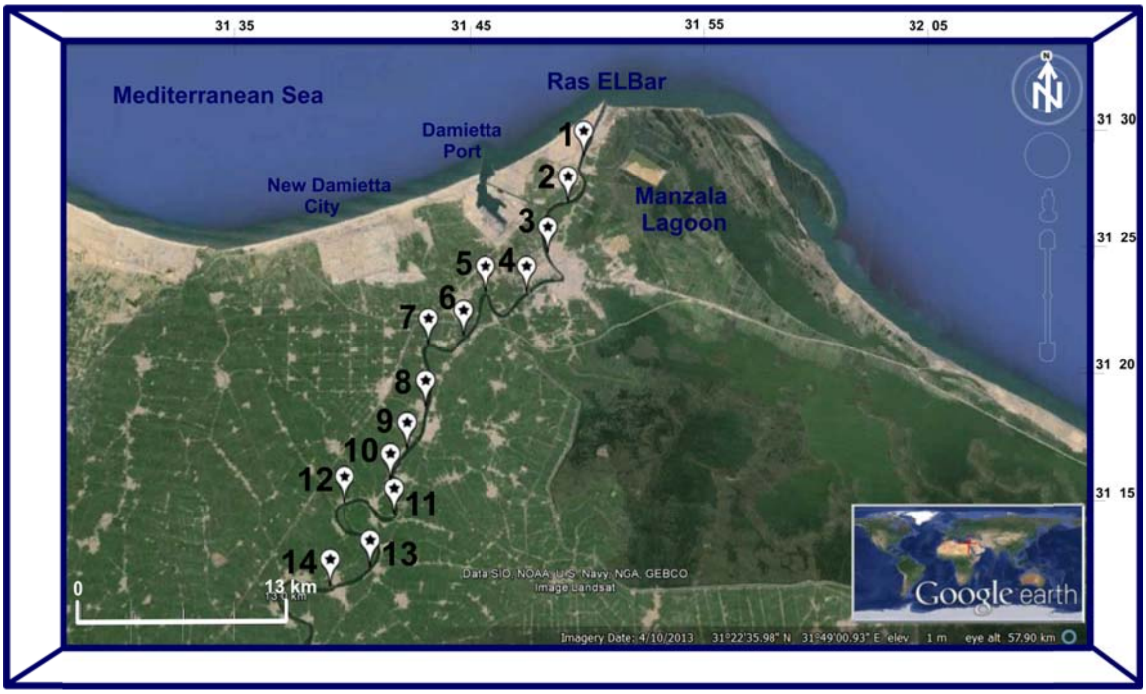

Fig. 2 Location of the water samples of Damietta Nile Branch in Damietta Governorate

TABLE III
LOCATION OF THE SAMPLES ALONG THE DAMIETTA NILE BRANCH COURSE

Samples	Latitude	Longitude
1 (Ras ELBar)	31º 29' 33.80"	31º 49' 40.71"
2	31º 27' 52.18"	31º 48' 56.33"
3	31º 26' 2.18"	31º 48' 0.55"
4	31º 24' 37.68"	31º 47' 4.16"
5	31º 24' 41.01"	31º 45' 20 56"
6	31º 23' 7.59"	31º 44' 22.84"
7	31º 22' 52.64"	31º 42' 55.53"
8	31º 20' 40.22"	31º 42' 46.03"
9	31º 19' 13.18"	31º 41' 59.21"
10	31º 18' 9.68"	31º 41' 17.74"
11	31º 16' 57.63"	31º 41' 25.64"
12	31º 17' 25.89"	31º 39' 25.24"
13	31º 15' 12.99"	31º 40' 26.39"
14 (Sheremsah)	31º 14' 37.16"	31º 38' 48.64"

