Influences of some pollutants on water quality of El-Bagouria Canal at Kafr El-Zayat Region, El-Gharbia Governorate, Egypt.

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ABSTRACT

The present study aims to describe the effect of heavy metals: copper, manganese, iron and zinc on the water quality of El-Bagouria Canal at Kafr El-Zayat region, El-Gharbiah Governorate. Seasonal variations of physico-chemical parameters were studied during the period from summer, 2013 to spring, 2014. Also, to study their effects on the different organs of the commercial fish species; Nile tilapia, *Oreochromis niloticus* by studying some of biochemical parameters of this fish species (total protein, total lipids, total carbohydrates, ASAT and ALAT) during the study period.

Results revealed that, heavy metals in the water showed seasonal variations. Also, data exhibited the highest values of heavy metals in the different organs of *O. niloticus* were recorded during winter in the liver and kidney and the lowest were observed in the muscles. Biochemical analysis indicated devastating effects, especially enzymes activities, in the metabolic organs. Statistical analysis using analysis of variance (ANOVA, at $p<0.05$) based on data represent the measured values of heavy metals in the different organs of *O. niloticus* during the different seasons. One way analysis proved that, there were highly significant differences between the metals and between the different seasons also between different organs. On the other hand, two ways of ANOVA provided highly significant differences between organs and metals at the same seasons. While, non-significant differences were detected at the interactions between seasons and organs at the same metals and between seasons and metals at the same organs. One way analysis for biochemical parameters in the different organs of *O. niloticus* during the different seasons proved that, there were highly significant differences between the parameters. Meanwhile, there were significant differences between the different seasons and between target organs. Moreover, two ways of ANOVA provided highly significant differences between organs and parameters at the same seasons. While, non-significant differences were found at the interactions between seasons and organs at the same parameters and between seasons and parameters at the same organs.

Keywords: Water quality, biochemical parameters, *Oreochromis niloticus*, El-Bagouria Canal, *pollutant.*

INTRODUCTION

Water always plays a central role as a source of life for all organisms. It is an input to almost all production, in agriculture, industry, energy, transport, by healthy people in healthy ecosystems (Grey and Sadoff, 2007). The River Nile travels along Egypt for about 940 km behind the High Dam. After passing Cairo, the Nile pursues a north westerly direction for about 23 km and divides at El-Kanater Barrage into two branches; Damietta and Rosetta branches and four Rayahs (Canals); El-Nassery, El-Behery, El-Menofy and El-Toufeky. Damietta Branch receives a large amount of untreated effluents from agricultural, domestic and partially treated industrial wastewater (Abdel-Aziz, 2005).

The average width and depth of Damietta Branch are 200 and 12 meter, respectively. It's the main source of drinking and irrigation waters for El-Qalyubia, El-Gharbia, El-Dakahlia and Damietta Governorates (Abdo, 2004). These branches are subjected to two sources of pollution. The first is a pointed source that refers to the contaminants that enter water way, such as sewage and industrial wastes. However, the second is non- pointed source that refers to contaminants that enter water way by diffusion such as agricultural, wastes (Kadry *et al.*, 2015).

In El-Gharbia Governorate (central of Nile Delta), excessive use of sewage effluents and sludge, over-fertilization, over-use of manures for irrigation purposes cause hazard effects on plants, animals and human health. In addition, discharge of liquid and solid wastes with different contaminants into the environment causes groundwater deterioration (Zeidan *et al.*, 2015). However, Kafr El-Zayat industrial area discharge industrial effluents from the factories of super phosphate and sulfur compounds, oil and soap industries and pesticides factories (Daboor, 2006). El-Bagouria Canal is diverting from El-Monofy Rayah at km 21.3 it is 90.0 km long and it serves around 210,000 feddans. The whole length of the canal inside El-Gharbia Governorate is 15.6 km which considering a carrier canal. At km 74.4, there is a main feeder to El-Bagouria Canal (Kafr El-Zayat Region) from the end of El-Melahia Canal (Tanta Region). Until the end of El-Monofiya directorate, the canal has two cross regulators; Shubrabas regulator (Km 29.8) and Kafr Rabie regulator (Km 53.55) (El-Gammal, 2009).

The construction of canals and drains in the River Nile valley including its delta has attracted farmers to locate villages on the banks of the canals and to lesser extent drains. Both canals and drains have been polluted by discharge from these developing communities. Some canals and drains have been contaminated with heavy metals, pesticides, insecticides, fertilizers, possible domestic and industrial wastes, and other chemicals (Zaki *et al.*, 2014). Water quality 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. The composition of surface waters is dependent on natural factors in the drainage basin and varies with seasonal differences in runoff volumes, weather conditions and water levels (Osman and Kloas, 2010). The Physico-chemical parameters are considered as the most important principles in the identification of the nature, quality and type of the water. The hardness of natural waters depends mainly on the presence of dissolved calcium and magnesium salts. Although, hardness (calcium carbonate) reduces the toxicity of divalent heavy metals, humic and fulvic acid, forms low toxicity complexes with some metals (Bujar *et al.*, 2008 and Noor El-Deen *et al.*, 2010). So, the increase of industry, agriculture urbanization and tourism, human activities are responsible for chemical pollution sources for the environment and aquatic ecosystems (Ashry *et al.*, 2013).

Metal can be incorporated into food chains and concentrated in aquatic organisms to a level that affects their physiological state. Trace metals such as Zn, Cu and Fe play a biochemical role in the life processes of all aquatic plants and animals. In the Egyptian irrigation system, the main sources are associated mainly with industrial and domestic effluents, urban storm, water runoff, landfill, atmospheric sources and inputs rural areas (Ciesielski *et al*, 2010). Long-term exposure to heavy metals by inhalation, ingestion and skin absorption may result in devastating effects on ecological balance of the recipient environment and a diversity of aquatic organisms plus slowly progressing physical, muscular and neurological degenerative processes (Otles & Cagindi, 2010 and Suruchi & Khanna, 2011).

Heavy metals like copper, iron and zinc are essential for fish metabolism, while some others such as mercury, cadmium and lead have no known role in biological systems. For normal metabolism the essential metals must be taken up from water or food, but excessive intake of the essential metals can produce toxic effects (Yousafzai, 2004).

Muscles are not always the best indicator of the entire body fish contaminations and therefore, it is vital to analyze other organs such as liver and kidney (Has-Schon *et al*., 2006). Any stress factor may lead to an internal physiological disturbance in fish appears through changing in some blood features, disorder hormones and enzymes dysfunctions. Aspartate aminotransferase (ASAT) and alanine aminotransferase (ALAT) are important diagnostic tools in medicine and are used to detect adverse effects produced by various pollutants (Eddy, 2006). The increment of alanine aminotransferase and aspartate aminotransferase levels occurs nervous shock, hypoxia and stress where their plasma standard levels would be affected by several factors such as pollution, ammonia and nitrite toxications and other environmental parameters like temperature and salinity (Das *et al*., 2004). Furthermore, increasing or decreasing in the values of ALAT and ASAT indicating damage in the liver, kidney, muscles and gills (Ghanem, 2011).

