Assessment of heavy metals in water, sediment and fish tissues, from Sharkia province, Egypt

El-Sayed A. El-Sayed[1], Mohamed S. El-Ayyat[2], El-Sayed Nasr[1] and Zeinab Z. K. Khater[1]

1- Department of Zoology, Faculty of Science, Zagazig University, Egypt
2- Department of Animal Production, Faculty of Agriculture, Zagazig University, Egypt

ABSTRACT

The present study was conducted to investigate factors affecting live fish at different sources of water (agriculture drainage, industrial drainage and sewage wastewater). Heavy metal residues (zinc, copper, lead, cadmium, chromium, aluminium, manganese, nikel and cobalt) were determined in water, sediment and fish organs (muscles, gills, kidney and liver tissues) of three fishes (*Oreochromis niloticus*, *Clarias gariepinus* and *Bagrus bayad*). The industrial drainage and sewage water revealed the highest concentrations of heavy metals followed by agriculture drainage water. The muscles, gills, kidney and liver tissues of fish samples collected from industrial drainage and sewage canals had the highest levels of heavy metal residues followed by agriculture drainage canals. The heavy metal studies revealed that there is a public health hazard associated with industrial drainage, sewage wastewater and agriculture drainage as the quality of fish did not comply with the standard levels recommended by **WHO**, **USEPA** and **ANZECC**. Potential adverse health effects in such applications could be avoided if the wastewater is sufficiently treated.

Keywords: water, sediment, fish tissue, heavy metals, Tilapia, Catfish.

INTRODUCTION

The pollution of aquatic ecosystems by heavy metals is an important environmental problem, as heavy metals constitute some of the most hazardous substances that can bioaccumulate in various biotic systems. Bioaccumulation is a process in which a chemical pollutant enters into the body of an organism and is not excreted, but accumulated in the organism's tissues. Metals that are deposited in the aquatic environment may accumulate in the food chain and cause ecological damage, while also posing a threat to human health. Cancer and damage of the nervous system have been documented in humans as a result of metal consumption. The U. S. Environmental Protection Agency conducted a national study of accumulated toxins documenting this concern (Van den Broek *et al*., 2002).

Anthropogenic impacts including industrial discharge, domestic sewage, non-point source runoff and atmospheric precipitation are the main sources of toxic heavy metals that enter aquatic systems (Langston *et al.*, 1999).However, metals also occur in small amounts naturally and enter aquatic systems through ore-bearing rocks, wind-blow dust, forest fires and vegetation (Fernandez-Leborans and Olalla-Herrero, 2000).

The heavy metal pollution of aquatic ecosystems is often most obvious in sediments , macrophytes and aquatic animals , than in elevated concentrations in water (Linnik and Zubenko, 2000).Therefore aquatic ecosystems are typically monitored for pollution of heavy metals using biological assays (Wong and Dixon, 1995).Many aquatic organisms have been used as bioindicators, including aquatic insects (Rayms-Keller *et al.*, 1998), plants (Mohan and Hosetti, 1999), protozoans (Fernandez-Leborans and Olalla-Herrero, 2000), crustaceans (Allinson *et al.*, 2000) and fish (Burger *et al.*, 2002).

Fish species are often the top consumers in aquatic ecosystems (Dallinger *et al.*, 1987) and thus metal concentrations in fish can act as an environmental indicator for the environmental state(Wildianarko *et al.*, 2000). Fish are known to bioaccumulate metals and therefore can be used as biomonitors, also they have the advandage of allowing the comparison of metal concentrations among sites ,where water samples are near or below the detection limits of the atomic absorption technique (Ramelow *et al.*, 1989).

The mechanisms of metal toxicity to fish are varied, although many act as enzyme poisons. Therefore, it is difficult to assess the probable effect of a measured concentration of a metal. In pond water heavy metals can be adsorbed onto clay particles and chelated by organic matter so that they remain in solution but may not have an adverse effect on fish or crustaceans (Boyd, 1990).

MATERIALS AND METHODS

1- Description of the investigated areas:

Fish samples were collected from five localities at Sharkia Province that are considered as natural sources for fishery. These localities lie east to Damietta Branch (Nile water). The five localities are: Kafr El-Hosr pond (at Kafr El-Hosr Bridge), Muweis canal (Zagazig canal at ADab Bridge near oil and soap factory), Bilbeis canal (at Bilbeis boat), Abbassa canal (Ismaillya canal at Ismaillya boat) and San El-Hagar canal (Faqus canal at south San El-Hagar Bridge). Kafr El-Hosr pond lies at the north of Zagazig city and was selected as a polluted area; where it receives several sources of pollution, as domestic and agricultural wastes. Muweis canal lies at the centre of Zagazig city and was selected as a polluted area; where it receives industrial wastes from oil and soap factory. Bilbeis canal lies at east of Muweis canal and was selected as a polluted area; where it receives agricultural wastes. Abbassa canal lies also at the east of Muweis canal and was selected as a polluted area (agricultural drainage area). San El- Hagar canal lies at the north of Faqus city and was selected as a polluted area; where it receives domestic and agricultural wastes.

2- Sampling sites:

Samples were collected monthly during the period from September 2007 to August 2008 at Kafr El-Hosr pond, Muweis canal, Bilbeis canal, Abbassa canal and San El-Hagar canal. A large number of peoples are visiting the above sites for heavy fishing, so these areas are suffering severe disturbance from human activity (agricultural, industrial, domestic or fishing).

3- The collected fish:

Oreochromis niloticus is the most economic fish in Egypt. Its production in 2003 was about 200000 tons. It is greenish–olive, shining silvery in color. Dorsal, anal and caudal fins may be edged with bright red. A dark spot appears on the operculum (Rakocy, 2011).

Clarias gariepinus is one of the most important freshwater fishes in Egypt. Total production of it in 2007 was about 31.9 thousand tons; i.e. it contributes about 17.5% of the total Nile catch in Egypt. It is grayish olive to olive brown to blackish above, white or grayish beneath (Abdel-Hafez and El-Caryony, 2009).

Bagrus bayad is well marketable. Its total production in 1996 of about 5826 tons; i.e. it contributes about 9% of the total Nile catch. It is silvery grey above, white beneath and its fins are colorless. Dark dots are sometimes scattered on the back, the adipose and the caudal fins (Bishai and Khalil, 1997).

4- Analytical procedures:

Water, sediments and fish samples (muscles, gills, kidney and liver of each fish) were taken monthly from each site and analyzed for heavy metal residues; copper (Cu), zinc (Zn), lead (Pb), cadmium (Cd), chromium (Cr), manganese (Mn), aluminium (Al), nikel (Ni) and cobalt (Co). Water samples were collected and kept in 500 ml sterile plastic containers while sediments and fish samples were collected and kept in plastic bags. Water samples for metal analysis was treated with 1 ml of HCL in 500 ml sample to arrest microbial activities.

A-Water analysis:

*** Heavy metals in water:**

Heavy metal concentrations in water were determined by atomic absorption spectrophotometer (Perkin Elmer, 2280). The samples were prepared and analyzed sequentialy for zinc, copper, lead, cadmium, chromium, manganese, aluminium, nikel and cobalt according to **APHA (1985)**. To 50 ml of unfiltered water sample (in 500 ml Taylor flask) 0.50 ml of concentrated sulphuric acid was added. This was boiled down to obtain white fumes, cooled and 1.0 ml of 60% $HCLO_3$ and 5.0 ml of concentrated HNO_3 were added. The resulting mixture was digested until a clear digest was obtained. This was cooled, filtered (No. 44 Whatman paper) into 500 ml volumetric flask, diluted to volume and mixed.

Heavy metal concentration (ppm) =

$$\frac{\text{reading of atomic absorption X volume of diluted solution}}{\text{Volume of water sample}}$$

B- Sediment analysis:

*** Heavy metals in sediments:**

Soil sample solution for metal analysis was prepared by treating 1 g soil sample with 10 ml of concentrated nitric acid and 5 ml of 60% perchloric acid in 100 ml Kjeldahl flask. The mixture was heated with moderate heat using a hot plate for about 15 min until white fumes appear. The digest was cooled, then filtered (No. 44 whatman paper) into 50 ml volumetric flask with rinsing in de-ionized water and made up to mark with de-ionized water (Akubugwo *et al*., 2007).

Heavy metal concentration (µg/g) =

$$\frac{\text{reading of atomic absorption X volume of diluted solution}}{\text{Weight of sample (g.)}}$$

C-Fish analysis:

*** Heavy metals in fish tissues:**

Thirty fish from each species (*Oreochromis niloticus*, *Clarias gariepinus* and *Bagrus bayad*) were collected monthly from each site for heavy metal analysis. The collected fish were washed with deionized water, put in cleaned plastic bags and stored frozen until analysis was carried out.

One gram of the prepared tissue sample (wet weight) was subjected to digestion by adding 10 ml of freshly prepared 1:1 concentrated HNO_3-$HClO_3$ in beaker, covered with a watch glass till initial reaction subsided in about 1 hour and gently heated at 160 ºC in a sand bath on a hot plate till reduction of volume to 2-5 ml. The digests were allowed to cool and transferred to 25 ml volumetric flasks and made up to mark with de-ionized water. The digests were kept in plastic bottles and latter heavy metal concentrations were determined using an atomic absorption spectrophotometer (Olaifa *et al*., 2004).

D- Statistical analysis:

The statistical analysis was performed using the analysis of variance (ANOVA) to determine the differences between treatments mean at significant level of 0.05. Standard errors were also estimated. All statistics were run on the computer using SPSS program. All graphics and tables were made by using Origin 7.5 and Microsoft word (2003). The methods for analysis of the results were done according to Bishop (1980) and McCreadie *et al*. (2006).

RESULTS

A-Water analysis:

*** Heavy metals in water:**

Comparing the average concentrations of heavy metals in the different study sites, the data recorded in Table (1) and Fig. (1) showed annual variations in heavy metal concentrations in water samples. The concentrations had the order: Zn > Al > Cr > Pb > MN > Co > Cu >Cd > Ni.

Table 1: Heavy metals concentration (mean ± SE) of water samples collected from the investigated sites from autumn 2007 to summer 2008.

Heavy metals \ Sites	Kafr El-Hosr pond	Bilbeis canal	Abbassa canal	San El-Hagar canal	Muweis canal
Zinc (Zn) µg/g	9.378±0.985	7.662±0.387	8.473±1.247	8.822±1.240	10.194±2.040
Copper (Cu) µg/g	0.920±0.134	1.335±0.216	1.327±0.490	2.818±1.498	1.981±0.859
Cadmium(Cd) µg/g	0.864±0.096	1.030±0.073	1.060±0.084	1.077±0.229	1.031±0.067
Chromium(Cr) µg/g	5.517±4.555	10.246±9.026	3.694±2.851	3.440±2.309	2.378±1.610
Aluminium (Al) µg/g	64.478±25.783	55.568±13.530	59.661±14.106	46.702±9.778	51.468±10.483
Lead (Pb) µg/g	5.014±2.005	4.398±1.399	4.945±2.121	4.554±1.002	4.148±1.251
Manganes (Mn) µg/g	0.804±0.074	0.865±0.156	0.847±0.125	0.647±0.113	0.658±0.087
Nikel (Ni) µg/g	0.398±0.086	0.302±0.066	0.301±0.062	0.354±0.058	0.328±0.066
Cobalt (Co) µg/g	6.296±3.316	4.949±2.098	5.757±2.896	6.353±3.488	6.275±3.425

**Means in the same row are not significantly different ($p > 0.05$), using ANOVA.

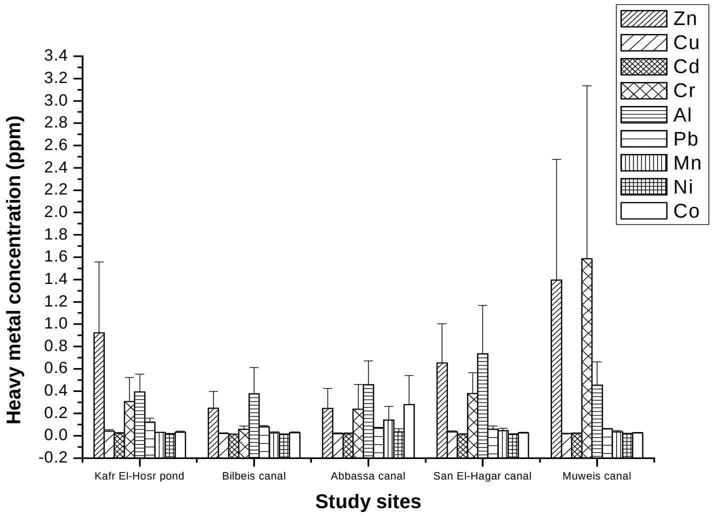

Fig. 1: Heavy metals concentrations (annual mean±SE) in water samples collected from the different investigated sites at Sharkia province.

B- Sediment analysis:

* Heavy metals in sediment:

Comparing the average concentrations of heavy metals in the different study sites, the data recorded in Table (2) and Fig. (2) showed annual variations in heavy metal concentrations in sediment samples. The concentrations had the order: Mn > Zn > Al > Cr > Cu > Pb > Co > Ni > Cd.

Table 2: Heavy metals concentration (mean± SE) of sediment samples collected from the investigated sites from autumn 2007 to summer 2008.

Heavy metals \ Sites		Kafr El-Hosr pond	Bilbeis canal	Abbassa canal	San El-Hagar canal	Muweis canal
Zinc (Zn)	µg/g	14.894±1.320	12.015±2.081	11.538±2.917	13.161±2.647	16.893±1.587
Copper (Cu)	µg/g	7.223±0.940	5.339±1.310	3.962±1.260	6.156±1.862	8.381±2.715
Lead (Pb)	µg/g	4.704±1.872	2.484± 0.905	2.316±0.783	3.764±1.298	2.349±0.662
Cadmium (Cd)	µg/g	0.222±0.070	0.149±0.066	0.183±0.050	0.179±0.060	0.176±0.012
Chromium (Cr)	µg/g	11.725±5.603	11.025±7.348	10.065±7.539	12.296±6.673	12.834±6.568
Aluminium (Al)	µg/g	15.196±7.052	8.119±3.295	5.756±3.431	19.309±7.956	15.660±4.264
Manganese(Mn)	µg/g	41.583±12.437	51.680±18.696	32.239±15.594	37.459±16.972	57.184±17.445
Nikel (Ni)	µg/g	2.035±0.139	1.383±0.339	1.144±0.500	1.954±0.628	2.330±0.260
Cobalt (Co)	µg/g	3.545±0.419	3.223±1.309	1.785±0.470a	2.821±0.647	4.891±1.492a

*Means with the same letters in the same row are significantly different (p<0.05), using ANOVA.

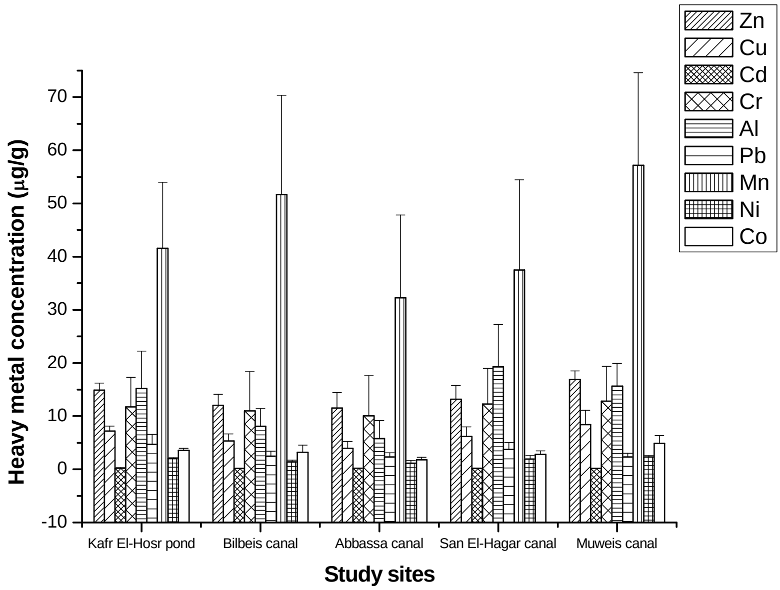

Fig. 2: Heavy metals concentration (annual mean±SE) in sediment samples collected from the different investigated sites at Sharkia province.

C- Fish analysis:

I- Heavy metals in fish muscle:

Comparing the average concentrations of heavy metals in the different study sites, (Tables 3, 4 and 5) showed variations between heavy metal concentrations in fish muscle. The concentrations had the order: Al > Zn > Co > Pb > Cr > Cd > Mn > Cu > Ni.

Table 3: Heavy metals concentration (mean±SE) in muscle tissues of *Oreochromis niloticus* collected from the investigated sites from autumn 2007 to summer 2008.

Heavy metals / Sites		Kafr El-Hosr pond	Bilbeis canal	Abbassa canal	San El-Hagar canal	Muweis canal
Zinc (Zn)	μg/g	4.844±1.363	4.4±0.953	4.767±0.686	4.273±0.238	4.14±0.611
Copper (Cu)	μg/g	0.392±0.110	0.270±0.101a	0.504±0.102	0.350±0.106	0.676±0.180a
Lead (Pb)	μg/g	3.275±1.004	2.945±0.341	3.149±0.996	3.871±0.793	3.477±0.894
Cadmium (Cd)	μg/g	0.727±0.069	0.879±0.082	0.610±0.086	0.992±0.190	0.833±0.040
Chromium (Cr)	μg/g	2.612±1.951	13.121±12.521	1.927±1.520	1.916±1.195	2.098±1.385
Manganese(Mn)	μg/g	0.453±0.063	0.568±0.175	0.523±0.084	0.581±0.082	0.492± 0.064
Aluminium (Al)	μg/g	40.219±8.659	36.028±10.686	40.549±8.010	47.323±9.890	41.481±9.271
Nikel (Ni)	μg/g	0.225±0.076	0.123±0.041	0.235±0.099	0.216±0.079	0.237±0.017
Cobalt (Co)	μg/g	3.486±1.188	4.735±2.420	3.354±1.003	5.323±2.797	5.084±2.366

*Means with the same letters in the same row are significantly different ($p < 0.05$), using ANOVA.

Table 4: Heavy metals concentration (mean±SE) in muscle tissues of *Clarias gariepinus* collected from the investigated sites from autumn 2007 to summer 2008.

Heavy metals / Sites		Kafr El-Hosr pond	Bilbeis canal	Abbassa canal	San El-Hagar canal	Muweis canal
Zinc (Zn)	μg/g	5.310±1.189	3.842±0.338	4.405±0.603	3.843±0.418	5.674±0.819
Copper (Cu)	μg/g	0.424±0.069	0.159±0.038a	0.545±0.208	0.556±0.126	0.899±0.335a
Lead (Pb)	μg/g	4.200±1.685	1.895±0.619	3.349±1.281	3.696±0.629	3.443±1.014
Cadmium(Cd)	μg/g	0.766±0.085	0.648±0.201	0.947±0.051	0.946±0.215	0.891±0.030
Chromium (Cr)	μg/g	3.737±3.240	6.684± 5.957	1.798±1.308	1.897±1.565	1.412±1.086
Manganese(Mn)	μg/g	0.666±0.099	0.465±0.130	0.640±0.119	0.439±0.068	0.522±0.068
Aluminium (Al)	μg/g	58.153±23.066	39.288±9.504	46.384±10.873	41.980±8.806	46.461±8.908
Nikel (Ni)	μg/g	0.303±0.075	0.187±0.085	0.155±0.050	0.188±0.070	0.239±0.072
Cobalt (Co)	μg/g	5.666±3.074	3.688±2.194	4.827±2.348	4.784±2.440	5.660±3.046

*Means with the same letters in the same row are significantly different ($p < 0.05$), using ANOVA.

Table 5: Heavy metals concentration (mean±SE) in muscle tissues of *Bagrus bayad* collected from the investigated sites from autumn 2007 to summer 2008.

Heavy metals / Sites		Kafr El-Hosr pond	Bilbeis canal	Abbassa canal	San El-Hagar canal	Muweis canal
Zinc (Zn)	μg/g	4.718±1.863	3.674±0.231	3.766±0.285	3.139±0.985	3.033±1.076
Copper (Cu)	μg/g	0.428±0.176	0.738±0.347	0.399±0.110	0.633±0.056	0.534±0.041
Lead (Pb)	μg/g	2.485±0.795	3.010±0.720	2.920±0.806	1.845±0.238	3.858±1.951
Cadmium (Cd)	μg/g	0.802±0.006	0.723±0.075	0.726±0.089	0.811±0.193	0.893±0.128
Chromium (Cr)	μg/g	0.385±0.104	6.493±6.031	2.018±1.485	0.679±0.424	1.610±0.988
Manganese(Mn)	μg/g	0.482±0.022	0.477±0.104	0.438±0.112	0.561±0.118	0.512±0.036
Aluminium (Al)	μg/g	36.745±18.705	28.578±10.145	41.303±14.651	43.842±9.735	47.518±15.955
Nikel (Ni)	μg/g	0.164±0.146	0.230±0.027a	0.085±0.016ab	0.239±0.030b	0.206±0.062
Cobalt (Co)	μg/g	7.965±5.415	4.401±1.842	4.857±2.555	6.320±2.564	5.080±2.659

*Means with the same letters in the same row are significantly different ($p < 0.05$), using ANOVA.

II- Heavy metals in gill tissue:

Comparing the average concentrations of heavy metals in the different study sites, (Tables 6, 7 and 8) showed variations between heavy metal concentrations in gill tissue. The concentration was as seen Al > Zn > Co > Pb > Cr > Cd > Mn > Cu > Ni.

Table 6: Heavy metals concentration (mean±SE) in gills of *Oreochromis niloticus* collected from the investigated sites from autumn 2007 to summer 2008.

Heavy metals / Sites		Kafr El-Hosr pond	Bilbeis canal	Abbassa canal	San El-Hagar canal	Muweis canal
Zinc (Zn)	µg/g	9.293±4.505	6.499±1.038	5.901±0.749	6.035±0.690	6.800±0.610
Copper (Cu)	µg/g	0.572±0.122	0.664±0.286	0.623±0.076	1.720±1.224	1.063±0.315
Cadmium (Cd)	µg/g	0.858±0.100	0.984±0.142	0.786±0.077	1.069±0.201	0.917±0.039
Chromium (Cr)	µg/g	2.975±2.217	15.300±14.651	3.835±3.144	3.115±2.235	2.716±1.925
Aluminium (Al)	µg/g	45.774±10.573	40.438±12.319	44.689±9.426	53.332±11.701	46.567±10.819
Lead (Pb)	µg/g	4.350±1.959	3.815±0.705	3.501±1.046	4.428±0.887	3.686±0.631
Manganes (Mn)	µg/g	0.581±0.077	0.80096±0.16252	0.593±0.095	0.770±0.094	0.574±0.078
Nikel (Ni)	µg/g	0.316±0.103	0.1925±0.02839	0.323±0.122	0.300±0.073	0.332±0.064
Cobalt (Co)	µg/g	4.584±1.730	6.313±3.443	3.831±1.219	6.054±3.377	5.545±2.674

*Means in the same row are not significantly different (p> 0.05), using ANOVA.

Table 7: Heavy metals concentration (mean±SE) in gills of *Clarias gariepinus* collected from the investigated sites from autumn 2007 to summer 2008.

Heavy metals / Sites		Kafr El-Hosr pond	Bilbeis canal	Abbassa canal	San El-Hagar canal	Muweis canal
Zinc (Zn)	µg/g	7.514±0.684	6.685±0.388	6.604±1.150	8.350±1.217	9.584±2.318
Copper (Cu)	µg/g	0.613±0.074	0.633±0.191	0.791±0.370	0.957±0.135	1.120±0.311
Cadmium (Cd)	µg/g	0.834±0.090	0.895±0.032	1.012±0.076	1.034±0.220	0.936±0.027
Chromium (Cr)	µg/g	5.129±4.288	7.725±6.677	3.079±2.297	2.974±1.993	1.861±1.262
Aluminium (Al)	µg/g	60.385±24.100	51.146±12.540	56.439±13.144	44.219±9.382	49.048±10.055
Lead (Pb)	µg/g	4.774±1.948	4.071±1.439	3.617±1.237	4.043±0.677	3.648±1.020
Manganese(Mn)	µg/g	0.766±0.082	0.768±0.113	0.740±0.125	0.586±0.098	0.617±0.074
Nikel (Ni)	µg/g	0.351±0.076	0.262±0.070	0.223±0.042	0.261±0.058	0.288±0.086
Cobalt (Co)	µg/g	6.151±3.280	4.703±2.148	5.526±2.752	5.518±2.941	5.857±3.151

*Means in the same row are not significantly different (p>0.05), using ANOVA.

Table 8: Heavy metals concentration (mean±SE) in gills of *Bagrus bayad* collected from the investigated sites from autumn 2007 to summer 2008.

Heavy metals / Sites		Kafr El-Hosr pond	Bilbeis canal	Abbassa canal	San El-Hagar canal	Muweis canal
Zinc (Zn)	µg/g	5.505±2.215	6.563±0.744	6.531±0.818	5.113±1.612	5.820±1.938
Copper (Cu)	µg/g	0.604±0.216	1.109±0.497	0.550±0.124	0.820±0.111	0.761±0.070
Cadmium (Cd)	µg/g	0.824±0.002	0.753±0.072	0.806±0.091	0.904±0.180	0.979±0.209
Chromium (Cr)	µg/g	0.556±0.264	15.373±14.619	2.181±1.606	0.924±0.385	1.736±1.051
Aluminium (Al)	µg/g	39.455±19.945	32.216±10.147	48.867±16.581	47.207±10.700	49.345±12.535
Lead (Pb)	µg/g	2.935±0.705	3.255±0.696	3.232±0.758	2.421±0.205	4.354±2.118
Manganese (Mn)	µg/g	0.574±0.035	0.609±0.145	0.587±0.109	0.637±0.097	0.611±0.063
Nikel (Ni)	µg/g	0.223±0.198	0.271±0.028	0.208±0.057	0.310±0.050	0.267±0.069
Cobalt (Co)	µg/g	8.018±5.413	4.766±2.114	5.388±2.898	6.881±2.779	5.974±3.428

*Means with the same letters in the same row are significantly different (p< 0.05), using ANOVA.

III- Heavy metals in kidney:

Comparing the average concentrations of heavy metals in the different study sites, (Tables 9, 10 and 11) showed variations between heavy metal concentrations in kidney. The concentrations had the order: Al > Zn > Co > Pb > Cr > Cd > Mn > Cu > Ni.

Table 9: Heavy metals concentration (mean±SE) in kidney of *Oreochromis niloticus* collected from the investigated sites from autumn 2007 to summer 2008.

Heavy metals \ Sites		Kafr El-Hosr pond	Bilbeis canal	Abbassa canal	San El-Hagar canal	Muweis canal
Zinc (Zn)	µg/g	15.150±9.023	6.784±0.962	6.621±0.855	6.638±0.851	7.354±0.557
Copper (Cu)	µg/g	0.750±0.086	1.118±0.550	0.922±0.076	2.630±1.437	1.996±0.791
Cadmium (Cd)	µg/g	0.938±0.080	1.024±0.174	0.861±0.046	1.112±0.207	1.121±0.151
Chromiu (Cr)	µg/g	3.811±2.950	15.624±14.898	4.024±3.147	3.336±2.256	2.867±1.968
Aluminiu (Al)	µg/g	48.516±11.626	43.249±12.501	48.958±11.290	57.421±13.007	55.045±12.367
Lead (Pb)	µg/g	4.469±1.957	4.261±1.092	3.801±0.889	4.505±0.888	3.875±0.682
Manganese (Mn)	µg/g	0.651±0.085	0.857±0.172	0.630±0.110	0.846±0.111	0.641±0.097
Nikel (Ni)	µg/g	0.364±0.103	0.229±0.025	0.370±0.115	0.338±0.071	0.360±0.072
Cobalt (Co)	µg/g	5.665±2.692	6.547±3.605	5.631±2.809	6.353±3.460	5.767±2.673

*Means in the same row are not significantly different (p> 0.05), using ANOVA.

Table (10): Heavy metals concentration (mean±SE) in kidney of *Clarias gariepinus* collected from the investigated sites from autumn 2007 to summer 2008.

Heavy metals \ Sites		Kafr El-Hosr pond	Bilbeis canal	Abbassa canal	San El-Hagar canal	Muweis canal
Zinc (Zn)	µg/g	9.378±0.985	7.662±0.387	8.473±1.247	8.822±1.240	10.194±2.040
Copper (Cu)	µg/g	0.920±0.134	1.335±0.216	1.327±0.490	2.818±1.498	1.981±0.859
Cadmium(Cd)	µg/g	0.864±0.096	1.030±0.073	1.060±0.084	1.077±0.229	1.031±0.067
Chromium(Cr)	µg/g	5.517±4.555	10.246±9.026	3.694±2.851	3.440±2.309	2.378±1.610
Aluminium (Al)	µg/g	64.478±25.783	55.568±13.530	59.661±14.106	46.702±9.778	51.468±10.483
Lead (Pb)	µg/g	5.014±2.005	4.398±1.399	4.945±2.121	4.554±1.002	4.148±1.251
Manganes (Mn)	µg/g	0.804±0.074	0.865±0.156	0.847±0.125	0.647±0.113	0.658±0.087
Nikel (Ni)	µg/g	0.398±0.086	0.302±0.066	0.301±0.062	0.354±0.058	0.328±0.066
Cobalt (Co)	µg/g	6.296±3.316	4.949±2.098	5.757±2.896	6.353±3.488	6.275±3.425

*Means in the same row are not significantly different (p> 0.05), using ANOVA.

Table (11): Heavy metals concentration (mean±SE) in kidney of *Bagrus bayad* collected from the investigated sites from autumn 2007 to summer 2008.

Heavy metals \ Sites		Kafr El-Hosr pond	Bilbeis canal	Abbassa canal	San El-Hagar canal	Muweis canal
Zinc (Zn)	µg/g	6.323±1.848	7.456±0.326	7.303±0.834	5.496±1.723	6.187±2.056
Copper (Cu)	µg/g	0.859±0.406	2.416±1.410	1.503±0.770	1.196±0.267	0.878±0.103
Cadmium (Cd)	µg/g	0.883±0.050	0.838±0.021	0.955±0.069	1.068±0.146	1.064±0.204
Chromium (Cr)	µg/g	0.607±0.268	15.647±14.784	2.658±1.937	1.193±0.360	2.956±2.199
Aluminium (Al)	µg/g	43.830±23.04٠	38.962±10.018	54.092±16.662	51.731±11.314	67.919±19.193
Lead (Pb)	µg/g	3.105±0.59٠	4.134±1.216	3.492±0.712	2.978±0.230	4.455±2.077
Manganese(Mn)	µg/g	0.602±0.029	0.686±0.151	0.661±0.140	0.674±0.094	0.650±0.062
Nikel (Ni)	µg/g	0.237±0.200	0.295±0.033	0.244±0.063	0.374±0.042	0.296±0.081
Cobalt (Co)	µg/g	8.063±5.533	4.968±2.248	6.116±3.369	7.537±2.788	6.175±3.419

*Means in the same row are not significantly different (p> 0.05), using ANOVA.

IV- Heavy metals in liver tissue:

Comparing the average concentrations of heavy metals in the different study sites, (Tables 12, 13 and 14) and Fig. (3, 4, 5, 6 and 7) showed variations between heavy metal concentrations in liver tissue. The concentration was as seen in the previous studied tissues Al > Zn > Co > Pb > Cr > Cd > Mn > Cu> Ni.

Table 12: Heavy metals concentration (mean±SE) in liver tissues of *Oreochromis niloticus* collected from the investigated sites from autumn 2007 to summer 2008.

Sites / Heavy metals	Kafr El-Hosr pond	Bilbeis canal	Abbassa canal	San El-Hagar canal	Muweis canal
Zinc (Zn) µg/g	17.941±9.869	9.114±1.451	8.685±0.636	7.944±0.689	8.260±0.697
Copper (Cu) µg/g	3.995±0.809	12.484±4.688	17.256±8.059	15.720±5.941	12.979±8.154
Cadmium (Cd) µg/g	1.015±0.062	1.123±0.229	1.007±0.035	1.168±0.210	1.269±0.220
Chromium (Cr) µg/g	6.545±5.342	16.609±15.299	4.191±3.104	4.784±3.535	3.229±2.054
Aluminium (Al) µg/g	52.948±13.003	48.901±12.924	60.389±12.776	69.895±17.927	60.719±14.050
Lead (Pb) µg/g	5.699±3.048	4.717±1.489	4.296±0.914	4.686±0.954	5.160±1.475
Manganese(Mn) µg/g	0.832±0.131a	0.954±0.143	0.832±0.131b	1.375±0.267ab	0.907±0.138
Nikel (Ni) µg/g	0.440±0.115	0.314±0.047	0.465±0.106	0.373±0.069	0.479±0.106
Cobalt (Co) µg/g	6.041±2.827	6.885±3.871	5.905±2.824	6.870±3.791	6.579±3.418

*Means with the same letters in the same row are significantly different (p< 0.05), using ANOVA.

Table 13: Heavy metals concentration (mean±SE) in liver tissues of *Clarias gariepinus* collected from the investigated sites from autumn 2007 to summer 2008.

Sites / Heavy metals	Kafr El-Hosr pond	Bilbeis canal	Abbassa canal	San El-Hagar canal	Muweis canal
Zinc (Zn) µg/g	12.575±1.485	11.247±0.973	12.996±3.053	15.404±1.469	14.536±2.778
Copper (Cu) µg/g	4.117±0.802	3.846±1.090	8.009±3.676	9.963±2.114	9.579±3.567
Cadmium (Cd) µg/g	0.932±0.092	1.097±0.111	1.236±0.193	1.206±0.232	1.216±0.167
Chromium (Cr) µg/g	7.666±5.930	15.922±14.385	4.474±3.300	6.853±5.351	3.748±2.883
Aluminium (Al) µg/g	67.871±25.802	64.154±16.237	67.696±15.574	66.971±17.047	59.977±13.610
Lead (Pb) µg/g	5.996±2.827	5.124±1.563	5.656±2.274	4.891±1.095	5.057±1.638
Manganese (Mn) µg/g	0.992±0.063	1.028±0.184	0.963±0.160	0.887±0.162	0.738±0.079
Nikel (Ni) µg/g	0.508±0.108	0.381±0.048	0.438±0.069	0.428±0.077	0.407±0.050
Cobalt (Co) µg/g	6.651±3.411	5.655±2.270	6.263±3.232	6.986± 3.860	6.649±3.624

*Means in the same row are not significantly different (p> 0.05), using ANOVA.

Table 14: Heavy metals concentration (mean±SE) in liver tissues of *Bagrus bayad* collected from the investigated sites from autumn 2007 to summer 2008.

Sites / Heavy metals	Kafr El-Hosr pond	Bilbeis canal	Abbassa canal	San El-Hagar canal	Muweis canal
Zinc (Zn) µg/g	7.696±0.985	15.768±5.112a	12.074±1.281	6.300±2.018a	8.697±3.008
Copper (Cu) µg/g	1.224±0.356	3.963±1.568	3.086±0.622	5.191±1.506	3.013±0.943
Cadmium (Cd) µg/g	0.934±0.036	0.965±0.008	1.1940±0.160	1.164±0.171	1.214±0.226
Chromium (Cr) µg/g	1.114±0.681	16.626±15.320	3.342±2.496	1.411±0.373	4.026±3.168
Aluminium (Al) µg/g	48.012±25.798	55.336±11.988	59.542±18.885	59.553±13.978	86.284±30.520
Lead (Pb) µg/g	3.113±0.553	4.320±1.165	4.237±0.988	3.276±0.232	5.025±2.168
Manganese(Mn) µg/g	0.733±0.015	0.783±0.141	0.807±0.146	0.903±0.142	0.810±0.124
Nikel (Ni) µg/g	0.371±0.103	0.380±0.038	0.294±0.065	0.472±0.083	0.337±0.092
Cobalt (Co) µg/g	8.483±5.898	5.298±2.476	6.418±3.484	8.411±3.149	6.564±3.602

*Means with the same letters in the same row are significantly different (p< 0.05), using ANOVA.

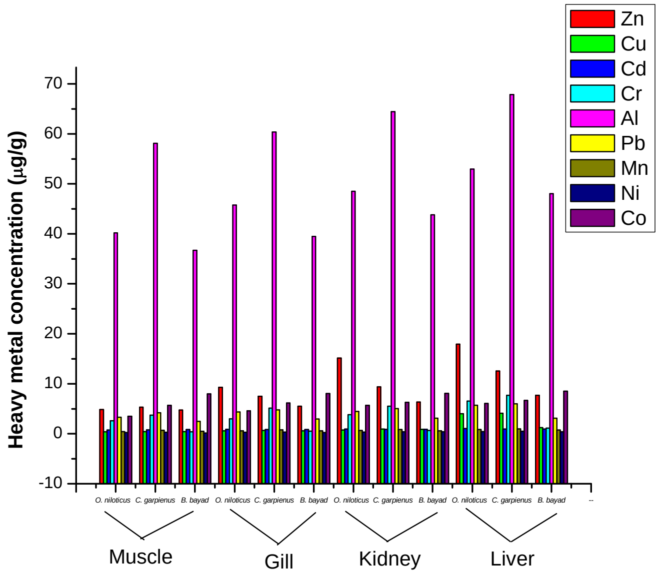

Fig. 3: Heavy metals concentrations (annual mean±SE) in muscle, gills, kidney and liver tissues of *Oreochromis niloticus*, *Clarias gariepinus* and *Bagrus bayad* at Kafr El-Hosr pond during autumn 2007-summer 2008.

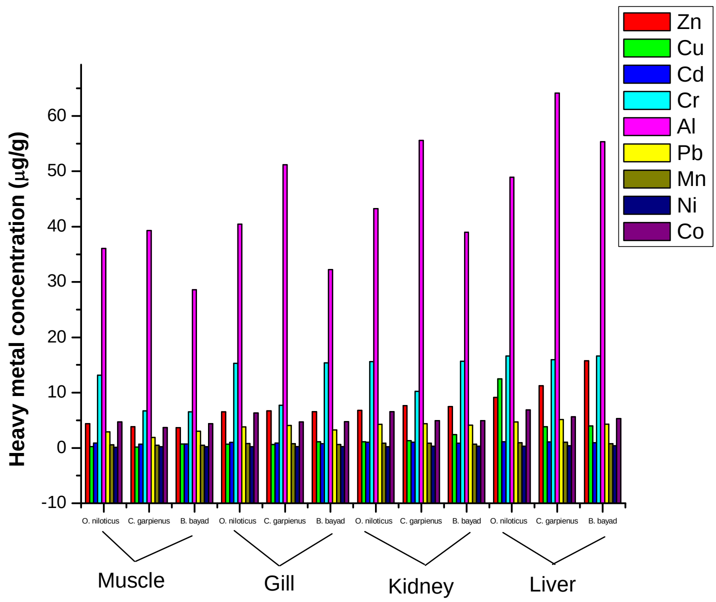

Fig. 4: Heavy metals concentrations (annual mean±SE) in muscle, gills, kidney and liver tissues of *Oreochromis niloticus*, *Clarias gariepinus* and *Bagrus bayad* at Bilbeis canal during autumn 2007-summer 2008.

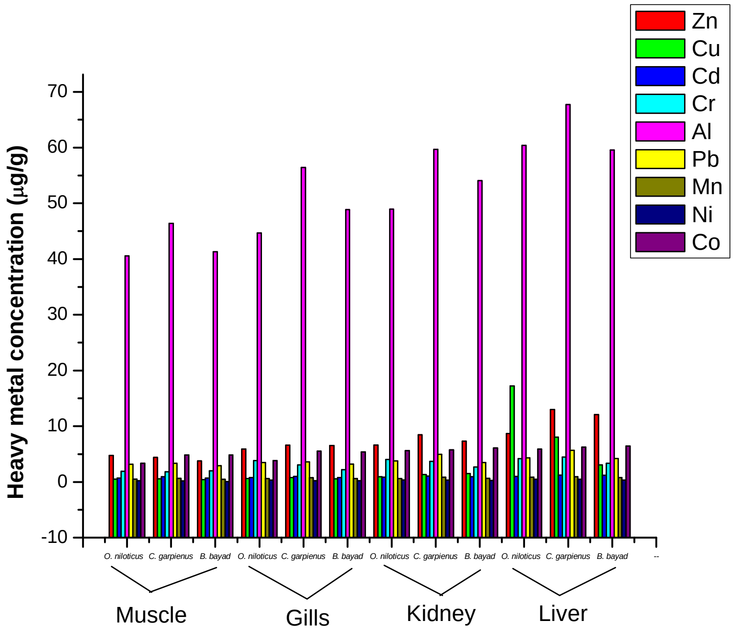

Fig. (5): Heavy metals concentrations (annual mean±SE) in muscle, gills, kidney and liver tissues of *Oreochromis niloticus*, *Clarias gariepinus* and *Bagrus bayad* at Abbassa canal during autumn 2007-summer 2008.

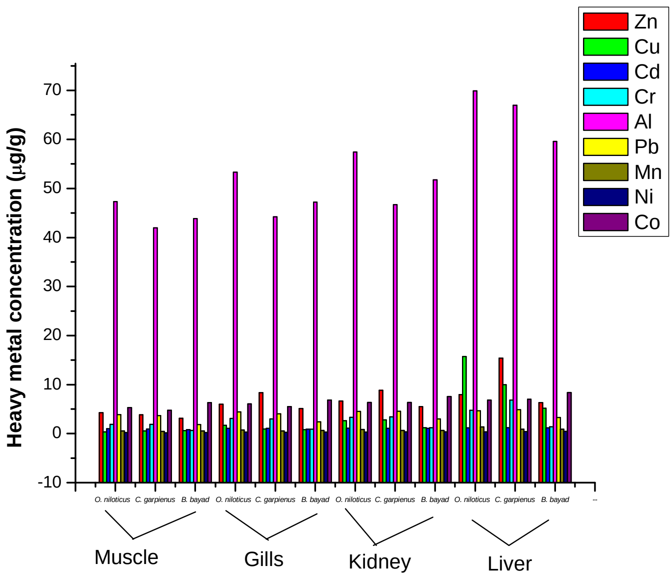

Fig. 6: Heavy metals concentrations (annual mean±SE) in muscle, gills, kidney and liver tissues of *Oreochromis niloticus*, *Clarias gariepinus* and *Bagrus bayad* at San El-Hagar canal during autumn 2007-summer 2008.

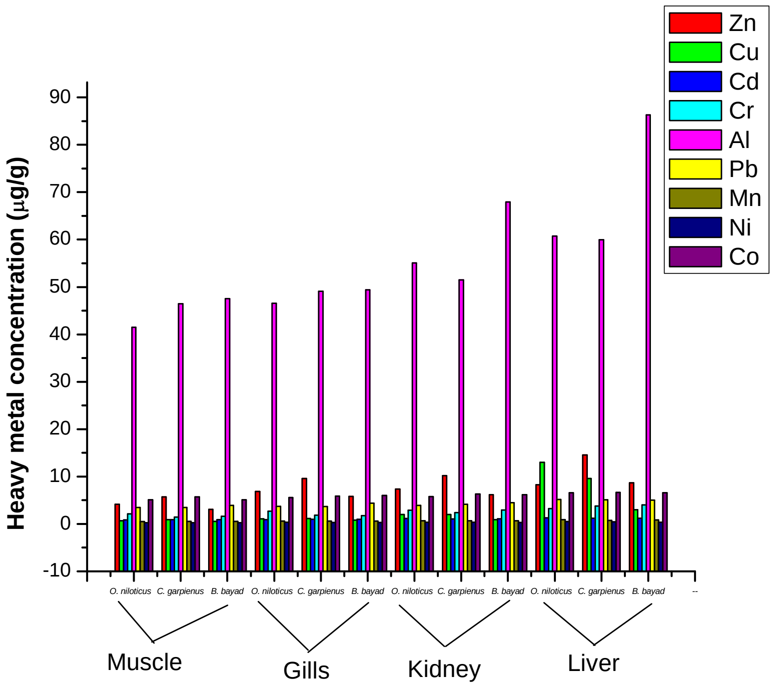

Fig. 7: Heavy metals concentrations (annual mean±SE) in muscle, gills, kidney and liver tissues of *Oreochromis niloticus, Clarias gariepinus* and *Bagrus bayad* at Muweis canal during autumn 2007-summer 2008.

DISCUSSION

Heavy metals in water:

For all heavy metals, the maximum concentrations were observed in spring and winter, while the minimum values were detected in summer and autumn. These results comply with those recorded by Saeed (2000) who found that heavy metals concentration showed seasonal variations, being greater in winter and lowest in summer. This may be attributed to the phytoplankton growth which was higher in summer and autumn seasons that can absorb large quantities of heavy metals from water. Moreover, the highest concentrations of all heavy metals were detected in water samples collected from Muweis canal [especially for zinc where zinc oxide is used as oxidizing agent to produce fatty acids) and chromium (chromium oxide is used as inorganic color additive) which are used in soap manufacture], Kafr El-Hosr pond and San El-Hagar canalwhich may be attributed to wastes of industrial activities and wastewater.

Heavy metals in sediment:

Concerning the mean concentrations of heavy metals Zn, Cu, Pb, Cd, Cr, Mn, Ni, Co and Al (< 120, < 16, < 31, < 0.6, < 26 , < 460, <16, 19 and 100 µg/g respectively), the levels were below the permissible limits reported by Ontario Ministry of the Environment (ANZECC, 2000), Shall standard [after Foerstner

& Wittmann (1979)] for cobalt, and Hamilton and Buhl (2003) for aluminium, at all study sites, and were accepted by Saeed and Shaker (2010) and Olubunmi (2010).

Heavy metals in fish tissues:

Muscle tissue:

The present study revealed that Pb, Cd, Cr, Al and Co were higher than the permissible levels recommended by WHO (1984 & 1993), USEPA (1986), ANZECC (2000) and Abbasi *et al.* (1997) [2.0, 0.5, 0.15, 0.1 and 1.2 µg/g respectively]. Although the results were higher than those recorded by Dobaradaran *et al.* (2010), the data were nearly similar to those of Schlotfeldt and Alderman (1995), Uluozlu *et al.* (2007), Mohamed (2008), Miclean *et al.* (2009) and Saeed and Shaker (2010). On the other hand, Zn, Cu, Mn and Ni levels were lower than permitted limits (50, 20, 2.5 and 0.4 µg/g respectively), but still lesser than those reported by Gabriel *et al.* (2006), Morshdy *et al.* (2007), Al-Bader (2008), Dobaradaran *et al.* (2010) and Saeed and Shaker (2010). These variations may be attributed to the differences between the localities, and the amount and source of pollution from an area to another.

Gills, Kidney and liver tissues:

From the present data, it is obvious that liver, kidney and gills accumulated higher concentrations of the studied heavy metals than the muscles. The mean of all studied metals of these tissues collected from the study sites exceeded the permissible concentrations (except for Zn, Cu, