Environmental and experimental studies of aluminium toxicity on the liver of *Oreochromis niloticus* (Linnaeus, 1758) fish

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Abstract: Specimens of water and the freshwater fish (*Oreochromis niloticus*) were sampled from Al-Atf drainage canal, Al-Minufiya Province, Egypt, for one year to determine aluminium (Al) concentrations in water and its accumulation in livers of such fish. It was found that Al accumulated in livers of *O. niloticus* in levels higher than that of the canal water. The concentrations of Al in water were higher than the world permissible limits. Experimentally, *O. niloticus* fishes were exposed to three doses of Aluminium sulphate and Al effects were evaluated with regard to hepatosomatic index and liver histopathological alterations. The hepatosomatic indices of fish treated with the three doses of Aluminium sulphate were higher compared to the control group. Fish exposed to the highest dose had significantly higher (P<0.05) hepatosomatic indices than the control fish. Liver tissues of treated fish revealed various histopathological lesions. From this investigation, it was suggested that, the liver of *O. niloticus* is convenient for testing the toxicity of metals such as aluminium.
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1. Introduction:

Environmental pollution represents a major problem in both developed and undeveloped countries **(Kazi *et al*., 2009; Ozden, 2010)**. There has been an increasing awareness that the aquatic pollution and other anthropogenic impacts on water resources may have the potential to damage natural fish stocks **(Abdelmeguid *et al*., 1999)**. The agricultural and industrial wastes partially treated or without treatment are being discharged into surface water **(Zaki *et al*., 2009)**.

Any change in the natural conditions of aquatic medium causes several adjustments in fish and metals are the main culprit for these undesirable changes in water quality **(Garg *et al*., 2009)**. Due to their toxicity, long persistence, bioaccumulative and nonbiodegradable properties in the food chain, metals constitute a core group of aquatic pollutants. In spite of their natural occurrence in the aquatic ecosystem, metals represent a major environmental problem of increasing concern, and their monitoring has received significant attention in the field **(Pandey *et al*., 2003; Barnhoorn and van Vuren, 2004)** and under laboratory conditions **(Long *et al*., 2003; Osman *et al*., 2007)**.

In Egypt; tilapias are the main species of freshwater fishes that inhabit River Nile, irrigation network and drainage canals connected to it. The Nile tilapia, *Oreochromis niloticus* (*Pisces*: *Cichlidae*), is an important fish in the ecology of tropical and sub-tropical region including Egypt and the most popular species of the bony fish in Africa **(Abdel Tawwab *et al*., 2007; Offem *et al*., 2007; Shalloof and Salama, 2008)**.

In the last years the problems of the drainage canals in Egypt have extremely increased. These problems include the presence of high concentrations of different metals and pesticides in both water and various fish organs **(Khallaf *et al*., 1994, 1995, 1998, 2003; Alne-na-ei, 1998, 2000, 2003; Authman, 2008; Authman *et al*., 2008)**. As a result, fish are exposed to water that contains high concentrations of metals including aluminium.

Aluminium (Al) is the third most common and abundant metal on earth after oxygen and silicon **(Sargazi *et al*., 2001; Ščančar *et al*., 2004; Camargo *et al*., 2009)**. Aluminium is similar to many other metals in that it is generally considered most toxic in its soluble ionic form **(Walton *et al*., 2009)**. Al is a harmful metal to the aquatic ecosystem, being responsible for events of toxicity with serious ecological consequences **(Correia *et al*., 2010)**. It is also found in the atmospheric air of the big cities and industrialized areas **(Casarini *et al*., 2001)**, and is used as a flocculation agent in water treatment **(Silva *et al*., 2007; Camargo *et al*., 2009)**.

Different physiological alterations frequently observed in different fish species exposed to Al were cardiovascular, hematologic, respiratory, ionoregulatory, reproductive, metabolic, endocrine

and gill damage **(Brodeur *et al*., 2001; Vuorinen *et al*., 2003; Barcarolli and Martinez, 2004)**.

The liver is the main and important detoxifying organ in fish and is essential for both the metabolism and the excretion of toxic substances in the body **(van Dyk *et al*., 2007)**; and several categories of hepatocellular pathology are now regarded as reliable biomarkers of toxic injury and representative of biological endpoints of contaminant exposure **(Stentiford *et al*., 2003; Feist *et al*., 2004; ICES, 2006)**. Exposure to metals such as Al may therefore cause histological changes in the liver and a histological investigation of exposed specimens may therefore produce meaningful results **(van Dyk *et al*., 2007)**.

The present study was concerned with aluminium because its detection in some drainage canals water in Al-Minufiya Province, Egypt was high, reach to 26.77 mg/l **(Authman, 2008; Authman *et al*., 2008)**.

So, the specific aims of this study were to determine Al concentrations in an drainage canal water to evaluate its occurrence, investigate the tissue accumulation of Al in the liver of Nile tilapia *O. niloticus* inhabiting this canal in order to establish the accumulation factor between metal in water and tissues, and document the effect of Al on the liver of *O. niloticus* in the laboratory to identify histological changes and effects on hepatosomatic index after exposing the fish to Al.

