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Article

Water Sodicity and Organic Pollution in Sediments and Organ Tissues of *Clarias gariepinus* and *Oreochromis niloticus* from Ammar Drain and Damietta Branch of the River Nile, Nile Delta – Egypt

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Abstract: The present investigation aimed to assess water sodicity and some organic pollution indicators in Ammar Drain and Damietta Branch of the River Nile, East Nile Delta, Egypt over the period from March (2015) to February (2016). Water, sediment and fish tissue samples (muscles and gonads) were collected and analyzed by means of standard techniques. The organic pollution indicators estimated comprises: Dissolved oxygen (DO), total phosphates (TP), total nitrates (TN), biochemical oxygen demand (BOD5), and total organic carbon (TOC). Two teleosts, namely the African sharptooth catfish, *Clarias gariepinus* and the Nile tilapia, *Oreochromis niloticus* were involved. TOC in sediment was positively correlated to that in fish organ tissues. All estimated physicochemical factors showed significant seasonal changes in the two aquatic ecosystems. However, their levels were higher in fish dwelling Ammar Drain than the River Nile. The irrigation water quality indices indicated higher levels of soluble sodium percent, sodium adsorption ratio and residual sodium carbonate in Ammar Drain than the River Nile, reflecting higher sodicity regime in the drain ecosystem. The water quality index (WQI) showed significant difference between the two ecosystems (Kolmogorov-Smirnov Goodness-of-Fit Test: $D = 2.449$; $P \leq 0.001$). Our data revealed that the water quality of Ammar Drain is ranked as bad drainage water, however the Damietta Branch of the River Nile is categorized as good surface water. The obtained data are dreadful and need for combined governmental and community efforts to overcome this crisis and remediate ecosystem degradation.

Keywords: Water Sodicity, Organic Pollution, Ammar Drain, River Nile, Water Quality Index: WQI, Nile Delta, Egypt.

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1. Introduction

Overload of phosphorous and nitrogen in surface run-off may leak into aquatic ecosystems and lead to nutrient enrichment of the waterbody, a phenomenon referred to as Eutrophication (Webber, 2010; Ansari *et al.,* 2011). Eutrophication promotes the growth of aquatic flora and algal blooms, and increases the primary productivity and species diversity of biological communities in aquatic ecosystems (Smith *et al.,* 1999; Shaw *et al.,* 2003). Algal blooms act to minimize the intensity of light, produce toxic compounds and deprive water of oxygen (deoxygentaion) through the aerobic decomposition of organic matter, leading to massive fish kills and huge economic losses. Ben Ameur *et al.,* (2012) suggested that eutrophication may play an important role in the flourishment of aquatic flora that in turn energizes the energy flow across food chains and food webs in aquatic ecosystem. Contamination of streams and rivers by nitrates and phosphates has been observed in many parts of the world. It is worth noting that nitrates and phosphates are probably the key nutrients in controlling aquatic plant growth (Ben Ameur *et al.,* 2012).

Poff *et al.* (2002) and Moore *et al.* (2011) highlighted the importance of aquatic ecosystems as stores for organic pollution and heavy metals. Stegeman (2000) suggested that pollutants bioaccumulate in fish tissues directly from dirty ambient water or indirectly through flow dynamics along the food chains and food webs. Kolo *et al.* (2010) stressed that the nutrient status of water is analyzed with regard to the key minerals phosphorus and nitrogen. Poliakova *et al.* (2000) inspected the building up of organic pollution in the food chains of Lake Baikal, southern Siberia, Russia using algae, planktons, plants, sediments, bird eggs, fish muscles, sponges and seal blubber. The authors found noticeable bioaccumulation of persistent organic compounds along the trophic chains in this aquatic ecosystem. Fish are used as a successful bioindicator in aquatic environmental pollution assessment essays (van der Oost *et al.,* 2003). The target fish tissue accumulating organic pollutants depends on the path of pollutant consumption and fish species. Akan *et al.* (2012) reported that hazardous pollutants accumulate in aquatic sediment as long as these toxic substances are discharged into the environment. According to Abida *et al.* (2008), aquatic organisms such as fish react variably to and accumulate pollutants depending on the amount and formula of contaminants in water, deposits or food items.

Dissolved oxygen (DO) is a key factor for the aquatic life. The amount of this physicochemical determinant attains marked variability with regard to diurnal and thermal regimes. Helawell (1986) suggested that dramatic oxygen depletion during night and early morning may lead to mortality of aquatic fauna and flora. Most aquatic organisms require dissolved oxygen for respiration and energy production. Unlike surface water fish which require greater quantities of the dissolved oxygen (from 4 to 15 mg/L), benthic dwellers, worms and crabs need marginal amounts (from 1 to 6 mg/L) (Osmond *et al.*, 1995). Microorganisms like fungi and bacteria also need dissolved oxygen in order to decompose organic matter accumulated in sediment. Microbial decomposition is an important contributor to nutrient recycling. According to Perlman (2014), an excess amount of decaying organic matter in water, with stratification and irregular turnover, can cause more rapid depletion of oxygen at deeper water layers. EPA (2014) reported that plants and microfloral organisms need dissolved oxygen to manage the respiratory process at night or dark cloudy daytime.

As the amount of dead organic material increases in water more oxygen is used by bacteria to decompose that material. These organic wastes can come from agricultural runoff, industrial wastes or sewage treatment plants. Chemical pollution can also reduce DO levels due to chemical reactions with dissolved oxygen. Nitrates, ammonia, sulfates and other ions reduce levels of dissolved oxygen when they enter streams. The biodegradable materials are easily oxidized by making use of dissolved oxygen (DO) in water. The oxygen demanding water soon depletes the DO. As DO drops, fish and other aquatic life are threatened or killed in extreme case. Under these circumstances, DO may be about 3 mg/l or less. As much as 9.2 mg/l at 25°C is required to support aquatic life (Ademoroti, 1996b).