Therefore, the present study aimed to evaluate the effect of water pollution on the physical and chemical parameters at Kafr El-Zayat regions represented in El-Bagouria Canal during the period from summer, 2013 to spring, 2014. Also, to study the effect of some heavy metals (copper, manganese, iron and zinc) on the water of the canal and their bioaccumulation in the different organs of the commercial fish species; *Nile tilapia (O. niloticus)* by studying some biochemical parameters of this fish species (total proteins, total lipids, total carbohydrates, ASAT and ALAT) during the study period. Such investigations may lead to a better understanding of some environmental and physiological aspects.

MATERIALS AND METHODS

Investigated area:

The investigated area (El-Bagouria Canal) includes five stations along the west side of Kafr El-Zayat city; Hesset Abar village, Kalleeb Ebiar village, Kafr El-Zayat city, Kasr Nasr El-Din village and Akwa El-Hessah village (Fig. 1).

Water analysis:

Collection of water samples:

Water samples were collected (subsurface about 30 cm) seasonally during the period from summer, 2013 to spring, 2014. A Van Dorn water sampler with capacity of 1.2 litters was used to obtain samples. After collection, water samples were kept in cleaned poly propylene bottles for latter examination; while some of physico-chemical properties as (temperature, turbidity, pH and conductivity) were measured in the field during samples collection.

Environmental Factors:

Water temperature:

Water temperature was measured during collection of the samples using WTW instrument model 330i (Willard *et al*., 1974).

Turbidity:

Water turbidity was measured during the sampling time in 1 liter of each sample using WTW instrument model Turb.430T (APHA, 2005) after calibration with standard formazin solutions (0.02, 10 and 1000 NTU); results were expressed as Nephelometric Turbidity Unit (NTU).

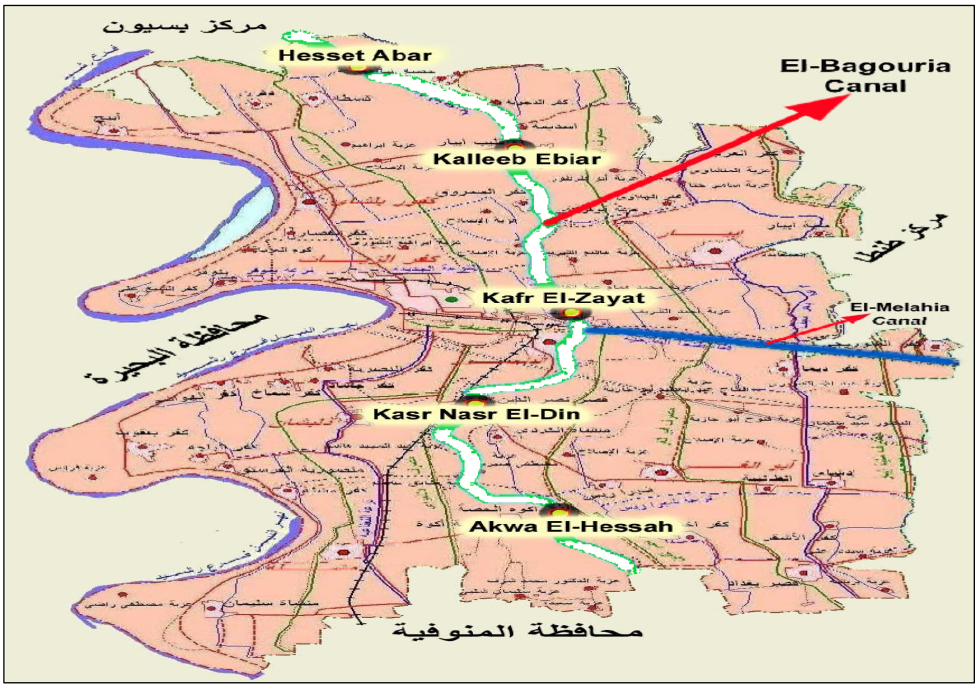

Fig. 1: Map of Kafr El-Zayat area showing the sampling stations in El-Bagouria Canal.

Total dissolved solids (TDS):

According to APHA (2012) conductivity was used to estimate total dissolved solids (mg/L) in a sample by multiplying conductivity (in micromhos per centimeter) by an empirical factor. This factor may vary from 0.55 to 0.9, depending on the soluble components of the water and on the temperature of measurement.

The factor in the current method is 0.53 which attributed to calibration of conductivity meter by 0.01M KCl solution.

TDS (mg/L) = conductivity × 0.53

Electrical conductivity:

It was measured immediately after sampling by using the conductivity meter WTW instrument (model 315i) calibrated with Potassium chloride solution (1413 µS/cm); Results were expressed as µS/cm (Willard *et al*., 1974).

Hydrogen ion concentration (pH):

Hydrogen ion concentration (pH) was measured directly after sampling using pH meter model (WTW 330i) after calibration with standard buffer solutions of pH 4,7 and 10 (APHA, 2005).

Total hardness:

Total hardness (calcium and magnesium) were determined by EDTA titrimetric method according to (APHA, 2005).

Calcium:

Calcium was determined by EDTA titrimetric method according to Katz and Navone (1964).

Magnesium:

Magnesium was estimated as the difference between hardness and calcium as CaCO3, according to APHA (2005).

Sodium:

Flame Atomic Absorption model Varian AA240FS was used for determination sodium. The concentrations were deduced from calibration curve resulted from a series of standard sodium solutions (APHA, 2012).

Determination of heavy metals in water samples:

Heavy metals in the present study are; Cu, Mn, Fe and Zn. Concentrations of heavy metals were determined after the digestion by nitric acid according to APHA (2012).

Fish analysis:

Collection of fish samples:

The selected species, *Oreochromis niloticus* (as a herbivore) was collected carefully from the canal during the study period.

Determination of heavy metals in the fish organs:

Preparation of samples:

Fish samples were stored in prewashed polyethylene bags and transferred immediately to the laboratory in ice box (at 4ºC). In the laboratory, fish were dissected and four organs (liver, kidney, muscles and gonads) were removed then an exact weight of each organ (0.5 g) was dried at 70ºC to constant weight then placed in Teflon vessel and 5 ml of analar nitric acid was added. The vessels were tightly covered and allowed to predigest at room temperature overnight. The digestion block was placed on a preheated hot plate at 80ºC for three hours. Samples were cooled at room temperature and transferred to 25 ml volumetric flask, and the volume was made up to 25 ml of distilled water (UNEP, 1984)

Digested solutions were analyzed by using Atomic Absorption Spectrophotometer (model Varian AA240FS and AA240Z) according to APHA (2012).

Biochemical analysis in the fish organs:

Biochemical parameters in the present study are; total protein [TP], total lipids [TL], total carbohydrates [TC], Aspartate aminotransferase enzyme activity [ASAT] and Alanine aminotransferase enzyme activity [ALAT].

Fish were dissected and four organs (liver, kidney, muscle and gonads) were sepalated then an exact weight of each organ (0.25 g) was grinded through homogenizer in 4 ml saline solution (NaCl 0.9%). Each sample was centrifuged at 4000 round for 15 minutes, the supernatant were transferred to clean wasserman tube and measured according to each parameter kit pamphlet.

Determination of the total protein:

Total protein contents were determined using Diamond commercial colorimetric kits according to Burtis and Ashwood (1999). Results were converted to mg/g wet wt.