A. Water Quality Indices

To investigate the water quality, four indices were used individually in this study, water quality index (WQI) using PH, TDS, Ec, DO, BOD, COD, CO_3, HCO_3, Cl, SO_4, Ca, Mg, NO3, Hardness and alkalinity parameters, and metal pollution index (MPI), pollution Index (PI) and heavy metal pollution index (HMPI) using the heavy metals concentrations. Values of desirable and maximum allowable limits of different parameters, according to [24] and according to [25] for drinking water and [26] for irrigation purpose are listed in Table IV. Each parameter is assigned a weight according to its relative importance for quality of water for drinking purposes, as shown in Table I. Maximum weight of 5 is assigned to total dissolved solids (TDS), pH, EC, NO_3, Mg, Ca, DO hardness and alkalinity Pb, Cd, Hg, and weight of 4 is assigned to BOD, COD, Mn and Cr, weight of 3 is assigned to SO_4, Cl, and Fe, and weight of 2 is assigned to CO_3, HCO_3, NO_3, Al, Ni, Zn and Cu [27] (Tables V and VI).

TABLE IV
STANDARDS OF DRINKING AND IRRIGATION WATER ACCORDING TO WHO, FAO AND EGYPTIAN STANDARDS

Parameters	**Mean**	**Drinking water standards**			**Irrigation standards**
		[25]	**Maximum Allowable Limit (mg/L)**	**[24]**	**[26]**
PH	7.94	6.5-8.5		8.5	8.5
TDS mg/L	2565.48	1000	1000	500	2000
EC µs/cm	4008.57	2000			3000
DO mg/L	7.87	6			
BOD mg/L	3.22	3			
COD mg/L	15.57	10		10	
$CO3^{2-}$ mg/L	9.85	100		100	3
HCO^{3-} mg/L	148.28	100		100	610
Cl- mg/L	1065.21	250	250	200	1063
$SO4^{2-}$ mg/L	64.07	250	250	250	960
Ca2+ mg/L	69	75	350	75	400
Mg2+ mg/L	71	50	150	50	60
NO3- mg/L	26.5	44	45	50	
T- Hardness mg/L	140	500	500	500	
Alkalinity mg/L	54.35			250	
Pb mg/L	0.020	0.01	0.01	0.01	5
Cd mg/L	0.002	0.003	0.003	0.003	0.01
Zn mg/L	0.191	3	3	0.5	2
Cumg/L	0.012	2	2	2	0.2
Cr mg/L	0.100	0.05	0.05	0.05	
Fe mg/L	0.221	0.3	0.3	0.3	5
Nimg/L	0.011	0.02	0.02	0.07	0.2
Mnmg/L	0.06	0.1	0.4	0.1	0.2
Al mg/L	0.017	0.2	0.2	0.2	5
Hg mg/L	0.001	0.001	0.001	0.001	

TABLE V
PARAMETERS OF THE WATER OF DAMIETTA NILE BRANCH IN DAMIETTA GOVERNORATE

Parameters	Samples														Relative Importance	Wi
	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
PH	8.41	8.39	8.39	8.4	8.12	7.98	7.85	8.29	7.21	7.77	7.25	8.11	7.99	7.1	5	0.083
TDS mg/L	14369.28	9808.64	5483.52	3636.48	422.4	270.72	289.28	270.08	255.36	227.84	220.8	222.72	224	215.68	5	0.083
EC µs/cm	22452	15326	8568	5682	660	423	452	422	399	356	345	348	350	337	5	0.083
DO mg/L	12.5	10.2	9.8	8.4	7.4	7.1	6.8	6.4	6.4	6.2	6.3	6.4	8.2	8.1	5	0.083
BOD mg/L	4.9	4.2	4.2	3.9	2.2	2.2	2.6	3.1	3.5	2.1	3.6	4.1	2.2	2.4	4	0.066
COD mg/L	28	24	25	16	12	14	15	11	13	12	12	14	11	11	4	0.066
CO_3^{2-} mg/L	15	11	12	11	11	10	12	9	8	7	9	8	8	7	2	0.033
HCO^{3-} mg/L	221	198	200	172	156	125	124	127	122	142	122	121	124	122	2	0.033
Cl- mg/L	8653	5645	82	66	52	53	58	55	49	51	42	40	34	33	3	0.05
SO_4^{2-} mg/L	290	123	101	66	52	41	32	28	24	33	25	28	25	29	3	0.05
Ca^{2+} mg/L	322	240	101	29	33	23	34	22	23	28	28	29	31	23	5	0.083
Mg^{2+} mg/L	421	320	15	20	19	22	25	24	24	23	22	20	21	18	5	0.083
NO^{3-} mg/L	17	18	15	19	20	21	20	19	29	32	36	41	40	44	2	0.033
T- Hardness mg/L	743	560	116	49	52	45	59	46	47	51	50	49	52	41	5	0.083
Alkalinity mg/L	126	121	102	85	30	35	42	33	36	38	31	25	29	28	5	0.083
								Sum Wi								1