2. Materials and Methods

(1) Field investigations

A- Study area

Al-Atf drainage canal (Fig. 1) is one of the important drainage canals present in Al-Minufiya Province, which extends more than 40 km throughout two governorates (Al-Minufiya and Al-Gharbiya), into the Egyptian delta. Its length is surrounded by more than 17 villages that begin by Meat Al-Beada. It is shallow and narrow canal where the average depth and width are about 1.5 and 6 m respectively. Wastes from more than 25,250 feddan of the cultivable land is directly discharged into this canal but the indirect discharges come from cultivable land (about to 93.000 feddan,) and also illegal sewage find its way to it from various villages**.** The fish fauna, in this canal, includes *Oreochromis niloticus, Tilapia zillii, Oreochromis aureus* and *Clarias gariepenus* **(El- Sehamy, 2001)**. This canal drains in Al-Rayah Al-Abbasy in Al-Gharbiya Province that finally drains into Damietta Branch of the River Nile near Zefta city.

B- Water sampling and analysis

Samples were collected monthly from Al-Atf drainage canal for a complete year. Water samples were obtained from six sites covered the whole length of the canal by a water sampler. Samples were preserved and Al was extracted according to **APHA (1998)**, where 500 ml of water sample were acidified with 5 ml of 6N HNO_3 and heated until the color was discharged. Other 2 ml of conc. HNO_3 were added and the sample warmed slightly to dissolve the residue. The sample was then cooled, filtered and stored for Al detection.

C- Fish sampling and Al residual analysis of liver tissue

Random samples of *O. niloticus* of different sizes were collected monthly from the studied area during the same period of waters sampling. Fishes (9.0–18.0 cm in total length and 12–125 g in total weight) were collected by the fishermen using bottom nets. Fish specimens were kept in an ice box, and transported to the laboratory, where they were killed by blows on the head and then the abdominal cavity was incised from the anus to the isthmus. The liver was dissected out using a sharp safety razor.

Parts of the liver were stored in a deep freezer until processing for aluminium detection. Wet liver samples were digested using HNO_3 (4 ml per gram liver tissue) at 70°C on a hot plate until NO_2 evaporation ceased **(Chernoff, 1975)**. A volume of reagent grade 10% H_2O_2 equal to the initial HNO_3 was added to the digested samples until the sample become clear and then allowed to cool. After cooling, the solution was filtered and the filtrate made up to a known volume (100 ml) with de-ionized water. The samples were stored cool till analyzed.

Different samples of water and fish liver were analyzed using flame atomic absorption spectrophotometer (G.B.C. 908 Avanta Σ), GBC Scientific Equipment PTY LTD, Australia, at the Atomic Absorption Laboratory, Egyptian Mineral Resources Authority, Ministry of Petroleum, Dokki, Giza, Egypt, to detect the concentrations of aluminium.

D- Accumulation factor (AF)

The accumulation factor (AF) was calculated **(Authman and Abbas, 2007)** using the following equation:

AF = aluminium concentration in fish liver (mg kg^{-1} wet wt) / aluminium concentration in water (mg l^{-1}).

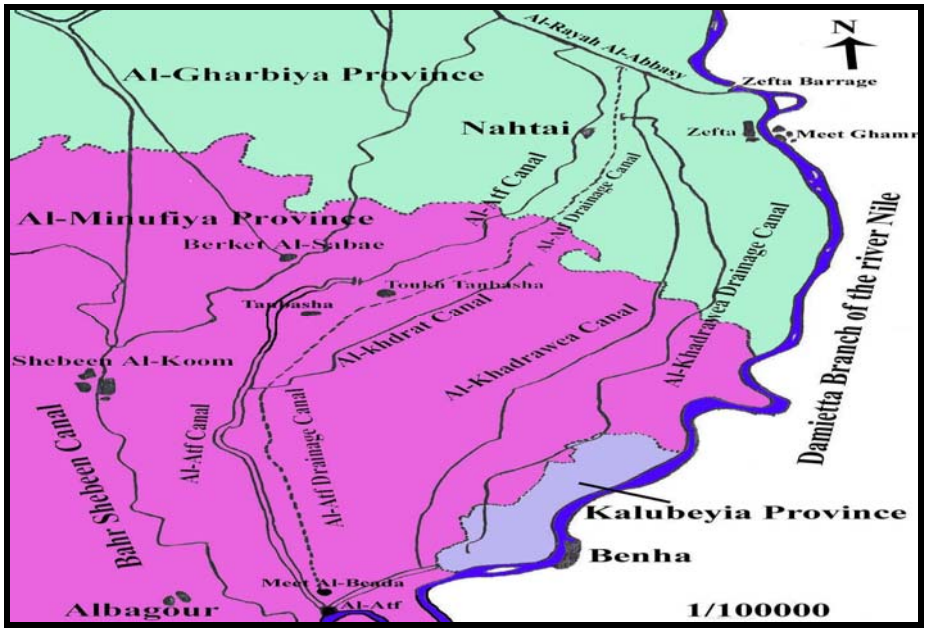

Figure (1): Map showing the area of study (Al-Atf drainage canal, dotted line).

(2) Experimental investigations

A- Sample collection for experimental test

Specimens of *O. niloticus* were obtained from Bahr Shebeen Canal, Al-Minufiya Province, Egypt, throughout commercial fishing using trammel nets. The average total length and body weight were 14.8±2.7 cm and 68.1±5.2 g, respectively. The fish were transported alive to the laboratory in special small water tanks provided by oxygen pumps working with battery; then kept in the laboratory in equipped glass aquaria (40x50x60 cm) containing dechlorinated tap water, and were continuously aerated by air pumps. The fish with external abnormalities such as damaged fins, fallen scales, swelling body and unnatural pigmentation were avoided. Fish were allowed to acclimate to laboratory conditions for two weeks, and were provided with suitable food composed of fishmeal (25% protein of total mass) once per day at a level of 5% of body weight.