Determination of the total lipids:

Total lipids content of the different organs was determined using ABC commercial colorimetric kits by rapid colorimetric method according to Tietz (1976). Results were converted to mg/g wet wt.

Determination of the total carbohydrates:

Total carbohydrate content of the different organs was determined according to Frolund *et al*. (1996). Results were converted to mg/g wet wt.

Determination of ASAT and ALAT activities:

The activities of ASAT and ALAT were estimated by spectrum kit. Kinetic method according to the International Federation of Clinical Chemistry (IFCC, 1986). Results were converted to U/g wet wt.

Statistical analysis:

Results were expressed in tables as mean±S.D. Data were analyzed by using analysis of variance (ANOVA) according to Bailey (1981).

RESULTS AND DISCUSSION

Environmental factors (Physico-chemical parameters):

Water temperature:

Temperature is the water quality indicator that exhibited little variance between the sites and showed clear seasonal variations.The changes of water temperature may depend on the variations in meteorological conditions, air temperature, latent heat of evaporation and different sampling times and seasons (Abdel-Satar, 2005 and Ahmed, 2012).

Data (Table 1) revealed that, water temperature at El-Bagouria Canal (Kafr El-Zayat Region) was peaked at Kafr El-Zayat city during summer (29.23 ± 0.25 ºC) and declined at Hesset Abar village during winter (17.1 ± 0.1 ºC). The results were in agreement with those obtained by Ezzat *et al*. (2012) and Kadry *et al*. (2015), who concluded that, the variation in water temperature depends mainly on the climatic conditions, sampling times, the number of sunshine hours and also affected by specific characteristics of water environment such as turbidity, wind force, plant cover and humidity.

Turbidity of water:

Turbidity is an indicator of the amount of material suspended in water; it measures the amount of light that is scattered or absorbed. Suspended silt and clay, organic matter as well as plankton can contribute to turbidity. It decreases the light penetration, limits the production of phytoplankton, which in consequence decreases the photosynthetic activity and depletion of oxygen content. It restricts the light penetration in water, resulting in reduced primary production (Siddaramu and Puttaiah, 2013).

The present data declared that, the maximum value of turbidity in the water was recorded during spring at Kalleeb Ebiar village (12.3 ± 0.1 NTU) and the minimum one (2.62 ± 0.01 NTU) occurred during summer at Akwa El-Hessah village (Table 1). These results may be due to sampling location, particularly at the industrial sites of Kafr El-Zayat. This elevation in the turbidity during spring may be attributed to the effect of the prevailing wind which helps in mixing water and stirring up the sediment. Similar observations were obtained by Moustafa *et al*. (2010) and Ashry *et al*. (2013) and differed with Ezzat *et al*. (2012) and Al-Obaidy *et al*. (2015) who observed the highest turbidity during summer.

Total dissolved solids:

Total dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium and manganese, organic matter, salt and other particles (Mahananda, 2010).

The present results (Table 1) showed that, the maximal value of total dissolved solids in the water of El-Bagouria Canal was recorded during winter at Hesset Abar and Kalleeb Ebiar stations (229 ± 1.0 mg/L) and the minimal value occurred during spring at Kasr Nasr El-Din Bridge (191 ± 1.0 mg/L). This may be attributed to the elevation of water salts during winter as a result of blocking period. The present observations were nearly agree with these obtained by El-Bouraie *et al*. (2011) and differ with Abdel-Hamid *et al*. (2013) who postulated the minimum value of TDS during winter, in addition to Khallaf *et al.* (2014) who recorded the highest TDS during spring.

Table 1: Seasonal variations of some physical – chemical parameters in the surface water at the different stations of El-Bagouria Canal, Kafr El-Zayat, during the period of study.

Parameters	Water temperature (°C)				Turbidity (NTU)				Total dissolved solid (mg/L)				Electric conductivity (µS/cm)				pH value			
Stations \ Seasons	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring
Hesset Abar	27.90 ±0.10	20.80 ±0.10	17.10 ± .10	26.00 ±0.10	3.39 ±0.02	3.72 ±0.02	5.30 ±0.03	9.07 ±0.02	204.00 ± 1.00	226.00 ± 1.00	229.00 ± 1.00	194.00 ± 1.00	383.33 ± 0.58	426.00 ± 1.00	433.00 ± 2.00	365.00 ± 1.00	7.66 ± .01	7.77 ±0.01	7.97 ±0.02	7.91 ±0.02
Kaleeb Ebiar	28.43 ±0.06	21.00 ±1.00	17.40 ±0.10	26.50 ±0.10	4.14 ±0.01	4.45 ±0.01	7.13 ±0.01	12.30 ±0.10	203.33 ± 0.58	225.00 ± 1.00	229.00 ± 1.00	194.00 ± 1.00	383.33 ± 0.58	426.00 ± 1.00	432.00 ± 2.00	366.00 ± 1.00	7.67 ± 0.01	7.79 ±0.02	7.99 ±0.02	8.07 ±0.02
Kafr El-Zayat	29.23 ±0.25	21.60 ±0.20	17.70 ±0.10	25.30 ±1.56	2.66 ±0.01	3.24 ±0.04	4.61 ± .01	10.00 ±0.20	206.33 ± 0.58	224.00 ± 1.00	227.00 ± 1.00	194.00 ± 1.00	389.33 ± 0.58	423.00 ± 1.00	428.00 ± 2.00	366.00 ± 1.00	7.69 ± 0.01	7.82 ±0.02	8.09 ±0.01	8.08 ±0.02
Kasr Nasr Eldin	28.60 ±0.10	21.40 ±0.10	17.90 ±0.20	26.60 ±0.10	4.13 ±0.02	3.48 ±0.02	5.38 ±0.02	11.50 ±0.20	205.33 ± 0.58	226.00 ± 1.00	228.00 ± 1.00	191.00 ± 1.00	387.33 ± 0.58	427.00 ± 1.00	430.00 ± 1.00	362.00 ± 1.00	7.64 ± 0.01	7.88 ±0.02	8.09 ±0.02	8.23 ±0.03
Akwa El-Hesaha	28.73 ±0.06	21.30 ±0.10	17.70 ±0.10	26.40 ±0.02	2.62 ±0.01	3.75 ±0.05	4.80 ±0.05	9.41 ±0.02	205.33 ± 0.58	225.00 ± 1.00	228.00 ± 2.00	192.00 ± 1.00	386.33 ± 0.58	425.00 ± 1.00	431.00 ± 2.00	362.00 ± 1.00	7.61 ± 0.01	7.91 ±0.02	8.06 ±0.03	8.23 ±0.02

Electric conductivity:

The conductivity increased with the increasing of total dissolved solids and water temperature (Entz, 1973). The present results indicated that, the high peak of electrical conductivity in the water was recorded during winter at Hesset Abar village (433 ± 2.0 µS/cm) and the lower one (362 ± 1.0 µS/cm) occurred during spring at Kasr Nasr El-Din and Akwa El-Hessah stations (Table 1). The explanation of conductivity variance depend on the concentration of total solids and ions however, high conductivity during winter may be attributed to stagnation of water and decrease of water level in the River Nile during the closing period of High Dam gates. The present findings are completely agreed with Al-Obaidy *et al.* (2015). While, the differed observations were obtained by Khallaf *et al.* (2014) who recorded the lowest conductivity during winter.