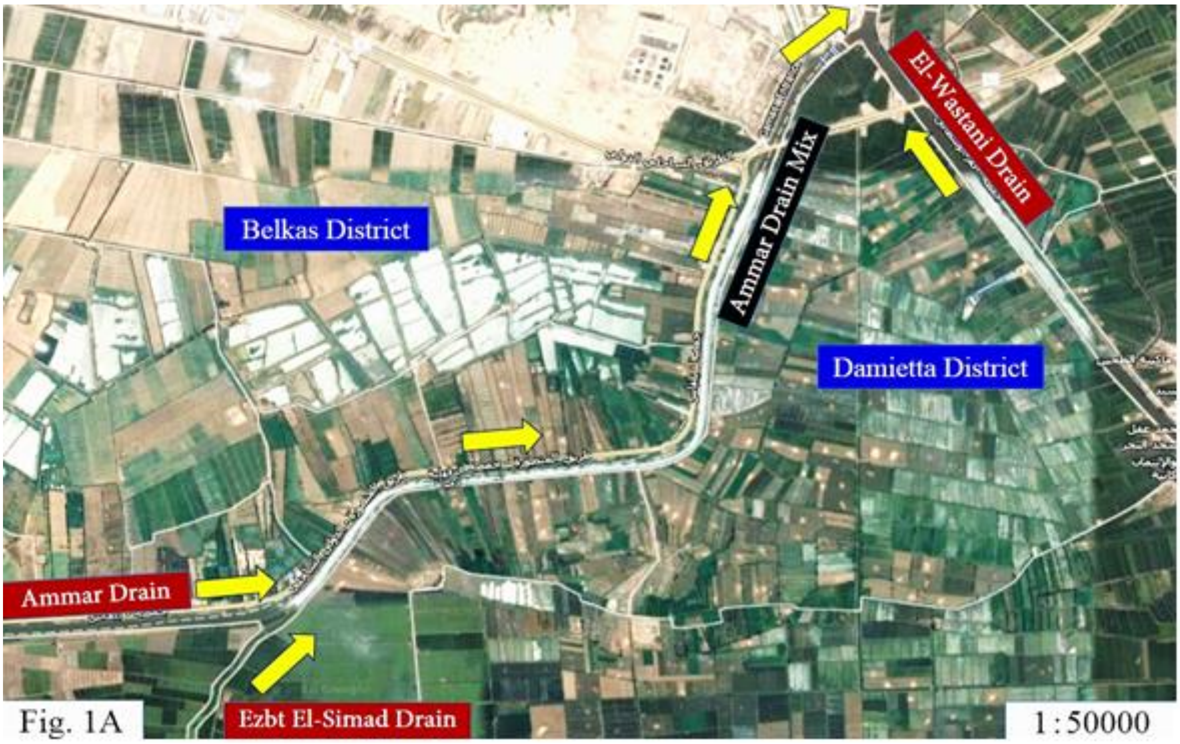
El-Naggar *et al.* (2016) inspected the physicochemical features of Ammar Drain, an annoying waterway flowing across the Nile Delta and compared the recorded data to corresponding parameters in the River Nile. The authors documented more bicarbonates, sulphates, chlorides, electrical conductivity, total dissolved solids, magnesium, sodium and calcium in Ammar Drain than Damietta Branch of the River Nile. Ammar Drain was oxygen-poor and exhibited higher levels of the biological oxygen demand, while the River Nile was oxygen-rich and showed lower levels of the biological oxygen demand. The authors contributed their findings to the proliferation of microorganisms in water. El-Naggar *et al*. (2016) found also that pH levels in Ammar Drain and Damietta Branch of the River Nile were weakly alkaline and fluctuated from 6.75 to 8.22. The present study is an extension of the work of El-Naggar *et al*. (2016) and aimed at evaluating some organic pollution indicators in two freshwater environments, namely the River Nile and Drain No. 2 (Ammar Drain) in the Nile Delta, Egypt. The organic pollution indicators comprised dissolved oxygen (DO), biochemical oxygen demand (BOD5) and total organic carbon (TOC) in aquatic sediment and organ tissues (muscles and gonads) of two teleosts, namely the African sharptooth catfish *Clarias gariepinus* Burchell, 1822 and the White Nile tilapia *Oreochromis niloticus*

Linnaeus 1758. Also, the Water Quality Index (WQI) of the two aquatic ecosystems was calculated to summarize the intermingling impacts of an array of physicochemical environmental factors. Moreover, water sodicity (sodium load of water) was calculated to demonstrate whether water received from the two aquatic ecosystems is valid for irrigation purposes.