B- Experiment design

The experiment was conducted to evaluate the aluminium toxicity in the laboratory. For the experiment, control and exposure tanks were set up in duplicate. A total number of 240 apparently healthy *O. niloticus* were used in this experiment.

Glass tanks (120-liter capacity) were used for the experiment and labeled for control, dose I, dose II and dose III treatments and the number of tanks was duplicated (total number = eight). Thirty fish were introduced in control and each treatment, and all tanks were moderately aerated during the experiment. Three concentrations of aluminium sulphate [$Al_2 (SO_4)_3$] were used as 0.05, 0.30 and 1.00 mg/l which represent 1/2, 3 and 10 times the dose used by **Peuranen *et al.* (2003)**. Also, the lowest used concentration was nearly equal to the highest concentration detected in the canal water samples in the present study. The stock solution of toxicant was prepared by dissolving in dechlorinated tap water. Renewal design experiment was conducted by replacing 90% of the solution in each exposure tank with fresh solution every 2 days to maintain the concentrations as needed. The control tank was treated similarly without addition of toxicant solution.

The water physico-chemical characteristics which were maintained during the study were presented in table (1). Temperature, salinity, conductivity, dissolved oxygen, and pH were measured using electronic portable meters (Yellow Springs Instrument Co., Ohio, USA, YSI S-C-T meter Model 33 and YSI oxygen meter Model 54 ARC) and digital pH meter, Model 206, Lutron, Taiwan). Total hardness, total alkalinity, total dissolved solids, ammonia, nitrate and nitrite were determined according to the methods of **APHA (1998)**.

C- Hepatosomatic (HSI) index

Twenty fish from control and each treatment (duplication) were sampled after 1, 3 and 7 days of exposure and the weight was recorded for each fish to

the nearest 0.1 mg. Every fish was killed by blows on the head, then the abdominal cavity was incised from the anus to the isthmus and the liver was dissected out using a sharp safety razor. This was weighed to the nearest 0.1 mg, and hepatosomatic index (HSI) was calculated **(Khallaf and Authman, 1991)** as follows:

HSI = liver weight (g)/ body weight (g) X 100

Table (1): Physico-chemical characteristics of the water used in the experiment.

Parameter	Value
PH	7.20±0.39
Dissolved Oxygen (DO)	7.71±0.07 mg/l
Temperature	24.3±0.1°C
Total hardness	40.0±2.1 mg/l as $CaCO_3$
Total alkalinity	96.0±3.48 mg/l as $CaCO_3$
Electric conductivity	68.017±0.114 µmohs/cm
Salinity	0.001±0.00 mg/l
NH_3 (Ammonia)	0.041±0.004 mg/l
NO_2 (Nitrite)	0.013±0.002 mg/l
NO_3 (Nitrate)	0.220±0.066 mg/l
Total dissolved solids	74.92±4.52 mg/l

D- Histopathological examination

After 1, 3 and 7 days, parts of livers from control and each treatment were preserved in 10 % phosphate buffered formalin for 24 hours, then dehydrated by a series of upgraded ethanol solution, embedded in paraffin, and sectioned at 5 µm thick. Tissue sections were routinely processed and stained with Hematoxylin and Eosin (H & E) and examined by light microscopy according to **Roberts (2001)**.

(3) Statistical analyses

Statistical analyses were performed using a computer program SPSS, version 17 for Windows. The comparison between means and standard deviations was tested for significance using ANOVA analysis. The differences between exposed and control fishes were considered significant if $P<0.05$.

3. Results

(1) Field observations

A) Al concentrations in water and liver

Table (2) and figure (2) illustrated the monthly variations of Al concentrations levels in canal water and liver of *O. niloticus*. The results indicated that, the average Al concentrations in water showed irregular distribution pattern. In water, it was ranged between 0.0018 and 0.0540 mg/l in September and April, respectively. The irregularities were also apparent in the changes of the Al concentrations in liver. Al concentrations in liver were higher than in water allover the year. These concentrations ranged between 0.92 mg/Kg wet wt in July and 6.49 mg/Kg wet wt in February.

B) Accumulation Factor (AF):

It was found that Al concentrations in liver of the studied fish species were several times higher than its concentrations in water. In addition, it is obvious from the data given in table (2) and figure (2) that, these factors in liver were ranged between 21.86 and 1475.14 times in April and September, respectively.

Table (2): Monthly variations of aluminum concentrations in water and liver of *O. niloticus* collected from Al-Atf drainage canal and the accumulation factor.

Months	No. of Fishes	Al Concentrations		Accumulation Factor (AF)
		Water (mg/l)	Liver (mg/Kg wet wt)	
January	33	0.0026	2.29	877.39
February	37	0.0129	6.49	502.71
March	31	0.0069	1.23	179.56
April	33	0.0540	1.18	21.86
May	34	0.0054	1.06	198.13
June	32	0.0043	1.20	277.14
July	33	0.0187	0.92	49.17
August	32	0.0056	4.00	720.72
September	35	0.0018	2.67	1475.14
October	34	0.0021	1.54	751.22
November	36	0.0046	2.87	622.56
December	31	0.0103	3.11	301.06