B. Water Quality Index (WQI)

WQI has been calculated to evaluate the suitability of water quality of Damietta Nile Branch using the weighted arithmetic water quality index method, which classifies the water quality according to the degree of purity by using the most commonly measured water quality variables. The calculation method of WQI was developed by [28], which has been widely used by many scientists [29]-[32]. The grading of the water quality is shown in Table VII.

TABLE VI
HEAVY METAL CONCENTRATION OF THE DAMIETTA NILE BRANCH WATER IN DAMIETTA GOVERNORATE

Heavy Metals	Samples															Wi
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Relative Importance	
Pb mg/L	0.03	0.04	0.03	0.04	0.02	0.02	0.01	0.01	0.001	0.01	0.01	0.04	0.01	0.01	5	0.147
Cd mg/L	0.003	0.003	0.004	0.004	0.002	0.001	0.003	0.002	0.001	0.001	0.001	0.001	0.002	0.002	5	0.147
Zn mg/L	0.4	0.3	0.2	0.5	0.01	0.2	0.06	0.005	0.02	0.4	0.06	0.5	0.01	0.01	2	0.058
Cu mg/L	0.02	0.02	0.02	0.03	0.01	0.01	0	0.01	0.01	0	0	0.03	0.01	0	2	0.088
Cr mg/L	0.04	0.05	0.04	0.9	0.02	0.03	0.05	0.06	0.05	0.04	0.04	0.06	0.02	0.01	4	0.117
Fe mg/L	0.4	0.2	0.3	0.5	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.5	0.1	0.1	3	0.058
Ni mg/L	0.01	0.01	0.02	0.02	0	0	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	2	0.058
Mn mg/L	0.09	0.08	0.06	0.1	0.02	0.08	0	0	0.08	0.06	0.04	0.05	0.09	0.09	4	0.117
Al mg/L	0. 2	0.01	0.02	0. 2	0.02	0.02	0.03	0.01	0.01	0.05	0.05	0.01	0.01	0.01	2	0.058
Hg mg/L	0.002	0.002	0.001	0.003	0.002	0.001	0.002	0	0.001	0.001	0.001	0.001	0	0	5	0.147
								Sum Wi								1

$$\mathbf{WQI} = \sum_{i=1}^{n}(\mathbf{Qi} \times \mathbf{Wi}) / \sum_{i=1}^{n}(\mathbf{Wi})$$

Qi (water quality rating) = 100 X (Va-Vi) / (Vs-Vi),

where Va = actual measured value of the water sample, Vi = ideal value (0 for all parameters except pH and DO which are 7.0 and 14.6 mg l-1 respectively). Vs = standard value.

$$Wi = wi / \sum wi$$

where wi is the weight of ith parameter and n is the number of chemical parameters.