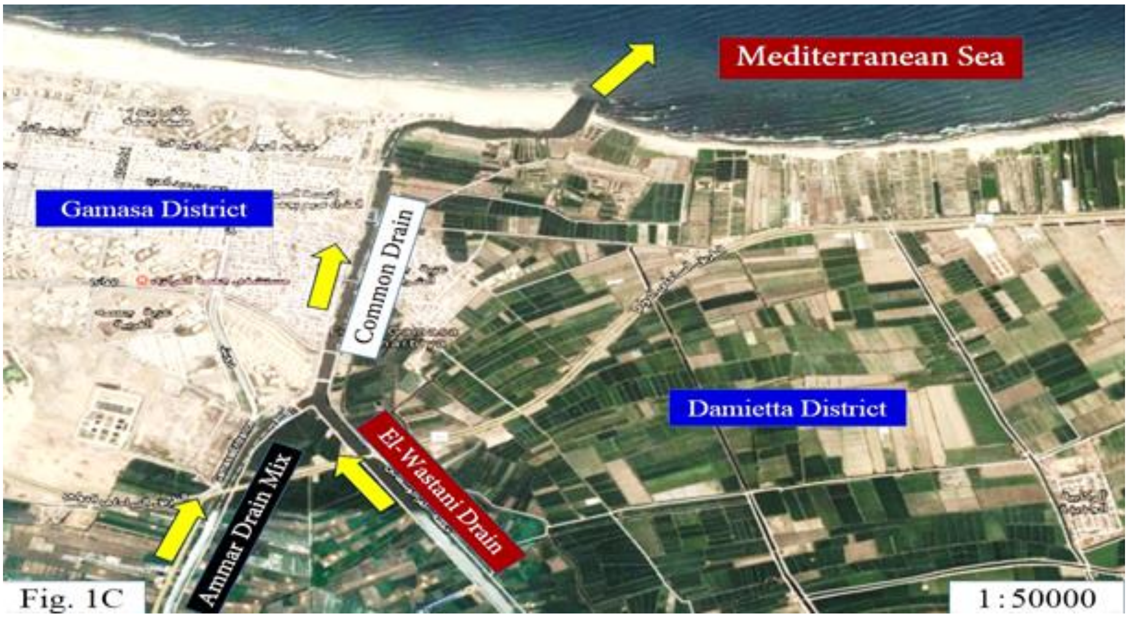
2. Materials and Methods

2.1. Study Area

Two different aquatic habitats were selected (Figures 1A – 1F): the Damietta Branch of the River Nile at Kafr AlTawila, Talkha and Ammar Drain in the vicinity of Belqas district, Dakahlia Governorate, Egypt. The study area shows the coordinates: 31°22'46.4556" N 31°29'13.2432" E. Ammar Drain receives huge quantities of agricultural and domestic discharges flowing from an array of secondary drains such as Ezbt Al-Simad and Al-Wastani waterways (Figures 1A, 1B, 1C and 1F). Ezbt Al-Simad is loaded with agricultural, domestic and the effluents of Belqas Factory for Organic Fertilizers. The River Nile locality at Kafr AlTawila area is shown in Figures 1D and 1E.




Ammar Drain
Ammar Drain Mix
Ezbt El-Simad Drain
Belkas District
Fig. 1B
1:2000


Mediterranean Sea
Gamasa District
Common Drain
Damietta District
Ammar Drain Mix
El-Wastani Drain
Fig. 1C
1:50000


Kafr El-Tawila
El-Tawila
El-Baramon
Damietta Branch
Fig. 1D
1:2000

Figures 1: (1A, 1B, 1C, 1D, 1E and 1F) Photographs showing the study areas: River Nile and Ammar Drain. Note the intensive agricultural activity on the border of the River Nile and Ammar Drain.

2.2. Water Sampling and Field Measurements

The present study was carried between March 2015 and February 2016. For studying the physicochemical parameters in Damietta Branch of River Nile and Ammar drain (drain No. 2), three sites were selected for each ecosystem with appropriate distances. However, ten water samples were collected monthly at each sampling site at 50-cm depth. In one-liter plastic container, primary treatment of the samples was carried out in the field at the time of sampling. Concurrently, water samples were kept according to the protocol designed by El-Naggar *et al.* (2016). The procedures were implemented according to Piper (1947), Hesse (1971), Olsen and Sommers (1982) and APHA (1998).

2.3. Sediment Sampling and Total Organic Carbon Measurement

To detect total organic carbon in sediment, each sample was filtrated, dried in direct sunlight and then crushed until it becomes smooth and fine. The sediment samples were analyzed for total organic carbon (TOC) using Winkler Black titration method (Goerlitz and Brown, 1972), as described by Hesse (1971).

2.4. Fish Sampling and Determination of Total Organic Carbon in Organ Tissues

About 40 samples of the catfish *C. gariepinus* and the cichlid, *O. niloticus* were caught at the same day of water sampling. Only healthy, highly active and likely normal fish were chosen and kept in large plastic containers, with plentiful amount of natural water and proper aeration. This procedure was done to minimize stresses and injuries, and to maintain physiological aspects of the fish. For each fish, the total length (from the tip of snout to the margin of caudal fin) and weight were recorded. Moreover, the gonads (testis and ovary) were weighed. After dissecting fish, muscles and gonads were isolated and analyzed for the total organic carbon (TOC). Fish samples were thoroughly dried at 75°C in an electric oven for 24 hrs. Following the digestion process, each sample was crushed to be smooth for analysis. Estimation of TOC was carried out according to the method described by Hesse (1971). The dried tissues were finely pulverized and 0.2 gram, 10 ml of 0.5M K2Cr2O7 were added and swirled gently for about 5 minutes. Concentrated H2SO4 (10 ml) was added with care directly into the suspension. The mixture was swirled gently and allowed to stand for about 20 minutes, 20 ml of distilled water was added, and 2-4 drops of diphenylamine indicator was involved. Then, the mixture was titrated with standard ammonium ferrous sulphate. The titration was continued until the colour turns green, which indicates the end-point.

2.5. Calculation of Water Quality Index WQI

To calculate the water quality index (WQI), six water quality parameters were considered, namely water temperature, total dissolved solids, hydrogen ion concentration, dissolved oxygen, total phosphate and biological oxygen demand. According to NSF (Brown et al., 1970), WQI oscillates between 0 and 100, and is divided into five intervals: (90-100), (70-90), (50-70), (25-50) and (0-25) reflecting excellent, good, medium, bad and very bad quality respectively.

2.6. Statistical Analysis

All values are given as (Mean ± SD). To calculate the irrigation water quality index (SSP, Soluble Sodium Percent; SAR: Sodium Adsorption Ratio and RSC, Residual Sodium Carbonate), the original data (measured in ppm) were converted to grams per liter (g/L), then divided by the atomic weight of the target element to be involved in the equations as milligram equivalent per liter (mEq/L) (Ezzat and Elkorashey, 2012). Kolmogorov-Smirnov Goodness-of-Fit Test (KS-test) was selected on SPSS statistical program (version 20) to define whether two datasets vary in a significant manner. This is a non-parametric and distribution free statistical method, and pays no attention to the distribution of obtained records. The output of the test is given as D statistic and P-value. This test was used to statistically analyze the values obtained for the Water Quality Index (WQI) in Ammar Drain and the River Nile. Seasonal differences of the physicochemical environmental factors in each locality were tested using the analysis of variance (One-way ANOVA test) on the same statistical program. ANOVA test was followed by Tukey HSD (Tukey’s honest significance test) was used to identify variances between season pairs. To clarify the relationship between the levels of the total organic carbon in sediment and organ tissues of the clariid and cichlid fish, Pearson’s correlation coefficient was chosen on SPSS software. The significance level was set at 0.05.

3. Results

3.1. Analysis of WQI Parameters

The seasonal records of the selected physicochemical environmental parameters at Ammar Drain and Damietta Branch of the River Nile are shown in Tables 1 and 2, respectively.

3.1.1. Temperature (°C)

The thermal regime in the Damietta Branch of the River Nile ranged from 22.03±1.78 to 32.07±0.42 °C. On the other hand, in Ammar Drain, it ranged from 17.70±1.65 to 31.93±0.76 °C.

3.1.2. Hydrogen Ion Concentration (pH)

The pH values in the Damietta Branch of the River Nile ranged between 7.45 ± 0.35 and 7.97±0.42. On the other hand, in Ammar Drain, it ranged between 7.09±0.34 and 7.56±0.20.

3.1.3. Dissolved Oxygen (DO)

The Damietta Branch of the River Nile was oxygen-rich; DO values ranged between 6.70±1.47 and 11.20±4.71 mg/l. In contrast, Ammar Drain was oxygen-poor; DO values ranged between 2.07±0.31 and 7.90±0.30 mg/l.

3.1.4. Total Phosphate (TP)

At the Damietta Branch of the River Nile, the values of TP ranged between 0.11±0.03 mg/l and 0.13±0.00 mg/l. Regarding Ammar Drain, TP concentrations ranged from 0.13±0.02 mg/l to 0.16 ±0.02 mg/l.

3.1.5. Nitrogen (N)

The levels of nitrogen ranged between 3.15±0.63 mg/l and 9.45±1.89 mg/l in the Damietta Branch of the River Nile. However, it fluctuated from 4.29±0.75 mg/l to 10.50±0.96 mg/l in Ammar Drain.

3.1.6. Biological Oxygen demand (BOD5)

BOD5 concentration ranged between 1.07±0.00 mg/l and 4.07±2.66 mg/l in the Damietta Branch of the River Nile. By contrast, in Ammar Drain, it ranged between 0.93±0.47 mg/l and 6.77±0.90 mg/l.

3.1.7. Total Dissolved Solids (TDS)

Ammar Drain showed higher TDS values than the River Nile. The levels of total dissolved solids values fluctuated from 246.72 ±2.24 mg/l to 282.03±29.25 mg/l in the Damietta Branch of the River Nile. However, TDS values ranged between 1339.40 ±174.27 mg/l and 1590.40 ±277.20 mg/l in Ammar Drain.

3.2. Water Quality Index (WQI)

The values of the water quality index were 73.92 ± 3.99 and 45.50 ± 11.39 in Damietta Branch of the River Nile and Ammar Drain, respectively. Statistical analysis indicated high significant seasonal differences of water quality index in the Damietta Branch of the River Nile (One-Way ANOVA test: $F = 8.439$; $P = 0.007$), and very highly significant at Ammar Drain (One-Way ANOVA test: $F = 26.756$; $P \leq 0.001$). The seasonal values of the water quality index at the Damietta Branch were 77.33 ±1.16, 69.67 ±1.16, 77.00 ±1.00 and 71.67 ±4.16 in spring, summer, autumn and winter, respectively. On the other hand, the corresponding values at Ammar Drain were 46.33 ±7.77, 34.67 ±1.53, 39.00 ±1.00 and 62.00 ±1.00, respectively (Figure 2). Moreover, Statistical analysis (Kolmogorov-Smirnov Goodness-of-Fit Test) revealed very high significant variation of the water quality index between the Damietta Branch of the River Nile and Ammar Drain ($D = 2.449$; $P \leq 0.001$).

3.3. Irrigation Quality Indices (IQI)

The soluble sodium percent of water in Ammar Drain was 80.54%, while that in the Damietta Branch of the River Nile was 18.30%. The sodium adsorption of water in Ammar Drain was 0.38, while that in the Damietta Branch was 0.01. The residual sodium carbonate of water in Ammar Drain was 0.001, while that in the Damietta Branch was 0.0004.

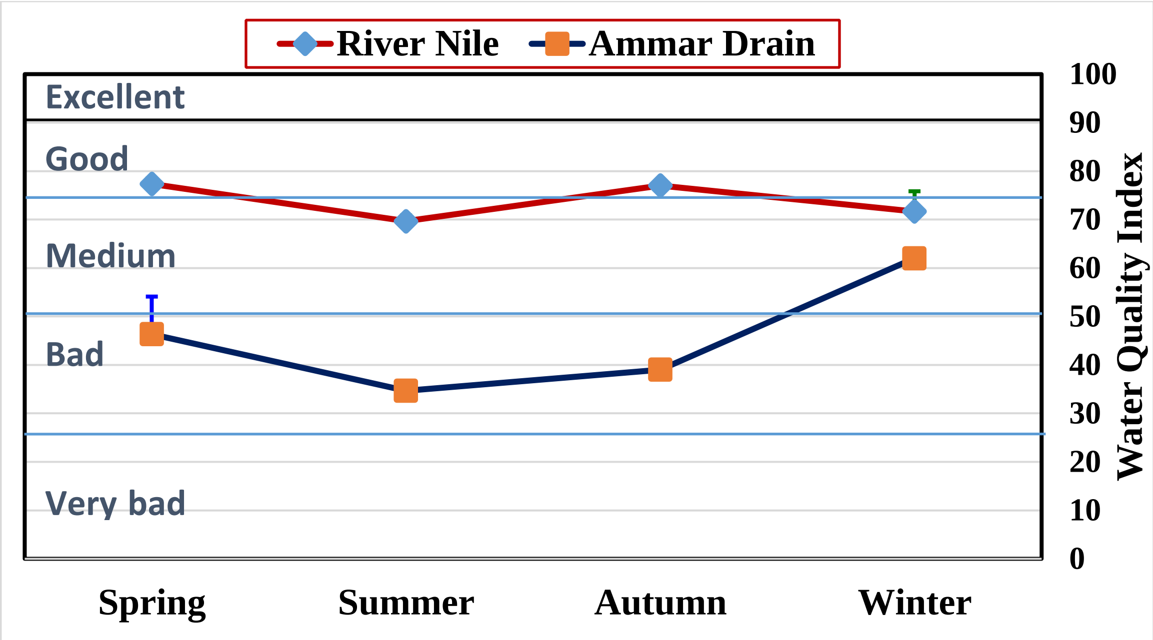


Figure 2. Seasonal changes of water quality index (WQI) of River Nile and Ammar Drain

3.4. Seasonal Fluctuations of Physicochemical Environmental Factors

Seasonal fluctuations of physicochemical environmental parameters of water (pH, temperature, electrical conductivity, dissolved oxygen, biological oxygen demand, total dissolved solids, bicarbonates, chlorides and sulphates, calcium, sodium, potassium, magnesium, nitrogen and phosphorus) from the River Nile and Ammar Drain are recorded in Tables 1 and 2 respectively. The parametric t-Test proved that variations in the electrical conductivity, total dissolved solids, bicarbonate, calcium and sodium were very highly significant ($p \leq 0.001$), those of pH, chlorides, sulphates, magnesium and dissolved oxygen were highly significant ($p \leq 0.01$), while those of potassium and phosphorous showed significant differences between the two investigated areas ($p \leq 0.05$). On the other hand, the remainder of physicochemical parameters showed non-significant differences between the River Nile and Ammar Drain ($p > 0.05$).

Seasonal changes in the dissolved oxygen showed that the dissolved oxygen content of water at the River Nile was higher than that at Ammar Drain. The maximum value of dissolved oxygen (11.20 mg/l) was recorded during winter at the River Nile, while the minimum value (2.07 mg/l) was recorded during autumn at Ammar Drain. Taking the BOD5 values in these two sampling localities in our consideration, it was proved that the maximal values attained (6.77 mg/l) was recorded during autumn at Ammar Drain, however the minimum value (1.07 mg/l) was recorded during spring at the River Nile (Table 2).

Table 1. Seasonal changes of the physicochemical parameters of water in the River Nile.

Water / Season	pH	Temp. (°C)	EC (µs/cm)	DO (mg/l)	BOD5 (mg/l)	TDS (mg/l)	N (mg/l)	P (mg/l)
Spring	7.447 ± 0.349	27.33 ±1.53	0.413 ±0.006	8.10 ±0.80	1.07 ±0.00	246.720 ±2.240	3.150 ±0.630	0.130 ±0.000
Summer	7.970 ±0.416	32.067 ±0.416	0.447 ±0.006	6.70 ±1.47	4.07 ±2.66	274.560 ±10.652	3.780 ±0.630	0.107 ±0.032
Autumn	7.800 ±0.191	22.133 ±3.544	0.463 ±0.006	7.13 ±0.45	1.20 ±0.66	282.027 ±29.254	7.560 ±1.890	0.127 ±0.018
Winter	7.500 ±0.027	22.033 ±1.779	0.403 ±0.023	11.20 ±4.71	2.63 ±1.36	257.920 ±17.209	9.450 ±1.890	0.127 ±0.015
WQI	73.92							

Table 2. Seasonal changes of the physicochemical parameters of water in Ammar Drain.

Water / Season	pH	Temp. (°C)	EC (µs/cm)	DO (mg/l)	BOD5 (mg/l)	TDS (mg/l)	N (mg/l)	P (mg/l)
Spring	7.093 ±0.340	25.750 ±1.750	2.490 ±0.300	7.90 ±0.30	0.93 ±0.47	1590.400 ±277.200	4.290 ±0.750	0.160 ±0.02
Summer	7.557 ±0.197	31.933 ±0.757	2.313 ±0.335	2.30 ±0.61	3.13 ±0.21	1420.803 ±214.091	6.090 ±0.962	0.127 ±0.015
Autumn	7.410 ±0.062	22.533 ±2.363	2.333 ±0.199	2.07 ±0.31	6.77 ±0.90	1339.400 ±174.274	8.820 ±1.667	0.156 ±0.038
Winter	7.300 ±0.121	17.700 ±1.652	2.377 ±0.618	6.10 ±2.08	5.10 ±0.10	1521.067 ±395.577	10.500 ±0.962	0.140 ±0.01
WQI	45.5							

°C = Temperature, pH = Hydrogen ion conc., EC = Electric conductivity, DO = Dissolved oxygen, BOD5 = Biological oxygen demand, TDS= Total dissolved solids, N = Nitrogen, P= Phosphorous.

3.5. Evaluation of Total Organic Carbon in Sediment

Seasonal fluctuations of the total organic carbon in sediment from the River Nile and Ammar Drain are presented in Tables 3 and 4. The highest amount of TOC was determined during summer (13.16), followed by spring (10.56). However, the amounts of TOC detected during autumn (4.46) and winter (4.04), were markedly low (Tables 3 and 4). On the other hand, at Ammar Drain, the maximum TOC level was recorded during autumn (29.90), followed by summer (24.10). Comparatively lower TOC was recorded during spring (15.59). The minimum TOC level was obtained during winter (6.71).

3.6. Evaluation of Total Organic Carbon in Muscles and Gonads

Tables 3 and 4 show the seasonal fluctuations of total organic carbon in organ tissues (muscles and gonads) of *C. gariepinus* and O. niloticus from the River Nile and Ammar Drain. The highest amount of TOC was determined in the muscles of male and female catfish during autumn either at the River Nile

(30.55, 26.63) or Ammar Drain (38.21, 29.91) respectively. Similar autumn peak of TOC was recorded for the testis and ovary of male (34.10, 38.4) and female catfish (31.99, 34.28) in both River Nile and Ammar Drain, respectively. From Table 3, it is obvious that TOC levels in sediment, muscles and gonads of the catfish *C. gariepinus* either at the River Nile or Ammar Drain were comparatively lower during winter than other seasons. Except for the muscles of female tilapia at the River Nile, similar seasonal patterns were recorded for TOC in muscles and gonads of male and female *O. niloticus* (Table 4). The maximum TOC levels were measured during autumn and the minimum levels were recorded during winter. The minimum amount of TOC in the muscles of female *O. niloticus* at the River Nile was recognized during summer (13.36).

Pearson's Correlation Coefficient revealed positive relationship between TOC levels infiltrated in sediment from the River Nile and the corresponding values accumulated in muscles of the catfish *C. garipinus* ($r2=0.338$, $p>0.05$). Similar positive correlation was calculated between amounts of TOC deposited in sediment of the River Nile and gonads of *C. garipinus* ($r2=0.328$, $p>0.05$). Total organic carbon infiltrated in the sediment of the River Nile showed positive relationship with TOC found in the muscles of *O. niloticus* from the same locality ($r2=0.303$, $p>0.05$). Pearson's correlation coefficient detected positive, highly significant, relationship between TOC in sediment and the corresponding values accumulated in gonads of *O. niloticus* from the River Nile ($r2=0.586$, $p\leq0.01$). Concerning Ammar Drain, Pearson's correlation coefficient indicated positive relationship between TOC infiltrated in the sediment of Ammar Drain and the corresponding values in gonads of *C. garipinus* ($r2=0.298$, $p>0.05$) and muscles of *O. niloticus* ($r2=0.136$, $p>0.05$). According to the statistical output, two relationships were not clear, namely TOC in sediment and the corresponding levels in the gonads of *O. niloticus* ($r2=-0.025$, $p>0.05$), and TOC in sediment and the corresponding values in the muscles of *C. garipinus* ($r2=0.061$, $p>0.05$) at Ammar Drain.

The seasonal variations of TOC in the muscles of male *C. garipinus* in Ammar Drain were very highly significant statistically (One-way ANOVA: $F=17.116$, $p\leq0.001$). Multiple Range Comparisons (Tukey HSD test) indicated significant differences between autumn and other seasons, as well as spring and winter. Similarly, very highly significant seasonal differences were recorded for the TOC accumulated in the testis of male *C. gariepinus* at Ammar Drain ($F=70.059$, $p\leq0.001$). Tukey HSD test showed significant variations between spring and other seasons, summer as well as autumn and winter. Moreover, very highly significant seasonal differences were attained by TOC in the muscles and testis of male *O. niloticus* in Ammar Drain (One-way ANOVA test: $F=35.700$, 15.092 and 23.111; $p\leq0.001$ respectively).

Regarding muscles, significant differences were found between winter and other seasons, spring and autumn as well as summer and autumn. Concerning testis, significant variations were recorded between winter and other seasons, spring and autumn, as well as summer and autumn. Regarding the ovary, significant differences were detected by Tukey HSD test between autumn and other seasons, as well as spring and winter. A highly significant seasonal variation was recorded by One-way ANOVA test for the muscles of female *O. niloticus* in ($F=13.200$, $p \leq 0.01$) and significant differences for the total organic carbon in sediment of Ammar Drain between autumn and other seasons. Regarding the sediment, there was a significant difference between autumn and winter. In contrast, no significant seasonal variations were detected for TOC in the muscles of female catfish in Ammar Drain ($F=1.562$, $p>0.05$).

A significant seasonal variation was obtained for the total organic carbon in the muscles of male *O. niloticus* inhabiting the River Nile (One-way ANOVA test: $F=5.641$, $p \leq 0.05$). Tukey HSD test showed a significant difference between autumn and winter. A high significant seasonal variation of TOC in the testis of male *C. garipinus* inhabiting the River Nile was evident (One-way ANOVA test: $F=9.433$, $p \leq 0.05$). Further statistical analysis indicated significant differences between autumn and other seasons. Very highly significant seasonal changes of TOC in muscles and ovary of female *O. niloticus* in the River Nile were revealed by One-way ANOVA test ($F=21.895$ and 16.824, $p \leq 0.001$ respectively). Tukey HSD test detected significant seasonal variation of TOC in the muscles between autumn and other seasons. Similar significant seasonal changes of TOC in the ovary were recorded between spring and winter, summer and autumn, and winter and autumn. In contrast, no significant seasonal differences were reported for TOC in sediment, muscles of male and female, and ovary of female C. garipinus, and testis of male *O. niloticus* inhabiting the River Nile ($p>0.05$ in all cases).

Table 3. Seasonal changes of total organic carbon (TOC %) (Mean ± SD) in sediment and organ tissues of the African catfish, *Clarias gariepinus* from the River Nile and Ammar Drain. S = sediment.

TOC / Season	River Nile					Ammar Drain				
	S	Male Fish		Female Fish		S	Male Fish		Female Fish	
		Muscle	Testis	Muscle	Ovary		Muscle	Testis	Muscle	Ovary
Spring	10.56 ± 7.48	24.56 ±5.37	20.60 ±1.55	22.79 ±4.67	22.38 ±0.95	15.59 ±9.27	28.34 ±1.66	28.17 ±1.43	28.19 ±2.24	27.41 ±1.01
Summer	13.16 ±5.43	19.44 ±9.06	20.12 ±6.64	16.74 ±9.20	16.77 ±6.04	24.10 ±14.94	21.79 ±6.39	21.37 ±2.34	20.97 ±4.65	21.51 ±1.52
Autumn	4.46 ±4.58	30.55 ±6.20	34.10 ±6.08	26.63 ±9.24	31.99 ±13.86	29.90 ±3.14	38.21 ±2.84	38.41 ±2.28	29.91 ±13.67	34.28 ±6.35
Winter	4.04 ±1.18	15.47 ±3.30	14.63 ±1.95	16.48 ±2.78	17.13 ±3.03	6.71 ±1.66	18.62 ±0.93	19.28 ±0.06	19.21 ±0.10	18.66 ±0.96

Table 4. Seasonal changes of total organic carbon (TOC %) (Mean ± SD) in sediment and organ tissues of the Nile tilapia, *Oreochromis niloticus*from the River Nile and Ammar Drain. S = sediment.

TOC / Season	River Nile					Ammar Drain				
	S	Male Fish		Female Fish		S	Male Fish		Female Fish	
		Muscle	Testis	Muscle	Ovary		Muscle	Testis	Muscle	Ovary
Spring	10.56 ± 7.48	24.86 ±4.85	21.11 ±1.17	21.27 ±1.02	24.80 ±4.82	15.59 ±9.27	25.90 ±4.01	28.23 ±2.03	25.55 ±1.67	26.00 ±1.46
Summer	13.16 ±5.43	19.76 ±8.87	17.88 ±2.98	13.36 ±5.06	17.69 ±2.58	24.10 ±14.94	25.84 ±1.95	20.64 ±4.91	21.64 ±4.12	21.76 ±0.86
Autumn	4.46 ±4.58	34.50 ±4.61	28.36 ±9.87	34.06 ±3.07	31.49 ±1.20	29.90 ±3.14	39.99 ±2.51	37.70 ±3.14	37.67 ±6.45	34.68 ±6.10
Winter	4.04 ±1.18	14.69 ±5.35	16.45 ±2.73	15.15 ±3.47	13.00 ±3.94	6.71 ±1.66	18.72 ±0.76	18.72 ±0.76	19.14 ±0.05	17.88 ±1.13

4. Discussion

In the present study, an evaluation of the water sodicity and organic pollution was performed in two differing-water quality aquatic ecosystem, namely Ammar Drain and Damietta Branch of the River Nile, East Nile Delta, Egypt from March (2015) to February (2016). The organic pollutants estimated included: Dissolved oxygen (DO), total phosphates (TP), total nitrates (TN), biochemical oxygen demand (BOD5), and total organic carbon (TOC). Two teleosts, namely the African catfish, *C. gariepinus* and the Nile tilapia, *O. niloticus* were selected to explore the accumulation of TOC in the most edible part (muscles) and reproductive organs (testis and ovary). TOC in aquatic sediment attained positive relationship with the corresponding values in organ tissues. There was significant seasonal variations of the studied physicochemical parameters in the two ecosystems. However, Ammar Drain recorded higher levels of these parameters than the River Nile. The irrigation water quality indices showed higher levels of the soluble sodium percent, sodium adsorption ratio and residual sodium carbonate in Ammar Drain, indicating higher sodicity in the drain. The water quality index (WQI) showed significant variation between the two ecosystems (Kolmogorov-Smirnov Goodness-of-Fit Test: D = 2.449; P ≤ 0.001). Unlike the Damietta Branch of the River Nile which is ranked as good surface water, the water quality of Ammar Drain is classified as bad agricultural drainage.

The water quality index (WQI) summarizes combined impacts of a spectrum of environmental parameters. WQI is informative and integrates the roles of many physical, chemical and biological aspects of water. Six physicochemical environmental parameters, namely water temperature, hydrogen ion concentration, total dissolved solids, dissolved oxygen, biological oxygen demand (BOD5) and total phosphates were employed to calculate the water quality index in Ammar Drain and the Damietta Branch of the River Nile. Mathematical calculation showed that Ammar Drain may be classified as bad water way (WQI= 45.5), with a significant threat to the aquatic fauna and flora, and economic crops frequently irrigated by water pumped from the drain. In contrast, water quality index calculated for the Damietta Branch of the River Nile was 73.92, indicating good quality water according to the physicochemical factors involved in the calculation. Ezzat and Elkoraskey (2012) investigated the characteristic features of the water body in Omar Bek Drain and draw conclusions on the possible impacts of this stressed waterway on the River Nile. The authors employed the ranking scheme developed by Khan et al. (2008) who categorized WQI values as follows: 95-100 (excellent), 80-94 (good), 65-79 (fair), 45-64 (marginal) and o-44 (bad). They found that Omar Bek Drain showed poor quality condition and is deviated from the natural or desirable level. It is worth noting that Ezzat and Elkoraskey (2012) considered 8 physicochemical and biological parameters, namely dissolved oxygen, fecal coliforms, hydrogen ion concentration, temperature, biology oxygen demand (BOD5) and total phosphates, nitrates and turbidity.

According to the Egyptian Environmental Law (48/1982), the permissible limits of the total phosphates, hydrogen ion concentration, total dissolved solids, nitrates, dissolved oxygen and biochemical oxygen demand are 1 ppm, 7.0-8.5, 500 ppm, 45 ppm, > 5 mg/l and <10 mg/l, respectively. According to Mitchel and Stapp (1990), when the total dissolved solids are more than 500 mg/l, the water quality index reaches 20, a very bad water regime. In the present study, the hydrogen ion concentration varied between 7.447 ± 0.35 and 7.97 ± 0.42 in the Damietta Branch of the River Nile. On the other hand, the pH values ranged between 7.09 ± 0.34 and 7.56 ± 0.20 in Ammar Drain. Concerning the electric conductivity (EC) levels, values recorded ranged from 0.403 ± 0.02 and 0.463 ± 0.01 µs/cm in the Damietta Branch of the River Nile. In contrast, at Ammar Drain, the EC values ranged between 2.313 ± 0.34 and 2.490 ± 0.30 µs/cm. FAO recommendations (Ayers and Westcott, 1985) established 0.7 µs/cm EC level as a standard limit for the electric conductivity in irrigation water. Our measurement indicated moderate restriction (0.7-3.0 µs/cm) to use Ammar Drain in irrigation purposes. However, the Damietta Branch of the River Nile was safe for irrigation, where the EC values did not exceed 0.463 µs/cm.

Dissolved oxygen in the aquatic ecosystem is defined as the free oxygen molecules which are not bonded to other elements (CWT, 2004). Free oxygen in the water body can vary from 0 to 14 parts per million (ppm) (Cleveland and Grable, 1998). Usually, the colder the water temperature the higher the dissolved oxygen, which creates a great habitat for animals. Streams and rivers require dissolved oxygen (DO) levels at a minimum of 5-6 parts per million (ppm) to support a healthy and diverse aquatic ecosystem. However, fish and macroinvertebrates are known to survive at dissolved oxygen levels as low as 3.0 ppm in warm water temperatures due to their adaptations for survival under these conditions. According to Caraco *et al*. (2006), many aquatic organisms are responsible for the fluctuation of organic substances and oxygen transmission through the ecosystem and this engineers the oxygen stability in water.

There are a variety of factors that can increase the level of dissolved oxygen in water. Dissolved oxygen naturally enters the water from the atmosphere and will continue to enter the water until it becomes saturated. When aquatic plants and algae are exposed to sunlight they produce oxygen as a waste product of photosynthesis. The structure of a stream or river affects dissolved oxygen. The more turbulence that a stream or river displays, such as waterfalls or rapids, the more oxygen is absorbed into the water. Also, turbulence on the surface of a body of water caused by wind tends to increase levels of dissolved oxygen. Turbulence or turbulent flow is a flow regime in fluid dynamics with chaotic changes in pressure and flow velocity. It is in contrast to a laminar flow regime, which occurs when a fluid flows in parallel layers, with no disruption between those layers.

Dissolved Oxygen is one of the best indicators of the health of a water ecosystem. Dissolved oxygen can range from 0 to 18 ppm, but most natural water systems require 5-6 ppm to support a diverse population (Cleveland and Grable, 1998). Oxygen enters water by direct absorption from the atmosphere or by plant photosynthesis. Oxygen is used by plants and animals for respiration and by aerobic bacteria which consume oxygen during the process of decomposition. When organic matter such as animal waste or improperly treated wastewater enters a body of water, algal growth increases and dissolved oxygen levels decrease as the plant material dies off, and is decomposed through the action of aerobic bacteria (Cleveland and Grable, 1998). Decreases in dissolved oxygen levels can cause changes in the types and numbers of aquatic macroinvertebrates in aquatic ecosystems. Species which cannot tolerate decreases in dissolved oxygen levels include mayfly nymphs, stonefly nymphs, caddis fly larvae and beetle larvae (Cleveland and Grable, 1998). As dissolved oxygen levels decrease, these pollution-intolerant organisms are replaced by pollution-tolerant worms and fly larvae (Cleveland and Grable, 1998).

A concentration of 5 mg/L DO is recommended for optimum fish health. Sensitivity to low levels of dissolved oxygen is species specific, however, most species of fish are distressed when DO falls to 2-4 mg/L. Mortality usually occurs at concentrations less than 2 mg/L. The number of fish that die during an oxygen depletion event is determined by how low dissolved oxygen gets and how long it stays down. Usually, larger fish are affected by low DO in an earlier time a smaller fish are. Dissolved oxygen (DO) is oxygen gas (O_2) that is dissolved in water. Most DO in ponds is produced during photosynthesis by aquatic plants and algae. For this reason, DO increases during daylight hours, declines during the night, and is lowest just before daybreak. Low levels of DO are most frequently associated with hot, cloudy weather, algae die-offs, or heavy thunderstorms. Dissolved oxygen can be monitored using an electronic oxygen meter or chemical test kit. Emergency aeration should be supplied whenever DO falls below 4 mg/L or environmental conditions favor an oxygen depletion event (Francis-Floyd, 2008).

Many important compounds such as nitrates, carbonates and phosphates are formed due to the combination of dissolved oxygen and minerals such as phosphorous, nitrogen and carbon. Photosynthesis, a biological process in which the green plant builds carbohydrate molecules (sugar, starch and saccharide) by the intermingling of carbon dioxide and water in the presence of the sunlight, is the primary source of oxygen in the aquatic ecosystem (Boyd, 1979). Other sources of oxygen in water comprise light and the availability of plants (Adeniji, 1991), temperature and turbulence (Araoye, 2007). Dissolved oxygen and hydrogen ion concentration regulate the amounts of transparency, viscosity, total dissolved solids and conductivity. King (1970) reported that carbon dioxide (CO_2) is removed from the aquatic ecosystem during the daylight as a result of photosynthesis and therefore the pH level is increased. On the other hand, carbon dioxide is released into water at night due to the respiratory processes performed by the aquatic organisms and therefore the pH value is declined (Boyd, 1970).

Inorganic nitrogen and phosphorous are key factors in the eutrophication of the surface water (Soulsby *et al.*, 2001). According to Sharply *et al*. (2001), phosphorous in phosphate compounds is more rapidly absorbed by the quantic flora than inorganic nitrogen and thus exhibits a greater impact on the building up of the algal blooms and proliferation of the surface vegetation cover. In the present study, Ammar Drain exhibited significantly higher levels of nitrogen and phosphorous than Damietta Branch of the River Nile. This could be attributed to the excessive amounts of the agricultural runoff and domestic sewage discharged from an array of suburban areas along the sides of the drain. However, no distinctive, highly proliferating algal communities were recognized. Algal blooms, the green slime or slush invading surface water, can garrote other aquatic organisms. The proliferating populations of the plants produce more and more oxygen in the vicinity of the upper water layers (photic or euphotic zone), however as the surface dwellers become died, they fall down to the bottom. Therein, they become degenerated or decomposed by bacteria and other benthic microflora and microfauna. These decomposers utilize excessive amounts of the dissolved oxygen accumulated on the bottom. Hooper (1998) suggested that aquatic ecosystems with high amounts of phosphorous typically exhibit elevated biological oxygen demand, consumed by the decomposers to break down the organic matter. According to Ravindra *et al*. (2003), elevated level of nitrate endorses high primary productivity and an excess of nitrate in surface water is regarded as a warning for algal blooms. The decrease of dissolved oxygen concentration in these drains may be related to the domestic wastes containing high amounts of biodegradable organic matter.

The irrigation water quality indices indicated higher levels of the soluble sodium percent, sodium adsorption ratio and residual sodium carbonate in Ammar Drain than the Damietta Branch of the River Nile. These finding indicated higher sodicity regime in Ammar Drain than the River Nile. However, the sodality regime calculated for the surface water is categorized as low hazard pollution, and the water withdrawn from the drain may be used for irrigation, with respect to the levels of sodium and related water quality indices. According to the National Sanitation Foundation USA, the residual sodium carbonate levels are categorized as follows: < 0.00 (harmless), 0-1.25 (low hazard), 1.25-2.50 (medium hazard) and > 2.5 (high hazard), whereas the sodium adsorption ratio is ranked in the following order: < 10 (harmless), 10-18 (low hazard), 18-26 (harm or hazard) and > 26 (unsatisfactory for irrigation). Rengasamy *et al*. (2010) suggested that sodium attains inconsistent impact of salinity on agriculture lands. The main physical progressions related to elevated sodium levels are soil diffusion and overall bulging. The authors added that the power that join clay particles together are dislocated when excessive sodium ions infiltrate in between. As a consequence, the clay molecules inflate, leading to enlargement and soil scattering, and reduced soil permeability (Rengasamy *et al*., 2010).

5. Conclusion

The present data demonstrated that Ammar Drain is heavily contaminated, and water reclamation is strongly recommended. Because Ammar Drain is the main water source of irrigation for thousands of acres in Dakahlia Governorate, a development plan should be implemented to overcome the pollution crisis of the drain, in order to prevent contamination of common cultivated crops which represent the basic food items for local residents. It is worth noting that education is an effective tool in tuning practices of the public, and this may reduce the pollution level of the drain as well as other threatened aquatic habitats. In this respect, additional efforts and coordination of the concerned authorities are needed to protect the drain from pollution and reduce environmental risk. This can be achieved by treatment of agricultural, industrial and sewage discharges that fulfill their safety.

The present findings indicate also that Ammar Drain represents a potential environmental disaster threatening human health, deteriorating aquatic life and degrading the ecosystem as a whole. The bad water quality of Ammar Drain may cause massive fish kills and induce chronic health problems such as renal failure and hepatic dysfunction, in addition to its deleterious impacts on the validity of soil.

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