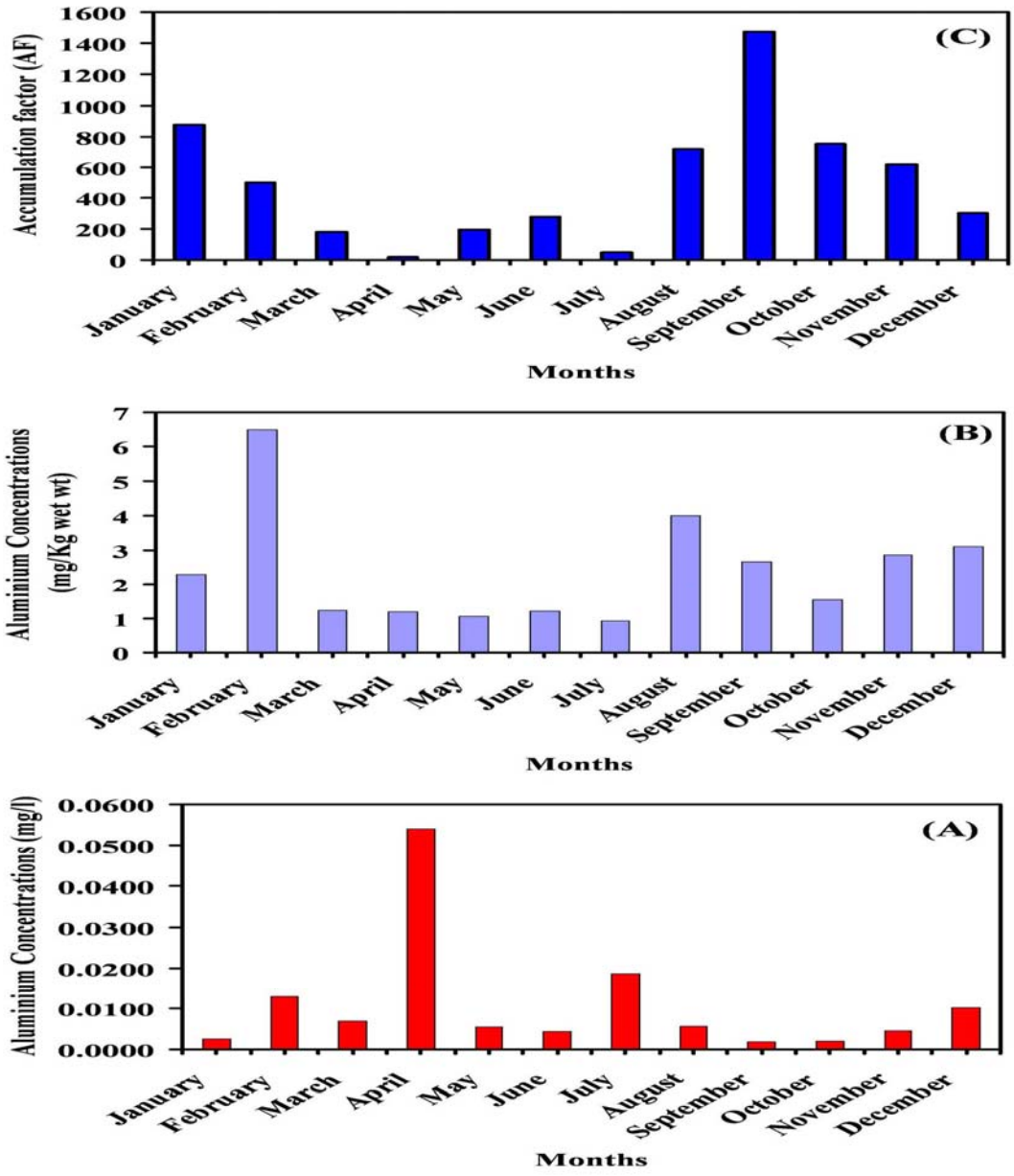

Figure (2): Monthly variations of aluminium concentrations in water (A) and liver of *O. niloticus* (B) and the accumulation factor (C).

(2) Experimental observations

Over the course of the study, the values of physico-chemical characteristics of water did not varied among control and Al groups (Table 1). Also, it was noticed that mortality did not occur and the fish demonstrated no visual signs of distress during the experiment, where an external investigation of each specimen was executed after the exposure and it was found that all fish seem to be of good health with regard to the macroscopic condition of their fins, eyes, mouth, and scales and their general external appearance.

A) Hepatosomatic index (HSI)

The HSI values of fish treated with all doses of Al were higher compared to the control group (Table 3; Figure 3). However, on the basis of the statistical analysis, HSI values of the fish of group III exposed to the 1.00 mg/l dose of Al were significantly higher (P<0.05) than the control fish.

Table (3): The effect of aluminum sulphate on the hepatosomatic index (HSI) of *O. niloticus* at different used concentrations.

Duration time (Day)	Hepatosomatic index (HSI)											
	C			I			II			III		
1	1.987	±	0.822	2.075	±	0.496	2.238	±	0.613	2.415*	±	0.496
3	2.054	±	0.363	2.174	±	0.465	2.395	±	0.673	2.498*	±	0.059
7	2.063	±	0.588	2.192	±	0.119	2.399	±	0.673	2.698*	±	0.799

C = Control. I = 0.05 mg/l of aluminum sulphate.
II = 0.30 mg/l of aluminum sulphate. III = 1.00 mg/l of aluminum sulphate.
The values are expressed as means ± standard deviation (95% confidence limits).
Number of fish samples in each treatment = 20.
* Values significantly different (P<0.05) compared with control group.

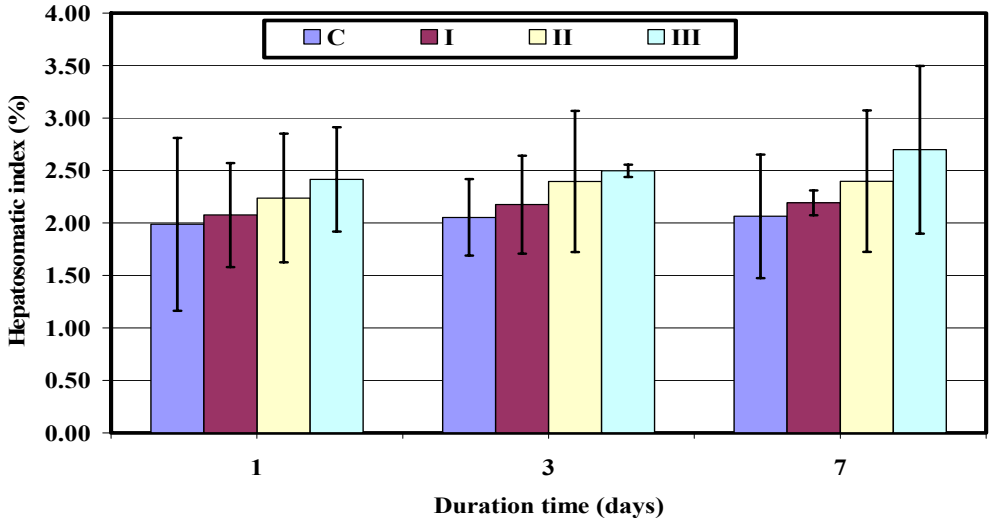

Figure (3): The effect of aluminum sulphate on the hepatosomatic index (HSI) of *O. niloticus* at different used concentrations. (Mean± standard deviation; C = Control, I = 0.05 mg/l, II = 0.30 mg/l and III = 1.00 mg/l of aluminum sulphate).

B) Histopathologic lesions of liver

The histology of normal hepatopancreas of *O. niloticus* consisted of hepatocytes arranged in cords, central vein, and pancreatic acini in the portal area, with numerous vacuoles indicates glycogen deposition which can be considered normal (Fig. 4a).

After 24 hrs of Al exposure, the microscopical examination of liver cells revealed loss of their regular morphology with mild congestion of blood vessels at all doses. Massive numbers of mononuclear inflammatory cells infiltration in the hepatic tissue were detected (Fig. 4b) associated with melanin carrying cells (melano-macrophages) surrounding the dilated central veins (Fig. 4c). Extravasated red blood cells arid few melanin (melano-macrophages) cells were demonstrated in the portal area in between and surrounding the pancreatic acini (Fig. 4d).

On the third day of Al exposure, focal necrosis in the hepatic parenchyma (Fig. 4e) was detected. Degenerated hepatocytes in diffuse manner (Fig. 4f) were noticed. Hyperactivation of melano-macrophage centers in the portal area in focal manner (Fig. 5a) were detected.

On day 7 of Al exposure, the severe congestion in the portal veins and sinusoids (Fig. 5b) were obvious. Necroses with inflammatory cells infiltration in the hepatocytes adjacent as well as surrounding the dilated central vein (Fig. 5c) were detected. Atrophy in the pancreatic acini (Fig. 5d) was demonstrated. Vacuolated hepatocytes in diffuse manner due to glycogen infiltration (Fig. 5e) were noticed. Hepatocytes had intra-cytoplasmic round

vacuoles (vacuolation) supposed to indicate fatty changes in diffuse manner (Fig. 5f) were visible in all specimens.

All these changes were more severe in the 2nd and 3rd groups of Al exposure and the frequencies and the severity of these changes were directly correlated to the increase in the Al sulphate concentrations.