TABLE VII
WATER QUALITY INDEX ACCORDING TO [33]

WQI Values	Grading
0–25	Excellent
26–50	Good
51–75	Poor
76–100	Very Poor
Above 100	Unsuitable for drinking purpose

C. Metal Pollution Index

Metal pollution index (MPI) is based on a total trend evaluation of the present status. It used to determine the metal contamination of Damietta Nile Branch Water. The higher the concentration of a metal compared to its respective MAC value, the worse the quality of the water. MI value >1 is a threshold of warning [34]. According to [35] the MI is calculated by:

$$\text{MPI} = \sum_{i=1}^{n}\left(\frac{Ci}{MACi}\right)$$

where: Ci: mean concentration; MAC: maximum allowable concentration.

Water quality and its suitability for drinking purpose can be examined by determining its metal pollution index [36]; [37]. According to [35], water samples can be divided into three groups including: potable (MPI <1), on the threshold of danger of drinking (MPI = 1) and non-potable (MPI> 1).

The quality grading for irrigation water were modified according to heavy metals where, MPI divided into suitable for irrigation or no threshold of danger (MPI<1), on the threshold of danger of irrigation (MPI=1) and unsuitable for irrigation or high danger (MPI>1).

D. Pollution Index (PI)

The pollution index was used in this study to evaluate the degree of heavy metal contamination in water samples [38]-[41]. The tolerable level is the element concentration in the water considered safe for human consumption [42]. Pollution index (PI) is based on individual metal calculations and categorized into 6 classes (Table VIII) according the following equation [43].

$$PI = \sum_{i=1}^{n} \frac{\left(\frac{Ci}{Si}\right)}{Nm}$$

where Ci = Heavy metal concentration in water; Si= permissible Level and Nm = Number of Heavy metals. Water sample with Pollution Index (PI) greater than 1 is regarded as being contaminated.

TABLE VIII
CATEGORIES OF WATER POLLUTION INDEX

Class	PI value	Class
1	<1	No effect
2	1–2	Slightly affected
3	2–3	Moderately affected
4	3–5	Strongly affected
5	>5	Seriously affected

E. Heavy Metal Pollution Index (HMPI)

The HMPI, represent the total quality of water with respect to heavy metals. HMPI was first suggested in 1996 that represents the overall quality of water which is based on heavy metals [36]. The index is calculated based on the weighting the parameters that the weight value is between zero and one, points the importance of the parameters. This index is calculated by:

$$\mathbf{HMPI} = \sum_{i=1}^{n}(\mathbf{Qi} \times \mathbf{Wi}) / \sum_{i=1}^{n}(\mathbf{Wi})$$

Qi (water quality rating) = 100 X (Va-Vi) / (Vs-Vi),

where Va = actual measured value of heavy metals of the water sample, Vi = ideal value of the heavy metals (0 for each heavy metals) Vs = standard value.

$$Wi = wi / \sum wi$$

where wi is the weight of ith parameter and n is the number of chemical parameters.

Water quality based on heavy metal pollution index can be divided into three categories including: low heavy metal pollution (HMPI <100), heavy metal pollution on the threshold risk (HMPI = 100) and high heavy metal pollution (HMPI> 100) [36]. If the samples have heavy metal pollution index values greater than 100, water is not potable.