Hydrogen ion concentration (pH):

Hydrogen ion concentration (pH) is the master control parameter in aquatic environment for the chemical and biological transformation of water (Goher, 2002).

Results (Table 1) revealed that, hydrogen ion concentration varied from 7.61 ± 0.01 during summer at Akwa El-Hessah village to 8.23 ± 0.03 during spring at Kasr Nasr El-Din and Akwa El-Hessah stations. This increasing in pH value may be related to photosynthesis and growth of aquatic plants, where photosynthesis consumes CO_2 leading to arise in pH values. These results are agreed with Khallaf *et al.* (2014) and El-Otify & Iskaros (2015) while they differed with Daifullah *et al.* (2003) and Ghannam *et al.* (2014) who recorded the highest value of pH during summer and the lowest one during winter.

Total hardness:

Total hardness in the water was declined from 156 ± 2.0 mg/L at Hesset Abar, Kalleeb Ebiar and Kafr El-Zayat stations during autumn to 132 ± 2.0 mg/L at Kafr El-Zayat and Kasr Nasr El-Din stations during spring (Table 2).

Table 2: Seasonal variations of total hardness, calcium, magnesium and sodium in the surface water at the different stations of El-Bagouria Canal, Kafr El-Zayat, during the period of study.

Parameters	Total hardness (mg/L)				Calcium (mg/L)				Magnesium (mg/L)				Sodium (mg/L)			
Stations \ Seasons	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring
Hesset Abar	143.33 ± 1.15	156.00 ± 2.00	140.00 ± 2.00	136.00 ± 2.00	37.94 ± 0.46	38.48 ± 0.80	34.47 ± 0.80	32.87 ± 0.80	11.84 ±0.56	14.59 ±0.49	13.13 ±0.97	13.13 ±0.97	25.67 ±0.58	26.67 ±0.71	23.67 ±0.89	21.00 ±0.31
Kaleeb Ebiar	139.33 ± 1.15	156.00 ± 2.00	138.00 ± 2.00	138.00 ± 2.00	36.61 ±0.46	39.28 ±0.80	35.27 ±0.80	33.67 ±0.80	11.67 ±0.49	14.11 ±0.97	12.16 ±0.84	13.13 ±0.97	56.00 ±1.00	26.33 ±0.58	21.67 ±1.53	21.67 ±0.80
Kafr El-Zayat	145.33 ± 1.15	156.00 ± 2.00	144.00 ± 2.00	132.00 ± 2.00	36.61 ±0.46	38.48 ±0.80	33.67 ±0.80	33.67 ±0.80	13.13 ±0.05	14.59 ±0.84	14.59 ±0.03	11.67 ±0.49	26.00 ±1.32	26.33 ±0.78	22.00 ±1.73	22.00 ±1.00
Kasr Nasr Eldin	147.33 ± 1.15	154.00 ± 2.00	144.00 ± 2.00	132.00 ± 2.00	36.61 ±0.46	38.48 ±0.80	34.47 ±0.80	33.67 ±0.80	13.62 ±0.49	14.11 ±0.08	14.11 ±0.84	11.67 ±0.07	26.00 ±1.22	27.33 ±0.67	20.67 ±0.58	21.33 ±1.19
Akwa El-Hesaha	146.67 ± 1.15	154.00 ± 2.00	146.00 ± 2.00	134.00 ± 2.00	36.61 ±0.46	37.68 ±0.80	34.47 ±0.80	33.67 ±0.80	13.46 ±0.82	14.59 ±0.02	14.59 ±0.97	12.16 ±0.49	25.67 ±1.37	28.67 ±0.63	20.67 ±0.71	19.67 ±0.58

Study area showed visible variations in total hardness. This may be due to the sum of the calcium and magnesium concentrations, expressed as calcium carbonate that may be elevated because of effluents of industrial wastes which decrease pH and facilitate carbonate dissolving. Similar observations were recorded by Abdel-Hamid *et al.* (2013) and Khallaf *et al.* (2014) and disagreed with Emara *et al.* (2012) and Hassanein *et al.* (2013) who revealed the maximum value of total hardness during winter.

Calcium:

Calcium compounds are widely used in pharmaceuticals, photography, lime, de-icing salts, pigments, fertilizers, and plasters. Calcium carbonate solubility is controlled by pH and dissolved CO_2 (APHA, 2012).

Results (Table 2) declared that, calcium concentration in the water was fluctuated between 32.87 ± 0.8 mg/L at Hesset Abar village during spring and 39.28 ± 0.8 mg/L at Kalleeb Ebiar village during autumn. The present study showed that, the increasing in calcium content is described by rising in water temperature which may lead to the increasing rate of decomposition of organic matter in sediment by bacterial action releasing the breakdown products including cations. While, decreasing in calcium content could be explained on the basis of its uptake by aquatic microorganisms and fishes. These observations were nearly similar to those notably by Emara *et al.* (2012) and Khallaf *et al.* (2014) who found the lowest concentration of calcium during spring and differed with Abdel-Satar (2005) and Ezzat *et al.* (2012) who reported the highest calcium during summer.

Magnesium:

Magnesium is one of the most important macro-element essential for all chlorophyll containing organisms. It plays an important role in photosynthesis, where give active center in the chlorophyll molecule (El-Enani, 2004).

Data (Table 2) exhibited the maximum concentrations of magnesium ion in the water (14.59 ± 0.97 mg/L) during winter at Akwa El-Hessah village and the minimum one (11.67 ± 0.07 mg/L) occurred during spring at Kasr Nasr El-Din village. Lower magnesium concentration than calcium may be due to supremacy of calcium ions over magnesium ions in sedimentary rocks which could release Mg^{+2} in the water stream as a result of effluents with low pH. The present findings are in agreement with Abdel-Satar (2005) and El-Otify & Iskaros (2015). While, Ezzat *et al*. (2012) was in contrast with current study by recording the highest magnesium during autumn and the lowest during winter. Also, Khallaf *et al.* (2014) showed the maximum magnesium value during spring and the minimum during summer.

Sodium:

Sodium salts are highly soluble in the water and hence all natural waters contain a little amount of sodium (Roberts and Marsh, 1987).

Results (Table 2) indicated that, sodium in the water was peaked during summer at Kalleeb Ebiar village (56 ± 1.0 mg/L) and declined during spring at Akwa El-Hessah village (19.67 ± 0.58 mg/L). This elevation of sodium concentration at Kalleeb Ebiar village during summer might be due to the high mobility of sodium ion and dominates in the natural solutions in the form of effluents near sampling site. The obtained results are in agreement with Ravindra *et al*. (2003) and Ezzat *et al*. (2012). Meanwhile, they are in contrast with Chandra *et al*. (2006) and Hassanein *et al*. (2013) who found the highest concentration of sodium during winter.

Analysis of variance (one way) proved that, there are highly significant differences between the different seasons and between parameters on the values of environmental factors. On the other hand, two ways of ANOVA showed that, the interactions between the different seasons and parameters were highly significant (Table 2).

Heavy metals:

Water samples:

Heavy metal pollution in air, water, soil and plant systems is one of major environmental concern on a world scale with the rapid development of the industry. Beside their natural occurrence, heavy metals may enter the ecological system through anthropogenic activities such as sewage sludge disposal, application of pesticides and inorganic fertilizers as well as atmospheric deposition (Haiyan and Stuanes, 2003).

Copper:

Copper is considered an essential trace element for plants and animals. Some compounds are toxic by ingestion or inhalation. The United Nations Food and Agriculture Organization recommended maximum level for irrigation waters is 200 µg/L (APHA, 2012).

Copper concentration in the water attained its high peak during summer at Kasr Nasr El-Din village (24.67 ± 5.51 µg/L) and the lowest one (3.00 ± 1.00 µg/L) during spring at Kafr El-Zayat City (Table 3). These seasonal variations may be due to the fluctuation of the amount of agricultural drainage water and sewage effluents discharged into the canal. Similar observations were obtained by Daifullah *et al*. (2003) and didn't match with the results of Moustafa *et al*. (2010) and Alawy *et al*. (2015) who obtained the highest level of copper during spring and the lowest level during autumn.

Manganese:

It is present in aquatic ecosystem in many oxidation states. Moreover, manganese is unstable in oxygenated water and easily to oxidized to higher most stable state with formation of solids MnO_2 (Ghallab, 2000).

The maximal value of manganese in the water was recorded at Kalleeb Ebiar village during spring (178.30 ± 24.30 µg/L) and the lowest one (11.33 ± 2.31 µg/L) occurred during autumn at Hesset Abar village (Table 3). This elevation of manganese during spring may be attributed to the effect of the drought period with probable presence of industrial effluents. These observations were in agreement with Venkatesha *et al*. (2013) and differed with Ibrahim and Omar (2013) who recorded the higher values of manganese during summer and the lowest one during winter.

Table 3: Seasonal variations of copper, manganese, iron and zinc in the surface water at the different stations of Bagouria Canal, Kafr El-Zayat, during the period of study.

Parameters	Copper (µg/L)				Manganese (µg/L)				Iron (µg/L)				Zinc (µg/L)			
Seasons / Station	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring
Hesset Abar	18.00 ±0 .61	5.33 ±0.58	5.67 ±0.58	6.00 ±0.05	29.00 ±11.14	11.33 ± 2.31	70.00 ± 7.81	164.33 ± 6.04	203.33 ± 15.28	73.33 ± 20.82	113.33 ± 5.77	906.67 ± 15.28	21.00 ± 6.24	4.50 ± 0.87	5.43 ± 0.40	5.30 ± 0.26
Kaleeb Ebiar	13.00 ± 5.29	4.33 ± .53	5.37 ±0.47	5.77 ±0.23	32.60 ±8.50	13.13 ± 2.71	81.00 ± 6.56	178.30 ± 24.30	176.67 ± 5.77	60.00 ± 10.00	186.67 ± 5.77	980.00 ± 62.45	4.33 ± 0.58	4.67 ± 0.58	5.17 ± 0.29	5.00 ± 0.81
Kafr El-Zayat	18.33 ± 2.08	5.33 ±0.58	5.87 ±0.15	3.00 ±1.00	21.33 ± 3.05	12.90 ± 2.54	80.67 ± 7.23	160.50 ± 1.14	123.33 ± 49.33	43.33 ± 32.15	130.00 ± 34.64	1156.67 ± 77.67	5.00 ± 0.31	5.00 ± 0.50	5.33 ± 0.29	5.43 ± 0.21
Kasr Nasr Eldin	24.67 ± 5.51	6.00 ± .02	5.70 ±0.26	3.67 ±1.15	23.00 ± 4.00	14.23 ± 0.40	85.67 ± 7.02	113.87 ± 6.61	180.00 ± 20.00	33.33 ± 5.77	180.00 ± 10.00	540.00 ± 10.00	5.00 ± 0.72	4.67 ± 0.29	5.17 ± 0.29	5.17 ± 0.29
Alkwa El-Hesaha	19.00 ± 1.00	5.83 ±0.29	5.77 ±0.25	4.33 ±1.15	13.33 ± 3.21	12.16 ± 0.84	73.00 ± 5.57	102.33 ± 7.28	120.00 ± 17.32	63.33 ± 5.77	153.33 ± 15.28	453.33 ± 35.12	5.00 ± 1.00	4.63 ± 0.55	5.00 ± 0.92	5.30 ± 0.26

Iron:

Iron is the most abundant trace metals and serves more biological roles than other metals. Iron occurs in two main oxidation forms; the first is ferric (Fe^{+3}) oxidized and it is insoluble compound and the second is ferrous (Fe^{+2}) reduced and soluble in aqueous media. Therefore, iron precipitate in alkaline and oxidized conditions (El-Enani, 2004).

The present study appeared that, iron concentration in the water was ranged between 33.33 ± 5.77 µg/L at Kasr Nasr El-Din village during autumn and 1156.67 ± 77.67 µg/L at Kafr El-Zayat City during spring (Table 3). This wide variation may be attributed to the direct precipitation of iron and clarity of water at Kafr El-Zayat City with high probability of industrial wastes. The present results are matching with Daifullah *et al*. (2003) and Osman *et al*. (2012) and disagree with Khallaf *et al.* (2014) who recorded the highest value of iron during autumn and the lowest during summer.

Zinc:

Zinc is an essential metal to all forms of life and a large number of diseases and congenital disorders had been trading to zinc deficiency. Also, it is widely used as skin ointment in the form of zinc oxide (Sader, 1991).

The results (Table 3) revealed that, zinc concentration in the water was ranged between 4.33 ± 0.58 µg/L at Kalleeb Ebiar village during summer and 21.00 ± 6.24 µg/L at Hesset Abar village during the same season. The disturbance in zinc concentration can be attributed to different pollution levels at the studied sites during summer. Such findings were obtained by Abdel-Hamid *et al*. (2013); however, Daifullah *et al*. (2003) and Abdel-Satar (2005) did not agree with the present results by recording the lowest concentration of zinc during winter.

The statistical analysis was performed using analysis of variance (ANOVA, at $p<0.05$) on data represent the measured values of heavy metals during the different seasons. One way analysis proved that, there are highly significant differences between seasons and metals on the values of heavy metals. However, two ways of ANOVA provided highly significant differences between organs and metals (Table 4).

Table 4: Analysis of variance (ANOVA) performed on the values of environmental factors and heavy metals in the water of El-Bagoria Canal, during the study period.

Sources of variance	**Environmental factors**		**Sources of variance**	**Heavy metals**	
	D. F.	**F-value**		**D. F.**	**F-value**
Total	107		**Total**	48	
Seasons	3	916.03**	**Seasons**	3	6.02**
Parameters	8	144044.55**	**Metals**	3	18.59**
Seasons * Parameters.	24	287.69**	**Seasons * Metals**	9	4.07**
Error	72		**Error**	33	

Note: ** = highly significant at $p<0.01$.

Heavy metals in the different organs of *O. nilotica:*

Fish are often the top of aquatic food chain and may concentrate large amount of some metals such as lead, cadmium, copper, zinc, mercury and iron. So, it can be considered as one of the most significant indicators in freshwater systems for the estimation of pollution level. These metals accumulate differently in fish organs; kidney, brain, muscles, gills, gonads and liver (El-Enani, 2004; Turkmen & Ciminli, 2007and Ghanem *et al*., 2015).

Copper concentration:

To protect fish, the maximum admissible copper concentration in water is within the range of 1 to 10 µg/L depending on the fish species and physico-chemical state of the water (Svobodova *et al.,* 1993). The permissible level of copper in the fish tissue is 20 µg/g, (WHO, 1999).

The present data revealed that, copper in the different organs of *O. niloticus* inhabited El-Bagouria Canal was decreased from 53.41± 20.55 µg/g wet wt. during spring in the liver to 0.6± 0.28 µg/g wet wt. in the muscles during the same season (Fig. 2). These observations were agree with that obtained by Salem *et al*. (2014) and differed with Demirak *et al*. (2006) who reported that, copper concentration was peaked in the muscles and declined in the gills. These findings were nearly agreed with Fallah *et al*. (2011) and disagreed with Edward *et al*. (2013) who found the highest copper concentration in the gills and the lower one in the muscles.

Accumulations of copper in the different organs of *O. niloticus* showed visible variations with the highest concentration of copper in the liver. However, muscles and gonads were tended to accumulate less level of copper. Fish absorb copper from its feeding diets, sediments and surrounding contaminant waters that, probably received large amounts of industrial, domestic effluents resulting to copper accumulation in different organs of the fish. The higher accumulation in the liver may alter the levels of various biochemical parameters thereby affecting the function of its detoxification and biotransformation of foreign compounds. The differences in the level of heavy metals accumulated by the studied species could be attributed to the differences in their metabolic rates, feeding habits, age, sex and fish species in accordance with Nanda (2014).

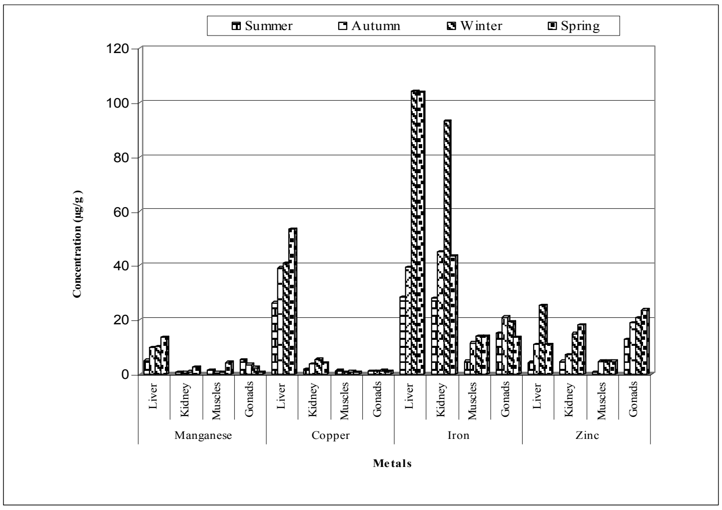

Fig. 2: Seasonal changes of heavy metals in the different organs of *O. niloticus* inhabiting El-Bagouria Canal, Kafr El-Zayat region, during the period of study.

Manganese concentration:

Manganese is an essential trace element for micro-organisms, plants and animals although that, it is sometimes exhibits toxicity (Burger and Gochfeld, 1995). The maximum permissible limit of manganese in the fish tissues according to WHO/FAO is 5.5mg/kg (Tiimub and Afua, 2013).

Results showed that, manganese concentration in the different organs of *O. niloticus* inhabited El-Bagouria Canal exhibited its highest peak during spring in the liver and the lower one during autumn in the kidney; being 13.5 ± 3.0 µg/g wet wt. in the first and 0.5 ± 0.09 µg/g wet wt. in the second (Fig. 2). These findings are agreed with Monferrán *et al.* (2015) and disagreed with Meche *et al.* (2010) who obtained the highest level of manganese during autumn and the lowest during summer. The concentrations of manganese in the different organs of *O. niloticus* showed remarkable variations with highest peak in the gonads and liver. This observation also agree with Al-Yousuf *et al.* (2000), who attributed that due to the greater tendency of the elements to react with the oxygen carboxylate, aminogroup, nitrogen and/or sulphur of the mercapto group in the metallothionein protein, which concentrate in the liver. The higher level of manganese in the liver and gonads of the fishes could be due to the fact that, manganese is naturally abundant in the soils, which is the main source of metals in the surrounding water of the fish samples as it is generally accepted that heavy metal uptake mainly from food, sediment and water that might be polluted with industrial and agricultural effluents discharged directly into the canals of study areas.

Iron concentrations:

Iron is essential to most life forms and to normal human physiology. According to WHO/FAO the maximum permissible limit of iron in the fish tissues is 43 mg/kg (Tiimub and Afua, 2013).

The present data (Fig. 2) declared that, the maximal iron value in the soft tissues of *O. niloticus* was measured during winter in the liver (104.18 ± 27.24 µg/g wet wt.) and the minimum (4.66 ± 2.46 µg/g wet wt.) occurred during summer in the muscles. Data indicated that, the highest concentrations of iron were accumulated in the liver followed by kidney. These results may be due to the influence of surrounding ecosystem or may be attributed to the abundance of iron metals in the water and sediment in addition to the amount of pollutants in the aquatic environment. Fish liver is directly proportional to the degree of pollution by heavy metals, as liver is a target organ of accumulation for metals and highly active in the uptake and storage of heavy metals, while muscle is not an active tissue in accumulating heavy metals. The elevation of iron in the metabolic organs confirm that, the surrounding environment is contaminated with industrial wastes, sewage and agricultural effluents that discharged into canal stream without any treatments to find their way inside the fish organs through their food. These observations are similar to that obtained by Yehia and Sebaee (2012) and differed with Eneji *et al*. (2011) who recorded the maximum value in the gills and the minimum one in the intestine.

Zinc concentration:

Zinc is one of the most abundant essential trace elements in the human body. It is a constituent of all cells and several enzymes depend upon it as a co-factor (Forstner and Wittmann, 1983). According to the declaration of trace heavy metals in fisheries and microbiological control, the permissible tolerance limits of Zn in fresh fish are 50 µg/g wet wt. (Taş *et al*., 2011).

Results (Fig. 2) revealed that, the concentration of zinc in the different organs of *O. niloticus* attained its maximum value during winter in the liver and the minimum one during summer in the muscles (25.25 ± 3.93 µg/g wet wt. in the former and 0.58 ± 0.54 µg/g wet wt. in the latter). These findings are in agreement with Osman (2012) and in contrast with Adeyeye *et al*. (1996) who recorded the higher level of zinc in the muscles of *Tilapia* sp. The previous data declared that, the highest concentrations of zinc were accumulated mainly in the gonads followed by liver. This elevation of zinc in the gonads of fish may be attributed to decomposition of organic matter and agricultural wastes that contain residual zinc and/or may be also associated to reproductive processes. Since gonads are likely to have high zinc concentration due to their participation in cellular division and growth processes.

Data in Table (5) showed the statistical analysis using analysis of variance (ANOVA, at $p<0.05$) based on data represent the measured values of heavy metals in the different organs of *O. niloticus* during the different seasons. One way analysis proved that, there were highly significant differences between the metals and between the different seasons also between different organs.

Table 5: Analysis of variance (ANOVA) performed on the values of heavy metals and biochemical parameters in the different organs of *Oreochromis niloticus*, during the study period.

Sources of variance	**Heavy metals**		**Sources of variance**	**Biochemical parameters**	
	D. F.	**F-value**		**D. F.**	**F-value**
Total	63		**Total**	79	
Seasons	3	4.81**	**Seasons**	3	3.98*
Organs	3	33.71**	**Organs**	3	3.59*
Metals	3	71.93**	**Parameters**	4	11.24**
Seasons * Organs	9	1.75 n.s.	**Seasons * Organs**	9	0.88 **n.s.**
Seasons * Metals	9	1.19 n.s.	**Seasons*Parameters**	12	1.96 **n.s.**
Organs * Metals	9	16.86**	**Organs*Parameters**	12	4.52**
Error	27		**Error**	36	

Note: ** = highly significant at $p<0.01$. **n.s.** = non-significant

On the other hand, two ways of ANOVA provided highly significant differences between organs and metals at the same seasons. While, non-significant differences were showed at the interactions between seasons and organs at the same metals and between seasons and metals at the same organs.

Biochemical analysis in the fishes:

The toxic effects of heavy metals on the fish have been demonstrated. It is abundantly clear that metals induce an early response in the fish as evidenced by alterations both at structural and functional levels of different organs including enzymatic and genetic effects, thereby affecting the innate immune system of exposed fish and/or increasing susceptibility to multiple types of disease (Authman *et al.*, 2015).

Total proteins:

Total proteins play an important role in the metabolism and regulation of water balance. Blood protein and enzyme levels in rainbow trout are affected by metals (Dethloff *et al.*, 1999).

Results showed that, the maximum value of total proteins in the different organs of *O. niloticus* was detected in the kidney during spring (108.8 ± 20.68 mg/g wet wt.) and the minimum (44.8 ± 4.54 mg/g wet wt.) was recorded during summer in the liver (Fig. 3). The present results confirmed that, there was clear depletion in the content of total proteins among different organs of studied fishes. This depletion may be explained on the basis of energy production during the pollutant toxicity through metabolic utilization of the ketoacids to gluconeogenesis pathway for the synthesis of glucose. These observations are similar to those obtained by Sobha *et al.* (2007) and El-Nabarawy (2014), who attributed low protein to other several pathological processes including impairment in protein synthesis machinery, renal damage and elimination in hepatic blood flow or plasma dissolution. Unsimilar findings were notably by Zaghloul (2000), who reported increasing in total proteins in soft tissues of the fishes exposed to heavy metals. This increasing in protein content may be also a mechanism of maturation of gonad and storage of reserves to meet spawning requirements (Jan *et al.*, 2012).

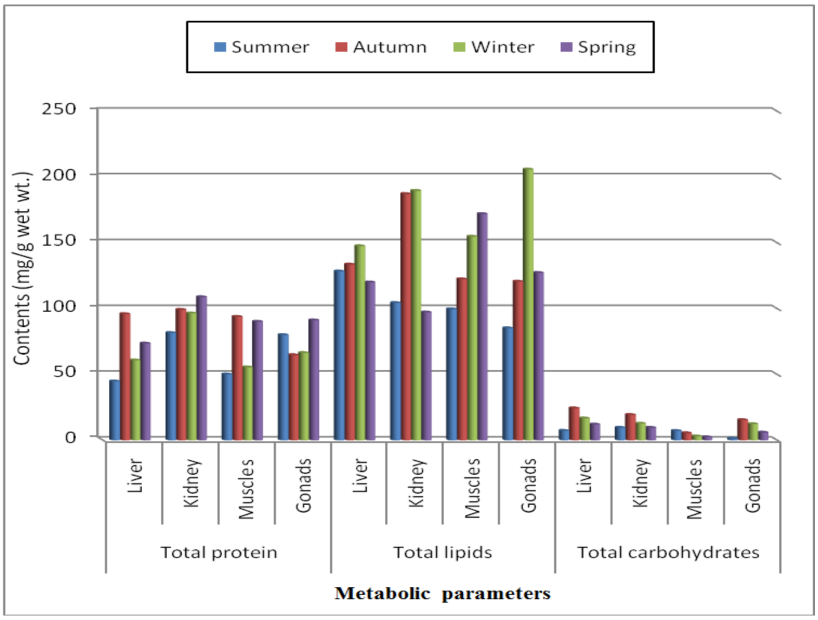

Fig. 3: Seasonal changes of metabolic parameters in the different organs of *O. niloticus* inhabiting El-Bagouria Canal, Kafr El-Zayat region, during the period of study.

Total lipids:

Lipids are an important component in human diets, both as energy and fatty acids sources. Fish like other animals, have the ability to accumulate lipids in their body. Fat content is influenced by species, geographical region, age and diet (Sargent *et al*., 2002).

The present study declared that, total lipid in the target organs of *O. niloticus* collected from El-Bagouria Canal was increased gradually from 85.2 ± 5.17 mg/g wet wt. in the gonads during summer to 205.8 ± 21.0 mg/g wet wt. in the same organ during winter (Fig. 3). According to the present data, the low concentration of lipids in different organs of the fish species especially the muscles could be attributed to poor storage mechanism and the use of fat reserves during spawning activity or imposition of high energy demands to counter the toxic stress beside many other factors that affect the lipids content of fish as seasonal effect, different provisioning origins and a reproduction period. The present results are nearly similar to those obtained by Sobha *et al*. (2007) and Mohanty *et al*. (2013) and disagree with Javed and Usmani (2015) who reported the increasing in lipids content in the internal tissues of fish exposed to heavy metals.

Total carbohydrates:

Carbohydrates serve as the instant energy source during stress, so during acute condition blood glucose level increases due to glycogenolysis but reduction can be correlated to utilization of stored glycogen to meet the energy demand or chronic exposure. In the liver, glycogen mobilizes to glucose whereas in the muscles glycogen /glucose served as readily available source of energy, thus hypoglycemia was observed (Javed and Usmani, 2015). Stress response in the fish is generally characterized by the increasing in adrenalin causing mobilization of liver glycogen into blood glucose (Swallow & Flemming, 1970 and Wepener, 1990).

Data revealed that, the content of total carbohydrates in the organs of *O. niloticus* collected was increased gradually from 1.25 ± 0.16 mg/g wet wt. in the gonads during summer to 24.38 ± 2.33 mg/g wet wt. in the liver during autumn (Fig. 3). Results showed remarkable elevation of total carbohydrates content in the liver tissues and decreasing in the fish muscles. The obtained results explain the fact that, heavy metals increase the glucose content in the blood, because of intensive glycogenolysis and the synthesis of glucose from extra-hepatic tissue proteins and aminoacids (Almeida *et al*., 2001). While, the decreasing in glycogen content in the muscles may be due to the inhibition of hormones which contribute to glycogen synthesis. These results are in agreement with Sobha *et al*. (2007) and Maharajan *et al*. (2012). While, different observations were recorded by Kavidha & Muthulingam (2014), who observed a remarkable decline in the carbohydrates content due to its rapid utilization to meet the reduced energetic efficiency at long exposure to heavy metals.

ASAT (Aspartate aminotransferase) activity:

Many studies consider that, the activity of alanine aminotransferase and aspartate aminotransferase is a sign for liver disease such as liver fibrosis, which may induce by several reasons such as chemicals, virus… etc. (Lee and Farrell, 1997).

ASAT activity in the target tissues of *O. niloticus* inhabited El-Bagouria Canal (Fig. 4) exhibited its maximum level in the muscles during winter and the lower one in the kidney during summer; being 3044.8 ± 641.78 U/mg wet wt. in the first and 16.8 ± 8.8 U/mg wet wt. in the latter.

The present data of ASAT illustrated that, the discharge of different effluents into the studied canal elevated heavy metals levels and reduced the activity of vital organs of *O. niloticus*; these heavy metals caused different degrees of injuries in the fish tissues and elevated ASAT activity. Also, results suggested that, the pollutants of

Nile water may be toxic to fish's cells, such toxic effects could be lipolytic in nature as a result the cell organelles releasing the enzymes into the blood.

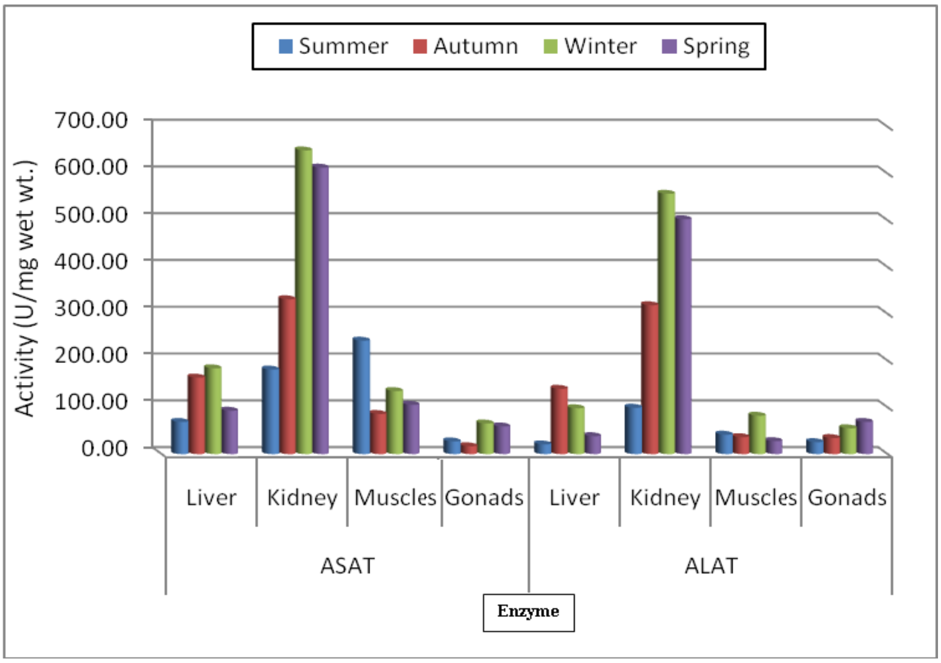

Fig. 4: Seasonal changes of enzymes activities in the different organs of *O. niloticus* inhabiting El-Bagouria Canal, Kafr El-Zayat region, during the period of study

Hence, the increased ASAT activity in the present investigation may be a result of liver cell damage. The obtained results are relatively compatible with those obtained by El-Seify *et al.* (2011) and Abumourad *et al.* (2013) while the incompatible observations were observed by Mohamed & Gad (2008) who recorded depletion in the activity of ASAT as a result of heavy metals stress.

ALAT (alanine aminotransferase) activity:

Alanine aminotransferase (ALAT) couple the protein, carbohydrate and fat metabolism and tricarboxylic acid cycle under altered physiological, pathological and induced environmental conditions (Murugesan *et al*., 1999).

The highest activity of alanine aminotransferase in the soft tissues of *O. niloticus* was observed in the kidney during winter (556.8 ± 146.28 U/mg wet wt.) and the lowest one (20.8 ± 1.27 U/mg wet wt.) was determined in the liver during summer (Fig. 4). Data suggested that, pollutants and different effluents that discharged into the canal elevated ALAT activity in the internal organs of *O. niloticus*. This may be attributed to the toxicity of heavy metals leading to production of mitochondrial enzymes which were subsequently released into the blood as a result of tissues damage. These findings are nearly agree with Thyagarajan *et al*. (2015) and disagree with Hedayati & Safahieh (2011), who recorded falling in ALAT activity due to heavy metals stress.

Data in Table (5) show the statistical analysis using analysis of variance (ANOVA, at $p<0.05$) based on data represent the measured values of biochemical parameters in the different organs of *O. niloticus* during the different seasons. One way analysis proved that, there were highly significant differences between the parameters. Meanwhile, there were significant differences between the different seasons and between target organs. Moreover, two ways of ANOVA provided highly significant differences between organs and parameters at the same seasons. While, non-significant differences were showed at the interactions between seasons and organs at the same parameters and between seasons and parameters at the same organs.

CONCLUSION AND RECOMMENDATIONS

The levels of accumulation of trace metals in the various organs of fish reflect to good extent the degree of aquatic environmental pollution by such metals. Therefore, fish can be considered as a good indicator for the pollution of aquatic environment.

The accumulation of heavy metals caused different degree of injuries in the livers, kidney of investigated fish species.

It is must to protect River Nile from pollution to reduce environmental risks and this study may provide preliminary database for future research on trace metals of the study area.

A recommendation can be made that it is advisable for public health that human must be use only muscles of fish for food and that the internal organs must not be used as fish meal for other purposes.

Making a research lab with new scientific techniques to monitor any defect in the physiology of fish, this in turn affects human health.

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ARABIC SUMMARY

تأثير بعض الملوثات على جودة المياه في ترعة الباجورية بمحافظة الغربية، مصر

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تهدف هذه الدراسة إلى تقدير تركيزات المعادن الثقيلة (النحاس، المنجنيز، الحديد والزنك) في مياه ترعة الباجورية (محافظة الغربية) وتأثيرها على جودة مياهها والأسماك القاطنة بها وخاصة سمكة البلطى النيلى، ودراسة تأثير تلك المعادن علي المعايير الفسيولوجية من المحتوي الكلى للبروتينات، الدهون و الكربوهيدرات و كذلك النشاط الإنزيمى لإنزيمىASAT وALAT فى كبد، كلى، عضلات ومناسل هذا النوع من الأسماك خلال عام ٢٠١٣-٢٠١٤.

أظهرت النتائج وجود تغيرات موسمية فى تركيزات العناصر الثقيلة محل الدراسة. كما أوضحت النتائج أن أعلى قيم للمعادن الثقيلة كانت لعنصر الحديد والتى سجلت خلال فصل الشتاء خاصة فى كبد وكلى أسماك البلطى النيلى. بينما سجلت أقل التركيزات داخل عضلات الأسماك. كما أوضحت التحاليل البيوكيميائية وجود أثار مدمرة وخاصة فى النشاط الإنزيمى داخل كبد وكلى الأسماك محل الدراسة. كما بينت التحاليل الإحصائية وجود فروق معنوية بين مختلف العناصر والمواسم وكذلك الأعضاء. كما أوضحت التحاليل وجود إختلافات جوهرية بين مختلف القياسات الفسيولوجية وكذلك مختلف الأعضاء المختبرة خلال مواسم الدراسة.