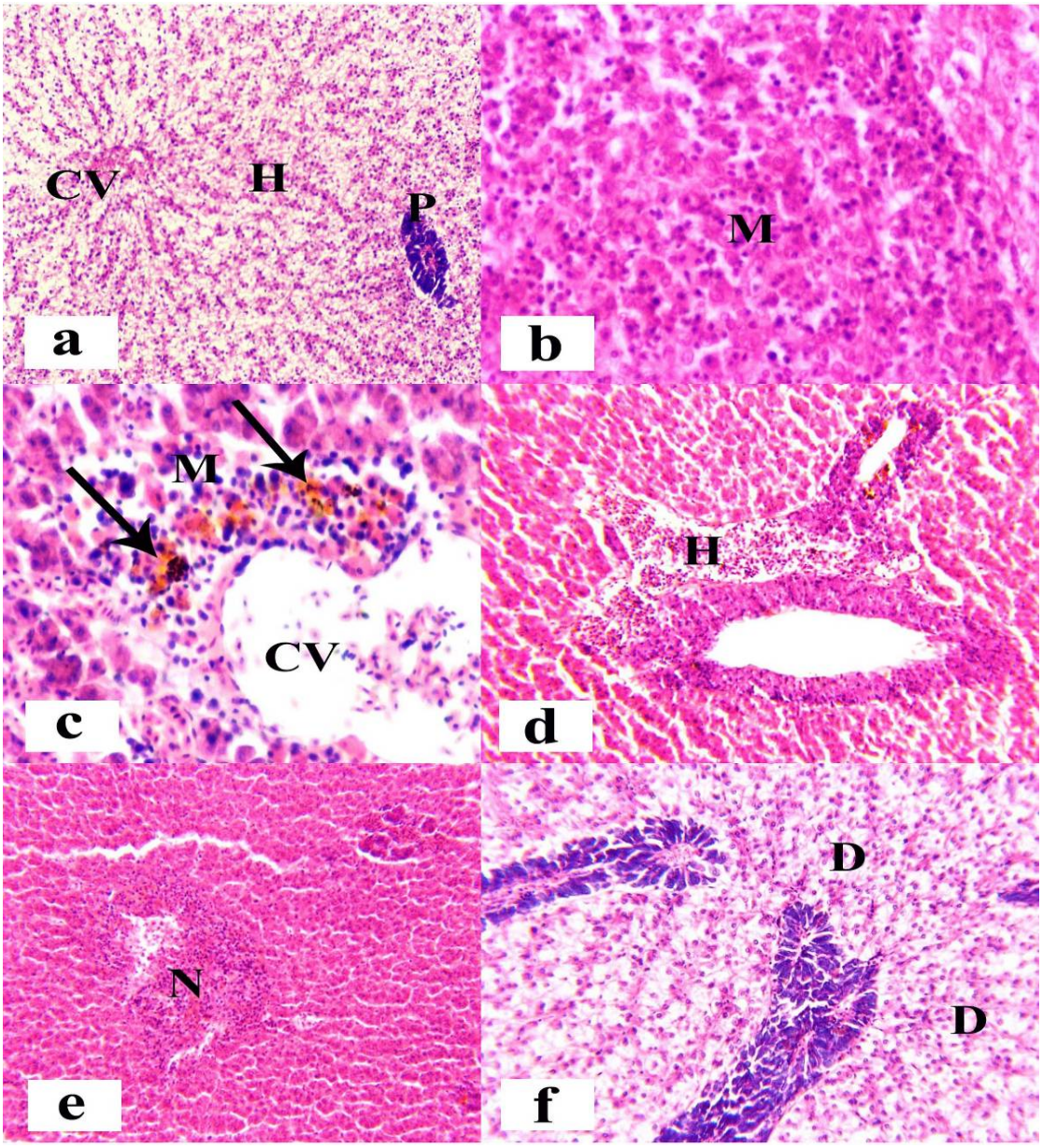

Figure (4): Transverse sections of *O. niloticus* liver. (a) Normal histology of liver showing the hepatocytes (H) in cords, central vein (CV), and pancreatic acini in the portal area (P), with diffuse glycogen deposition which can be considered normal (H&E, X40). (b) Liver after 24 hrs of Al exposure showing mononuclear inflammatory cells infiltration (M) in the hepatic tissue (H&E, X160). (c) Liver after 24 hrs of Al exposure showing the inflammatory cells infiltration (M) and melano-macrophage cells (arrows) surrounding dilated central vein (CV) (H&E, X160). (d) Liver after 24 hrs of Al exposure showing the extravasated red blood cells (H) arid few melano-macrophage cells in the portal area in between and surrounding the pancreatic acini (H&E, X64). (e) Liver after 3 days of Al exposure showing the focal necrosis (N) in the hepatic parenchyma (H&E, X64). (f) Liver after 3 days of Al exposure showing the degenerated hepatocytes (D) in diffuse manner (H&E, X64).

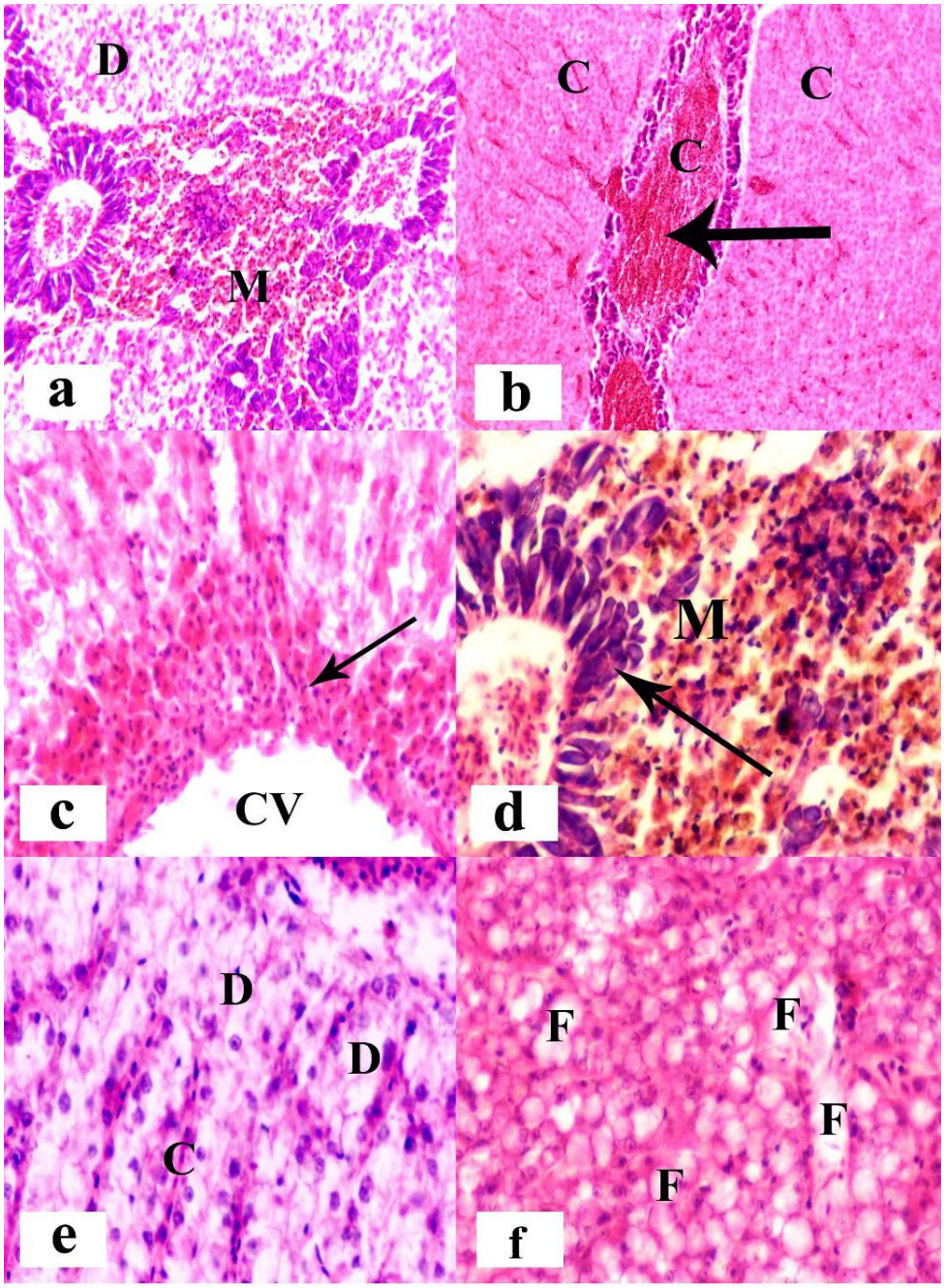

Figure (5): Transverse sections of *O. niloticus* liver. (a) Liver after 3 days of Al exposure showing activation of melano-macrophage centers (M) were allocated in the portal area in focal manner and degenerated hepatocytes (D) (H&E, X64). (b) Liver after 7 days of Al exposure showing severe congestion (C) in the portal vein (arrow) and sinusoids (H&E, X40). (c) Liver after 7 days of Al exposure showing hepatocytic necrosis adjacent as well as surrounding the dilated central vein (CV) with inflammatory cells infiltration (arrow) (H&E, X160). (d) Liver after 7 days of Al exposure showing atrophy (arrow) in the pancreatic acinar cells and activation of melano-macrophage centers (M) adjacent to the pancreatic acinar area (H&E, X160). (e) Liver after 7 days of Al exposure showing vacuolated hepatocytes (D) in diffuse manner (Glycogen infiltration) and congestion (C) (H&E, X160). (f) Liver after 7 days of Al exposure showing hepatocytes had intra-cytoplasmic round vacuoles supposed to indicate fatty change (F) in diffuse manner (H&E, X160).

4. Discussion

The pollution of the aquatic environment with metals has become a serious health concern because of their toxicity and accumulation by organisms **(Mendil *et al*., 2010; Shah *et al*., 2010)**. Fish, in comparison with invertebrates, are more sensitive to many toxicants and are a convenient test subject for indication of ecosystem health **(Moiseenko *et al.*, 2008)**.

Domestic sewage, agricultural drainage water and other wastes heavily contaminate the drainage canals in the Egyptian Delta **(Alne-na-ei, 1998)**. Polluted drainage water heavily loaded with different contaminants such as pesticides and metals **(Alne-na-ei, 1998; Khallaf *et al*., 1998, 2003)**. In the present study, it was determined that, the Al concentrations in the canal water tended to vary among months, and displayed particularly high levels (Table 2). The increase of metals in drainage water attributed to the large amount of sewage and other pollutants discharged at Al-Atf drain and the decomposition of the organic matter and/or the use of fertilizers and other chemicals in agriculture **(Abdel-Satar, 2005; Ibrahim and Tayel, 2005)**. The mean Al concentrations in Al-Atf drainage canal water are lower than the mean Al concentrations recorded previously by **Authman (2008)** and **Authman *et al.* (2008)** in the Sabal drainage canal. This variation may be due to the differences in the sources of Al pollution and physical–chemical conditions of the water. It was noticed that Al concentrations detected in Al-Atf drainage canal water have exceeded the world permissible limits [i.e. 1 µg l^{-1} at <pH 6.5 and 55 µg l^{-1} at >pH 6.5, **ANZECC and ARMCANZ (2000)**] for the protection of freshwater ecosystems. The present results indicated that, Al-Atf drainage canal water in Al-Minufiya Province is contaminated by elevated quantities of Al. From an ecological standpoint, this is a matter of concern as this metal represent a threaten for the fish resources in River Nile, where this canal drains in Al-Rayah Al-Abbasy which finally drains in Damietta branch of the River Nile. This will be causing changes in water quality and considerable amount of pollution in Nile aquatic environment, and fish health may suffer and mortality rates increase.

Many studies showed that metals accumulate mainly in metabolic organs such as liver that stores metals to detoxificate, thus, the liver in fish is more often recommended as environmental indicator organ of water pollution than any other fish organs **(Karadede *et al*., 2004; Yilmaz *et al*., 2007)**. In the present study, it was found that, the levels of Al concentrations in *O. niloticus* livers are higher than in the canal water. This is in agreement with that obtained previously by **Authman *et al.* (2008)** who found that, metals concentrations in livers of *O. niloticus* caught from Sabal drainage canal were higher than their concentrations in canal water. The values of Al in *O. niloticus* livers obtained in the present study were lower than those recorded by **Authman *et al.* (2008)** in livers of the same species in the Sabal drainage canal. The accumulation factor (AF) or the relative index of the concentration **(Khallaf *et al*., 1998)** of Al in the fish liver to that in canal water, in the present study, showed dreadful results when compared to the real concentrations of this pollutant in water (Table 2). **Moon *et al.* (1985)** and **Triebskorn *et al.* (1997)** mentioned that, the liver has a key role in basic metabolism and is the major site of accumulation, biotransformation, and excretion of contaminants in fish.

Consistent with the present observations, **Authman (2008)** and **Authamn *et al.* (2008)** have detected highest levels of Al in the Sabal drainage canal in Al-Minufyia Province. Also, **Authman (2008)** found that, the Al concentrations in the muscles of *O. niloticus* were above the tolerance levels for human consumption. Accordingly, the long-term and frequent intake of fishes with high Al levels constitutes a human health risk, where Al is not considered to be an essential element in humans, but its toxicity is known, particularly in patients with chronic renal failure **(D'Haese and De Broe, 1994)**. Also, the accumulation of aluminium has been related to the neurodegenerative process in Alzheimer's disease **(Sarzagi *et al*., 2001; Ščančar *et al*., 2004)**.

Hepatosomatic index (HSI) is general measurement of the overall condition of fish or the growth status of liver **(West, 1990)** and can be an excellent predictor of adverse health in fish **(Adams and McLean, 1985)**. In the present study, there was insignificant difference in the values of hepatosomatic indices (HSI) between control and treated fish with either I or II doses of aluminium sulphate. On the other hand, *O. niloticus* fishes treated with dose III of aluminium sulphate showed significantly high values of HSI. This may be attributed to the accumulation of lipid in liver tissue of fish exposed to highly dose of aluminium sulphate. The fatty changes that were detected in histological sections may confirm this suggestion. Similarly, **Abdelmeguid *et al.* (1999)** reported that, hepatosomatic index of *Oreochromis niloticus* exposed to lead acetate was increased as a result of change in quantity of fat in liver. **Munshi and Dutta (1996)** stated that the HSI of *Osteichthyes* is normally between 1% and 2%. The HSI values of the treated specimens exposed to the three doses of Al exceeded this range. Although hepatosomatic indices can vary

with nutrition, season, fish condition and disease, a relationship between hepatosomatic index and levels of contamination was reported by **Sloof *et al.* (1983)**. The possible interpretation of the variation of hepatosomatic index may coincide with that suggested by **Fabacher and Baumann (1985)**, that the enlarged livers could result in increased activity of hepatic mixed-function oxidase enzymes and thus develops an increased ability to metabolize xenobiotics.

The teleost liver is one of the most sensitive organs with regard to showing alterations in histoarchitecture, biochemistry, and physiology following exposure to various types of environmental pollutants **(Roy and Bhattacharya, 2006)**. **Bruslé and González I Anadon (1996)** stated that, fish liver histology could serve as a model for studying the interactions between environmental factors and hepatic structures and functions. The harmful effect of metal pollution on fish liver histology may, however, depend on the duration of the exposure and the concentration level of the specific metal **(van Dyk *et al.*, 2007)**.

The present study documents pathologic changes in fish treated with three different doses of Al for 7 days. The degree of pathology gradually increased during the entire days of experiment which exhibited dose-and time-dependent changes.

During the present investigation intense degenerative changes in the livers of *O. niloticus* were found to occur within the period of exposure to Al. The degenerative changes were characterized by vacuolation of the hepatocytes, necrotic cells, atrophy of the pancreatic tissue, and congestion of blood veins. The widespread vacuolation might be likely due to accumulation of glycogen in hepatocytes **(Wester and Canton, 1986)**. Also, the widespread vacuolation of the liver might be a common response in fish hepatocyte to various chemical stressors, which indicates a higher hepatocellular lipid, water and/or glycogen content (**Liao *et al.*, 2006)**. Vacuolation of the hepatocyte, pycnosis in many of the necrotic cells, necrosis of the pancreatic tissue, and disintegration of blood sinusoids **(Roy and Bhattacharya, 2006)** characterized the degenerative changes. The vacuolizations is commonly found following toxic injury of the fish liver **(Abdelmeguid *et al.*, 1999)**. Hepatocellular lipid vacuolation commonly occurs in fish as a histopathological reaction to aquatic pollutants **(Alne-na-ei, 1998)**. Degeneration and necrosis of hepatocytes may be attributed to the cumulative effect of the metal such as Al and to the increase of its concentration in the hepatic tissue during experimental period **(Zaki *et al.*, 2009)**. These results agreed with **Förlin *et al.* (1986)**, who stated that, liver has an important detoxical role of exogenous waste products as well as externally derived toxins such as metals.

Among the observed histopathological lesions of liver, the melano-macrophage aggregates have been shown to be involved in a number of fish diseases, and as phagocytic cells **(Agius and Robert, 2003)**. It was noticed by **Stentiford *et al.* (2003)** that, the prevalence of melano-macrophage centers was highest in flounder captured from the sites with the highest PAH contamination. The prevalent of this pathologic condition in the present study may be because, with the expenditure of energy in the detoxification process, more melano-macrophage aggregates appeared from increases in metabolic byproducts **(Authman *et al.*, 2008)**. These histopathological findings are similar to those mentioned by **Liao *et al.* (2006)** when exposed medaka (*Oryzias latipes*) to sublethal exposure of methylmercury chloride, **Roy and Bhattacharya (2006)** when exposed *Channa punctatus* to arsenic, and **van Dyk *et al.* (2007)** when exposed *Oreochromis mossambicus* to cadmium and zinc.

5. Conclusion

In conclusion, the present study points out the contamination of Al-Atf drainage canal by aluminium. Also, it could be concluded that Al induced deleterious effect in *O. niloticus* such as damage of the liver. It induced cumulative effect; therefore equivalent lesions of fish may occur in humans. In addition, the experimental results demonstrated that *O. niloticus* liver could be used as a useful tool in the research on Al toxicologies.

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