III. Results and Discussion

A. Physicochemical Characteristics

The physicochemical parameters of Damietta Nile branch water in Damietta Governorate were shown in Tables V and VI compared with the standards values of drinking purpose in Table IV. PH values range from 7.1 to 8.41 with mean value was 7.94. All values of PH were in the normal range of [24] and [25] (Table IV). PH used as indicators of alkalinity and acidity of water, where, the PH values may affects in many chemical and biological processes in the water. TDS values range from 215.68 to 14369.28 mg/L with mean value of 2565.48 mg/L. TDS values were lower than the values of [24] and [25] in all samples except in samples 1, 2, 3 and 4. EC values ranged from 337 to 22452 µs/cm, with mean of 4008.57 µs/cm. EC values were lower than the values of [25] in all samples except in samples 1, 2, 3 and 4. Dissolved Oxygen (DO) is required for the metabolism of aerobic organisms and it influences organic decomposition, where, DO ranged from 6.2 to 12.5 mg/L with mean of 7.87 mg/L. DO values were more than the values of [25] in all samples. The BOD ranged from 2.1 mg/L to 4.9 mg/L, with mean of 3.22 mg/L. The COD ranged from 11 mg/L to 28 mg/L, with mean of 15.57 mg/L. All COD of samples were more than the value of [25]. CO_3 concentration ranged between 7 mg/L to 15 mg/L with an average value of 9.85 mg/L while the concentration of HCO_3 varied from 121 to 221 mg/L with a mean value of 148.22 mg/L. CL concentration ranged between 33 mg/L to 8653 mg/L with an average value of 1069.21 mg/L while the concentration of SO_4 varied from 24 to 290 mg/L with a mean value of 64.07 mg/L. CO_3 concentration ranged between 22 mg/L and 322 mg/L with an average value of 69 mg/L, while the concentration of Mg varied from 18 to 421 mg/L with a mean value of 71 mg/L. NO_3 concentration ranged between 15 mg/L and 44 mg/L with an average value of 26.5 mg/L. Hardness ranged between 41 and 743 mg/L with average of 140 mg/L, while Alkalinity ranged from 25 to 126 mg/L, with mean of 54.4 mg/L. The concentration of these heavy metals (Pb, Cd, Zn, Cu, Cr, Fe, Ni, Mn, Al and Hg) were introduced into the Damietta Nile Branch in Damietta Governorate from agricultural drains, which are heavily polluted by industrial and domestic sewage, many villages on each banks of Damietta Nile branch without sanitation services, Kafr Saad electric power stations, and Talkha fertilizer factory. The average concentrations of the heavy metals were shown in the following descending order: Fe> Zn > Cr >Mn> Pb> Al> Cu> Ni > Cd>Hg.

For irrigation purpose, average values of PH, HCO_3, SO_4, Ca, Pb, Cd, Cu, Fe, Ni, Al and Mn were less than the values of [26]. Other values may be more than or not detected in the [26] standards (Table. IV).

Finally, the physicochemical parameters of this study are compared with many parameters in different years (Table IX). Some parameter ranges of the present study were more than the most previous studies [19], [44]-[46] such as PH, DO, BOd, COD, CO_3 and Ca, while the others may be less than or not detected.

B. Assessment of Water Quality:

Tables X and XI and Figs. 3-6 illustrate the values of the WQI, HMPI, MPI and PI of Damietta Nile Branch water in Damietta Governorate. The WQI, HMPI, MPI and PI scores for Drinking water was computed using guidelines of [25] and [24]. Guidelines of [26] were used to compute the WQI, HMPI, MPI and PI value for irrigation water.

1) Water Quality Index (WQI)

The parameters PH, TDS, Ec, DO, BOD, COD, CO_3, HCO_3, Cl, SO_4, Ca, Mg, NO_3, hardness and alkalinity were used to calculate the WQI for drinking and irrigation water (Tables X and XI). For drinking water, the water quality was unsuitable in samples 1, 2, 3 and 4 (samples in the north near from the Mediterranean Sea). WQI were classified as poor in samples 5, 6, 7, 8, 12 and 13, while the water is good in the samples 9, 10, 11 and 14 (toward south) (Table X, Fig. 3). For irrigation water, the water quality was excellent in most samples (samples 6 to 14), good in samples 5, poor in samples 3 and 4 and the water was unsuitable for irrigation in samples 1 and 2 (near the Nile outlet to the sea) (Table XI, Fig. 3).

TABLE IX
PHYSICAL AND CHEMICAL CHARACTERISTICS OF DAMEITTA BRANCH WATER DURING DIFFERENT TIME PERIODS COMPARED WITH THE PRESENT RESULTS

Parameters	[44]	[19]	[45]	[46]	Present results (Damietta Governorate)
Wat. Temp. 0C	15.9-32.3	17-33.6	16.1-27.5	17-35	
Trans. cm	35-90	70-150	45-200	50-150	
EC µmohs/cm	500-44000	316-503	1007-69260	330-50200	370-22452
Salinity ‰	ND-30	-	9.87-42	ND-32	
TS mg/L	502-34300	186-454	710-41340	256-56302	215- 14369
pH	7.66-8.05	6.97-8.45	7.53-7.97	7.24-8.30	7.1 – 8.41
DO mg/L	6.07-7.23	6.60-9.60	3.03-10.37	5.5-11.0	6.2 – 12.5
BOD mg/L	3.45-8.45	1.20-3.50	1.67-7.70	1.5-4.0	2.2- 4.9
COD mg/L	6.92-10.12	2.8-8.8	9.47-24.67	8.0-26.0	11 - 28
CO_3^{2-} mg/L	2.5-14.7	nil-5	nil-30.13	nil-10	7- 15
HCO^{3-} mg/L	155-174	96-156	115-150	150-220	122 - 200
Cl^- mg/L	75-17835	11.34-36	38-24480	35-25500	33 - 8653
SO_4^{2-} mg/L	137-2643	13.87-45.40	60-10970	30-3000	24 - 290
Ca^{2+} mg/L	19.3-187.8	27-38	26-803	28-290	22 - 322
Mg^{2+} mg/L	11-590	17.5-3016	20-1850	19-1300	18 - 421
NO^{2-}µg/l	25-128	3.70-37.91	10-96	11-36	
NO^{3-} µg/l	233-1056	11.19-89.75	27-386	30-100	15 - 44
NH_3 mg/L	0.91-14.54	0.38-1.08	0.35-1.895	0.15-1.0	
PO_4^{3-} µg/l	166-259	11.24-9605	45-417	35-255	
TP µg/l	338-574	48-283	290-904	250-440	
SiO_3^{2-} mg/L	4.36-5.27	1.07-5.55	1.65-6.00	1.0-3.0	
T- Hardness mg/L					41 - 743
Alkalinity mg/L					25 - 126

2) Heavy Metals Pollution Index (HMPI)

Heavy metal pollution index (HMPI) is an effective method to evaluate the surface water quality. Where, HMPI values in drinking water were high heavy metal pollution (HHMP) in samples which near the Damietta Nile branch outlet (samples 1, 2, 3 and 4) and they were low heavy metal pollution (LHMP) in sample from 5 to 14 (Table X, Fig. 4). For irrigation water, HMPI values were low heavy metal pollution (LHMP) in whole samples (Table XI and Fig. 4).

3) Metal Pollution Index (MPI)

Metal pollution index is also an effective method to evaluation the quality water for drinking and irrigation purposes. In Table X and Fig. 5, the MPI showed that all samples were non-potable water for drinking purpose. For irrigation, the samples were suitable for irrigation purpose in samples from 5 to 14, while the water in samples from 1 to 4 were high danger for irrigation purpose (Table XI and Fig. 5).

4) Pollution Index (PI)

Pollution index is also an effective method to evaluation the quality water for drinking and irrigation purposes. The water quality according to PI was as following: Samples from 5 to 14 and sample 3 were classified as no effect, they slightly effect in samples 1 and 2 (Near outlet of Damietta Nile Branch) and strongly effect in sample 4 (Table X and Fig. 6). For irrigation water, all samples classified as no effected water by heavy metals (Table XI and Fig. 6).

TABLE X
QUALITY OF DRINKING WATER OF DAMIETTA NILE BRANCH IN DAMIETTA GOVERNORATE

Samples	WQI	Quality of Drinking water	HMPI	Quality of Drinking water	MPI	Quality of Drinking water	PI	Quality of Drinking water
1	504	Unsuitable	124.8	HHMP	10.00	non-potable	1.08	Slightly affected
2	368	Unsuitable	130.4	HHMP	9.52	non-potable	1.02	Slightly affected
3	162	Unsuitable	106.9	HHMP	8.51	non-potable	0.85	No effect
4	123	Unsuitable	366.5	HHMP	30.4	non-potable	3.13	Strongly affected
5	60	Poor	77.8	LHMP	5.55	non-potable	0.57	No effect
6	56	Poor	70.01	LHMP	4.97	non-potable	0.59	No effect
7	56	Poor	78.00	LHMP	6.50	non-potable	0.58	No effect
8	59	Poor	45.11	LHMP	4.09	non-potable	0.37	No effect
9	44	Good	47.44	LHMP	3.52	non-potable	0.38	No effect
10	50	Good	62.1	LHMP	5.33	non-potable	0.57	No effect
11	44	Good	54.19	LHMP	4.33	non-potable	0.43	No effect
12	61	Poor	111.7	HHMP	9.05	non-potable	0.99	No effect
13	55	Poor	44.3	LHMP	3.18	non-potable	0.35	No effect
14	40	Good	41.9	LHMP	2.97	non-potable	0.33	No effect

HHMP: High heavy metal pollution, LHMP: Low heavy metal pollution

TABLE XI
QUALITY OF IRRIGATION WATER OF DAMIETTA NILE BRANCH IN DAMIETTA GOVERNORATE

Samples	WQI	Quality of Irrigation water	HMPI	Quality of Irrigation water	MPI	Quality of Irrigation water	PI	Quality of Irrigation water
1	255	Unsuitable	12.85	LHMP	1.22	High danger	0.188	No effect
2	181	Unsuitable	11.54	LHMP	1.05	High danger	0.131	No effect
3	73	Poor	11.93	LHMP	1.07	High danger	0.133	No effect
4	55	Poor	16.08	LHMP	1.54	High danger	0.228	No effect
5	26	Good	4.78	LHMP	0.383	suitable	0.047	No effect
6	23	Excellent	7.52	LHMP	0.698	suitable	0.087	No effect
7	25	Excellent	5.35	LHMP	0.458	suitable	0.057	No effect
8	24	Excellent	3.96	LHMP	0.346	suitable	0.043	No effect
9	17	Excellent	7.10	LHMP	0.632	suitable	0.079	No effect
10	18	Excellent	7.08	LHMP	0.752	suitable	0.094	No effect
11	17	Excellent	4.5	LHMP	0.412	suitable	0.051	No effect
12	21	Excellent	8.21	LHMP	0.91	suitable	0.113	No effect
13	20	Excellent	9.15	LHMP	0.779	suitable	0.097	No effect
14	14	Excellent	8.71	LHMP	0.729	suitable	0.091	No effect

IV. CONCLUSIONS

The parameters (PH, TDS, Ec, DO, BOD, COD, CO_3, HCO_3, Cl, SO_4, Ca, Mg, NO_3, hardness and alkalinity) and heavy metals concentration are used for evaluation of water for drinking and irrigation purposes. Most of water samples were suitable for irrigation, while some were suitable for drinking. The water near the Damietta Nile Branch Outlet was unsuitable for drinking and irrigation, but the water sample in the south of study area was suitable for all purposes.

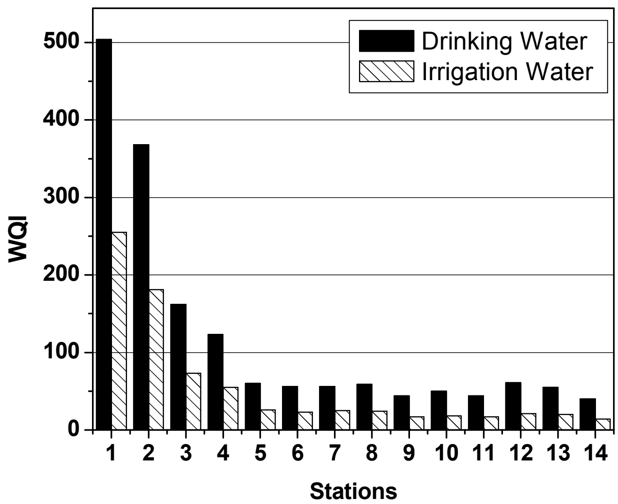

Fig. 3 WQI of Drinking and Irrigation water of Damietta Nile Branch in Damietta Governorate

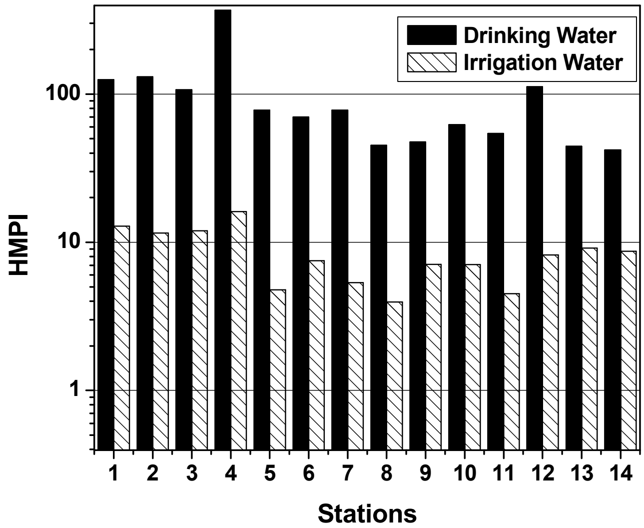

Fig. 4 HMPI of Drinking and Irrigation water of Damietta Nile Branch in Damietta Governorate

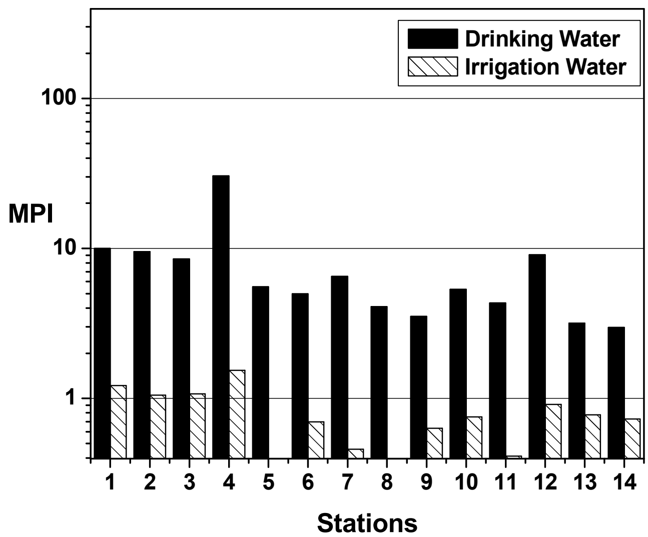

Fig. 5 MPI of Drinking and Irrigation water of Damietta Nile Branch in Damietta Governorate

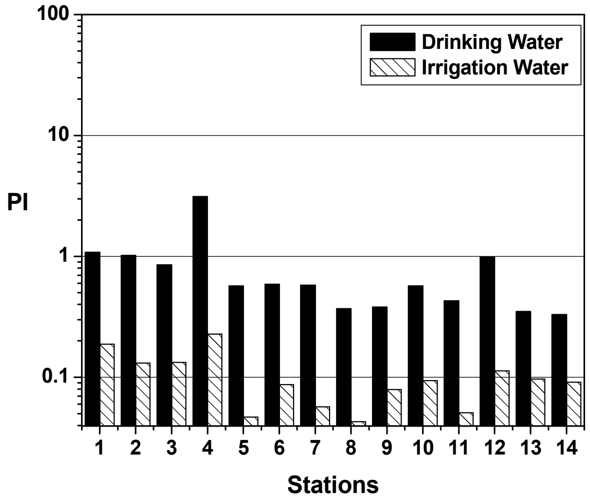

Fig. 6 PI of Drinking and Irrigation water of Damietta Nile Branch in Damietta Governorate

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