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Oreochromis niloticus as a Biomonitor of Heavy Metal Pollution with Emphasis on Potential Risk and Relation to Some Biological Aspects

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Abstract: Heavy metal concentrations were determined in water and in muscle of *Oreochromis niloticus* fish to study the potential human risk of consumption and the relationship between the heavy metal load of fish and some of their biological aspects (age, sizes, sex and condition factor). Water and fish samples were analysed using Atomic Absorption Spectrophotometer to determine concentrations of Al, Cd, Cu, Fe, Pb, Mn, Hg and Zn. It was found that heavy metals accumulated in muscle of *O. niloticus* in concentrations higher than that of the water. A highly significant ($P<0.01$) positive relationships were found between metal concentrations and fish age and sizes and a negative correlation was found only for aluminium, cadmium and mercury. The correlations between the heavy metal concentrations and the condition factor of fish samples have opposite trends to those of age and sizes of fish. The metal concentrations in muscle of female were higher than those in male fish. Present results suggest the loss of homeostatic capacity of *O. niloticus* under chronic metal exposure leading to bioaccumulation. The metals in the muscle of fish were above the maximum permissible concentrations for human consumption.

Key words: Heavy metals · muscles · bio-monitor · length and weight · age · condition factor · sex · *Oreochromis niloticus*

INTRODUCTION

Heavy metals from man-made pollution sources are continually released into aquatic ecosystems. The contamination of heavy metals is a serious threat because of their toxicity, long persistence, bioaccumulation and biomagnification in the food chain [1]. As direct analysis of such pollutants does not provide information about their effect on the ecosystem, the use of biomonitors is a highly recommended option because biomonitors respond specifically to the bioavailable pollutant loads [2, 3]. Fishes can be considered as one of the most significant biomonitors in freshwater systems for the estimation of metal pollution concentration [4, 5], they offer several specific advantages in describing the natural characteristics of aquatic systems and in assessing changes to habitats [3, 6]. In addition, fish are located at the end of the aquatic food chain and may accumulate metals and pass them to human beings through food causing chronic or acute diseases [7]. The heavy metal concentration in fish tissues reflects past exposure via water and/or food and it can demonstrate the current situation of the animals [8]. Studies from the field and laboratory experiments showed that accumulation of heavy metals in a tissue is mainly dependent upon water concentrations of metals and exposure period; although some other environmental factors such as salinity, pH, hardness and temperature play significant roles in metal accumulation. Ecological needs, sex, age, size, feeding habits as well as biological conditions of the fish affect the heavy metals accumulation in their tissues [9, 10].

Due to the deleterious effects of metals on aquatic ecosystems, it is necessary to monitor their bioaccumulation in key edible species, because this will give an indication of the temporal and spatial extent of the process, as well as an assessment of the potential impact on organism health [11] and in order to check for those hazardous to human health. Thus, the aim of this study is to determine heavy metal concentrations in muscle of tilapia, *Oreochromis niloticus* from Sabal drainage canal (Egypt) to determine the possible potential human risk of consumption of *O. niloticus* and to investigate the relationships between some biological aspects of fish and metal concentrations in the muscle.

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MATERIALS AND METHODS

A) Study area: Sabal drainage canal is the largest drain in Al-Menoufiya Province, Egypt, which extends for more than 62 km, through Menouf and Al-Shouhada cities and pours into Rossetta Branch of the River Nile, at Tamalay village. This drain receives untreated domestic sewage from numerous towns and villages in addition to the agricultural and industrial wastes.

B) Water sampling and analysis: Samples were collected monthly during the period between January to December 2007. Water samples were obtained from different sites of the canal by a water sampler. Samples were preserved and heavy metals were extracted according to [12].

C) Fish sampling and heavy metals residual analysis of muscle tissue: 20 samples of *O. niloticus* fish of different sizes of both sexes were collected from the studied area during the same period of waters sampling. Fish samples were placed in an ice box and transported to the laboratory. In the laboratory, total body length (cm) and weight (g) were recorded for each fish. Sex was determined by inspection of gonads after opening the body cavity. A block of edible portion (muscle), devoid of skin and bone, was taken and stored in a deep freezer (-20°C) until processing for metal analysis. Heavy metals were extracted from the fish muscle samples according to the method of [13].

Heavy metal (Al, Cd, Cu, Fe, Pb, Mn, Hg and Zn) concentrations in water and muscle samples were determined using a flame atomic absorption spectrophotometer (Model 2380, Perkin Elmer, USA).

D) Condition factor (K): The condition factor (K) was determined by using the Fulton's condition factor equation [14]:

$K = W/L^3 \times 100$, W= wet body weight (g) and L = total length (cm).

E) Fish ageing: The age was determined from scale samples according to the annual ring structure of scales [15].

F) Statistical analyses: Statistical analyses were performed using a computer program SPSS, version 14 for Windows. The statistical significance of the correlation was reported at both the $P \leq 0.01$ and $P \leq 0.05$ levels.

RESULTS

A) Biology of *O. niloticus*: Table 1 shows number of fish sampled, length, weight and condition factor means and their standard errors (SE). The fish samples under study belonged to 4 age-groups (0, I, II and III).

B) Heavy metals in water: Table 1 illustrates the average concentrations of heavy metals in water.

C) Heavy metals in muscles and Accumulation Factor (AF): The average concentrations of the metals detected in fish muscles and the values of accumulation factor (AF) are summarized in Table 1. It was found that, the concentrations of metals in muscles are much higher than in the water with the exception of aluminium. The AF for these metals was found to follow the order: Al>Mn>Fe >Pb>Cu>Zn>Cd>Hg.

D) Relationship between metal concentrations and body sizes: An increasing trend in copper, iron, lead, manganese and zinc values was observed with increasing fish length (Table 2) and weight (Table 3). This was more conspicuous when the correlations are considered (Table 5), where a highly significant ($P<0.01$) positive

Table 1: Total length, weight, condition factor of *Oreochromis niloticus* and heavy metal concentrations in water and muscle of *O. niloticus*

	Biological aspects of *Oreochromis niloticus*							
No. of fishes	Total length (cm) Mean±SE			Weight (gm) Mean±SE			Condition factor (K) Mean±SE	
240	14.8±0.19			79.78±2.89			1.39±0.13	
Average heavy metals concentrations (mg/l) in water								
Water	Al	Cd	Cu	Fe	Pb	Mn	Hg	Zn
	27.39	0.08	0.18	20.14	1.48	2.01	0.91	0.67
Permissible limits	87.0$^{\bullet}$	0.25$^{\bullet}$	9.0$^{\bullet}$	1000$^{\bullet}$	2.5$^{\bullet}$	NA$^{\bullet}$	0.77$^{\bullet}$	120$^{\bullet}$
Average heavy metal concentrations (µg/gm dry wt) in muscle								
Muscle	Al	Cd	Cu	Fe	Pb	Mn	Hg	Zn
	3.78	3.40	4.60	359.81	31.95	11.25	39.13	42.44
Permissible limits	NA	0.5*	5.0*	5.0*	2.0*	100.0*	0.3*	40.0*
AF	0.18	210.50	59.20	29.44	58.98	19.74	210.98	103.21

$^{\bullet}$µg/l [18]. *µg/gm [20], NA= not available, AF = Accumulation factor, SE = Standard Error

Table 2: Variations of total length (cm) and heavy metal concentrations (µg/gm dry wt) in muscle of *O. niloticus*

	Average heavy metal concentrations in muscle (µg/gm dry wt)							
Length (cm)	Al	Cd	Cu	Fe	Pb	Mn	Hg	Zn
9	5.50^{b}	5.74^{b}	3.20^{a}	227.12^{a}	12.37^{abc}	5.10^{a}	72.60^{a}	26.87^{a}
11	4.76^{ab}	3.93^{ab}	3.20^{a}	269.23^{a}	17.50^{abc}	5.48^{a}	54.13^{a}	38.54^{ab}
13	4.42^{ab}	3.36^{ab}	4.18^{a}	279.64^{a}	19.22^{ab}	6.53^{a}	41.90^{a}	39.16^{ab}
15	4.38^{ab}	3.23^{ab}	4.60^{a}	295.16^{a}	24.53^{a}	9.70^{ab}	38.62^{a}	39.42^{ab}
17	4.30^{ab}	2.80^{ab}	4.67^{a}	325.20^{a}	24.92^{abc}	10.10^{ab}	31.73^{a}	40.93^{ab}
19	2.84^{ab}	2.72^{ab}	4.83^{a}	336.53^{a}	31.26^{abc}	10.40^{ab}	30.60^{a}	42.47^{ab}
21	2.70^{ab}	2.67^{ab}	5.13^{a}	360.43^{a}	32.53^{c}	11.22^{ab}	30.43^{a}	52.98^{ab}
23	1.87^{a}	2.54^{a}	5.74^{a}	412.90^{a}	63.28^{bc}	14.02^{ab}	28.80^{a}	53.63^{ab}
25	1.70^{a}	2.50^{a}	5.93^{a}	720.42^{b}	64.50^{a}	20.58^{b}	24.52^{a}	61.30^{b}

Means with the same letter in the same column are not significantly different ($P>0.05$)

Table 3: Variations of weight (gm) and heavy metal concentrations (µg/gm dry wt) in muscle of *O. niloticus*

	Average heavy metal concentrations in muscle (µg/gm dry wt)							
Weight (gm)	Al	Cd	Cu	Fe	Pb	Mn	Hg	Zn
50	5.50^{b}	4.40^{a}	3.45^{a}	255.88^{a}	17.50^{a}	5.10^{a}	74.53^{b}	30.62^{a}
100	5.18^{b}	3.93^{a}	4.02^{a}	325.20^{a}	24.53^{a}	6.53^{a}	54.13^{ab}	40.93^{a}
150	3.98^{ab}	3.23^{a}	4.67^{a}	336.53^{a}	32.53^{a}	9.90^{a}	36.82^{ab}	41.10^{a}
200	3.00^{ab}	3.17^{a}	5.13^{a}	341.07^{a}	33.20^{a}	10.40^{a}	30.43^{ab}	42.47^{a}
250	2.70^{ab}	2.80^{a}	5.28^{a}	360.43^{a}	38.43^{a}	11.57^{a}	28.80^{ab}	44.08^{a}
300	1.87^{a}	2.58^{a}	5.93^{a}	573.70^{a}	45.72^{a}	13.67^{a}	20.78^{a}	53.63^{a}

Means with the same letter in the same column are not significantly different ($P>0.05$)

Table 4: Variations of age and heavy metal concentrations (µg/gm dry wt) in muscle of *O. niloticus*

	Average heavy metal concentrations in muscle (µg/gm dry wt)							
Age (years)	Al	Cd	Cu	Fe	Pb	Mn	Hg	Zn
0	3.65^{a}	3.75^{a}	4.02^{a}	323.48^{a}	20.43^{a}	7.34^{a}	37.79^{a}	44.08^{a}
I	3.36^{a}	3.32^{a}	4.48^{a}	334.76^{a}	24.86^{a}	9.90^{a}	37.72^{a}	45.68^{a}
II	3.10^{a}	2.85^{a}	4.57^{a}	340.72^{a}	34.55^{a}	12.08^{a}	36.87^{a}	52.30^{a}
III	3.00^{a}	2.58^{a}	5.24^{a}	341.07^{a}	38.43^{a}	14.20^{a}	27.23^{a}	52.75^{a}

Means with the same letter in the same column are not significantly different ($P>0.05$)

Table 5: Correlation matrix between total lengths (cm), weight (gm), age (years) and condition factor (K) and heavy metal concentrations (µg/gm dry wt) in muscle of *O. niloticus*

	Length	Weight	Age	K
Al	-0.971**	-0.987**	-0.980*	0.713*
Cd	-0.840**	-0.972**	-0.994**	0.464
Cu	0.974**	0.989**	0.962*	-0.776*
Fe	0.814**	0.840*	0.923	-0.949**
Hg	-0.892**	-0.942**	-0.818	0.573
Mn	0.926**	0.980**	0.999**	-0.941**
Pb	0.909**	0.983**	0.985*	-0.815**
Zn	0.945**	0.914*	0.943	-0.732**

*Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

correlations between concentrations of Cu, Fe, Pb, Mn and Zn and body length and weight were found. On the other hand, a decreasing trend in aluminium, cadmium and mercury values was observed with increasing fish length and weight. This was evident by the highly significant ($P<0.01$) negative correlation between concentrations of these metals and fish length and weight (Table 5).

E) Relationship between metal concentrations and age of fish: An increasing trend was found for copper, iron, lead, manganese and zinc values in muscle with age variations (Table 4). Pearson correlation tests revealed obvious positive correlations (Table 5) between these metals concentrations and the age of fish samples. While decreasing trend (Table 4) and

Table 6: Heavy metal concentrations (µg/gm dry wt) in muscle of male and female *O. niloticus*

	Average heavy metal concentrations in muscle (µg/gm dry wt)							
Sex	Al	Cd	Cu	Fe	Pb	Mn	Hg	Zn
Male	3.48	3.38	4.35	347.98	30.20	9.56	34.71	38.44
Female	4.06	3.41	4.84	371.01	33.81	12.85	43.32	46.66

negative correlations (Table 5) were found for aluminium, cadmium and mercury concentrations in muscle with variation of age.

F) Relationship between metal concentrations and condition factor (K) and sex of fish: In general most correlations (Table 5) were negative for all elements analyzed. Iron, manganese and lead concentrations ($P<0.01$) as well as, copper and zinc ($P<0.05$) were negatively correlated with fish condition. Only correlations between fish condition (K) and aluminium, cadmium and mercury concentrations were positive.

It was found that, the correlations between the heavy metal concentrations of muscles and the condition factor of fish samples were varied with characteristic opposite trends compared to those related to length, weight and age (Table 5).

From Table 6, it is obvious that the concentrations of heavy metals in muscles were higher in the females in comparison with those of the males.

DISCUSSION

Contamination of aquatic ecosystems with heavy metals has seriously increased worldwide attention [1, 16]. In the present study, it was determined that the investigated canal water is contaminated by different kinds of heavy metals, which were obviously high and appeared to be harmful to fishes. Mean metal concentrations in Sabal drainage canal water are generally higher than metal concentrations in other regions (Table 7) with the exception of Shanawan drainage canal [17]. By comparing measured concentrations of metals with water quality standards [18], it was found that all metal concentrations were higher than the permissible limits. The values of metals in fish muscles obtained in the present study were higher than those found in other localities (Table 7), except that of fishes from Shanawan drainage canal [17]. The level of Cd in fish muscles from Abu Za'baal ponds [19] was higher than that of Sabal drainage canal. It was found that the concentrations of metals in muscles of the studied species were higher than the concentrations issued by [20], so, they are regarded as potential hazards that can endanger both animal and human health.

The present results showed that there were positive relationships between fish sizes (length and weight) and age and metal concentrations in most cases. The data showed that the negative relationships were found only between aluminium, cadmium and mercury concentrations in muscle and sizes and age. It is generally accepted that trace element accumulation in living organisms controlled by specific uptake, detoxification and elimination mechanisms, depends significantly also on the size-specific metabolic rate of organisms [21]. Therefore, the negative correlations between the concentration of metals and fish sizes and age do not necessarily mean that there is a particular metal concentration at the beginning of the growth period and no new metal is further absorbed; rather, it is determined by the variation of feeding rate with age of individuals, the dilution by growth and of course by the food speciation of certain age classes [22]. Another explanation for the negative relationships found in this study may be the difference in metabolic activity between younger and older fish [9]. Some metals do not increase in concentrations with age or size because they are thought to be under homeostatic control [23]. So, in present study, the positive correlation between some metals and fish age and sizes may be due to loss of homeostasis capacity of *O. niloticus* under chronic metal exposure leading to bioaccumulation.

The mean value of condition factor (K) found in the present study (1.39 %) were lower than those found in *O. niloticus* captured in Ismalia canal (2.30%), River Nile (1.64%), lake Manzalah (1.41%), lake Edku (1.50%), lake Burullus (1.57%), lake Qarun (1.90%) and lake Mariut (1.55%), as detected by [24]. The negative relationship between the heavy metal concentration and the condition factor of fish suggests the relative dilution effect of the lipid content of tissues. This assumption is supported well also by the fact that lipid as a percent of body weight is usually lower in younger fish, decreases during winter and spawning and reaches its peak at the end of the main feeding period [25]. These variations may explain also the opposite correlations observed in present study between heavy metals-size and heavy metals-condition factors of fish [26]. Sex of fish can be considered as a main factor affecting the concentration of trace elements in fish where higher concentrations were found in muscle of females

Table 7: Comparison of heavy metals concentration in water and *O. niloticus* muscle in Sabal drainage canal and other localities

	Al	Cd	Cu	Fe	Pb	Mn	Hg	Zn	Author
Water (mg/l):									
Sabal drainage canal	27.39	0.06	0.18	20.14	1.48	2.01	0.91	0.67	Present study
Shanawan drainage canal	NM	0.06	0.013	23.03	0.65	1.42	1.87	0.59	[17]
Abu Za'baal ponds	NM	0.03	NM	3.57	0.144	0.202	NM	0.112	[19]
Lake manzalah	NM	ND	NM	6.23	0.061	0.285	NM	0.071	[27]
River nile	NM	0.050	NM	2.03	0.061	0.189	NM	0.076	[28]
O. niloticus fish muscle (µg/gm dry weight):									
Sabal drainage canal	3.78	3.40	4.60	359.81	31.95	11.25	39.13	42.44	Present study
Shanawan drainage canal	NM	4.90	6.30	530.9	48.7	20.9	67.1	55.4	[17]
Abu Za'baal ponds	NM	3.60	NM	65.00	21.30	10.13	NM	40.90	[19]
River nile	NM	0.04	1.10	21.30	1.22	NM	NM	34.00	[24]
Lake manzalah	NM	1.17	NM	64.00	5.80	7.00	NM	2.00	[29]

NM= not measured, ND= not detected

than those in males [10]. The nature of hormones and the available number of active sites in the protein and cytochrome *P*-450 in female and male fish may account for this behavior [7].

It could be concluded that, Nile tilapia is a good species for biomonitoring pollution as it could withstand the adverse conditions in the ecosystem. The concentrations of heavy metals in fish vary significantly not only as function of fish sizes and age, but is influenced in a remarkable degree by the fish condition and sex. Based on the samples analyzed, metal concentrations found in the muscles of *O. niloticus* proved to be above the tolerance levels for human consumption. Attention therefore, has to be focused by local authorities to ensure forbidding fishing from this drainage canal.

REFERENCES

1. Yilmaz, F., N. Özdemir, A. Demirak and A. Levent Tuna, 2007. Heavy metal levels in two fish species *Leuciscus cephalus* and *Lepomis gibbosus*. Food Chem., 100: 830-835.
2. Ruelas-Inzunza, J.R. and F. Páez-Osuna, 2000. Comparative bioavailability of trace metals using filter-feeder organisms in a subtropical coastal environment (Southeast Gulf of California). Environmental Pollution, 107: 437-444.
3. Lamas, S., J.A. Fernández, J.R. Aboal and A. Carballeira, 2007. Testing the use of juvenile *Salmo trutta* L. as biomonitors of heavy metal pollution in freshwater. Chemosphere, 67: 221-228.
4. Rashed, M.N., 2001. Monitoring of environmental heavy metals in fish from Nasser Lake. Environ. Intl., 27: 27-33.
5. Begum, A., Md. N. Amin, S. Kaneco and K. Ohta, 2005. Selected elemental composition of the muscle tissue of three species of fish, *Tilapia nilotica*, *Cirrhina mrigala* and *Clarias batrachus*, from the fresh water Dhanmondi Lake in Bangladesh. Food Chem., 93: 439-443.
6. Chovanec, A., R. Hofer and F. Schiemer, 2003. Fishes as bioindicators. In: Bioindicators and Biomonitors. Principles, Concepts and Applications, Eds., Markert, B.A., A.M. Breure and H.G. Zechmeister. Elsevier, Amsterdam, pp: 639-676.
7. Al-Yousuf, M.H., M.S. El-Shahawi and S.M. Al-Ghais, 2000. Trace metals in liver, skin and muscle of *Lethrinus lentjan* fish species in relation to body length and sex. The Science of the Total Environment, 256: 87-94.
8. Birungi, Z., B. Masola, M.F. Zaranyika, I. Naigaga and B. Marshall, 2007. Active biomonitoring of trace heavy metals using fish (*Oreochromis niloticus*) as bioindicator species. The case of Nakivubo wetland along Lake Victoria. Physics and Chemistry of the Earth, 32: 1350-1358.
9. Canli, M. and G. Atli, 2003. The relationships between heavy metal (Cd, Cr, Cu, Fe, Pb, Zn) levels and the size of six Mediterranean fish species. Environmental Pollution, 121(1): 129-136.
10. Shakweer, L.M. and M.M. Abbas, 2005. Effect of ecological and biological factors on the uptake and concentration of trace elements by aquatic organisms at Edku Lake. Egyptian Journal of Aquatic Research, 31(1): 271-288.
11. Fernandes, C., A. Fontainhas-Fernandes, F. Peixoto and M.A. Salgado, 2007. Bioaccumulation of heavy metals in *Liza saliens* from the Esmoriz-Paramos coastal lagoon, Portugal. Ecotoxicology and Environmental Safety, 66: 426-431.

12. APHA-American Public Health Association, 1998. Standard methods for the examination of water and wastewater. 20th Edn., Greenberg, A.E.; Clesceri, L.S. and Eaton, A.D. (Eds). APHA, WEF and AWWA, Washington DC, USA, pp: 1193.
13. AOAC-Association of Official Analytical Chemists, 1995. Official Methods of the Association Official Analytical Chemists. 16th Ed., Chapter 29, Atomic Absorption Methods for Fish. Washington DC, USA, pp: 399.
14. Schreck, C.B. and P.B. Moyle, 1990. Methods for fish biology. American Fisheries Society, Bethesda, Maryland, USA.
15. Bagenal, T.B. and F.W. Tesch, 1978. Age and growth. In Methods for Assessment of Fish Production in Freshwater, Ed., Bagenal, T. B. Oxford: Blackwell Scientific Publications, London, pp:101-136.
16. Wagner, A. and J. Boman, 2003. Biomonitoring of trace elements in muscle and liver tissue of freshwater fish. Spectrochimica Acta Part B-Atomic Spectroscopy, 58: 2215-2226.
17. Khallaf, E.A., M. Galal and M. Authman, 1998. Assessment of heavy metals pollution and their effects on *Oreochromis niloticus* in aquatic drainage water. J. Egypt. German Soc. Zool., 26 (B): 39-74.
18. U.S.EPA-United States Environmental Protection Agency, 2006. National Recommended Water Quality Criteria. Office of Water, Office of Science and Technology, 2006 (4304T), pp: 25.
19. Abdo, M.H., 2006. Levels of some trace metals in the water and fish flesh of common species in Abu Za'baal ponds, Egypt. Egypt. J. Aquat. Res., 32 (2): 308-320.
20. WHO, 1993. Evaluation of certain food additives and contaminants (Forty-first report of the joint FAO/WHO Expert Committe on Food Additives). WHO Technical Report Series No. 837, WHO, Geneva.
21. Newman, M.C. and D.K. Doubet, 1989. Size-dependence of mercury (II) accumulation kinetics in the mosquitofish, *Gambusia affinis* (Baird and Girard). Archive of Environmental Contamination and Toxicology, 18: 819-825.
22. Farkas, A., J. Salánki and I. Varanka, 2000. Heavy metal concentrations in fish of Lake Balaton. Lakes and Reservoirs: Research and Management, 5: 271-279.
23. Evans, D.W., D.K. Dodoo and P.J. Hanson, 1993. Trace elements concentrations in fish livers Implications of variations with fish size in pollution monitoring. Marine Pollution Bulletin, 26 (6): 329-334.
24. Elghobashy, H.A., K.H. Zaghloul and M.A.A. Metwally, 2001. Effect of some water pollutants on the Nile tilapia, *Oreochromis niloticus* collected from the River Nile and some Egyptian lakes. Egypt. J. Aquat. Biol. Fish., 5 (4): 251-279.
25. Weatherly, A.H. and H.S. Gill, 1987. The biology of fish growth. Academic Press, Orlando, FL.
26. Farkas, A., J. Salánki and A. Specziár, 2003. Age-and size-specific patterns of heavy metals in the organs of freshwater fish *Abramis brama* L. populating a low-contaminated site. Water Res., 37: 959-964.
27. Abdel-Satar, A.M., 2001. Environmental studies on the impact of the drains effluent upon the Southern sector of Lake Manzalah. Egypt. J. Aquat. Biol. Fish., 5 (3): 17-30.
28. Abdel-Satar, A.M., 2005. Water quality assessment of River Nile from Idfo to Cairo, Egypt. Egypt. J. Aquat. Res., 31 (2): 200-223.
29. Abdel-Satar, A.M. and A.M. Yacoub, 2005. Heavy metals and macro nutrients concentration in *Oreochromis niloticus* and *Tilapia zillii* fish species inhabiting some Egyptian Lakes and El-Salam Canal. Egypt. J. Aquat. Biol. Fish., 9 (1): 97-116.

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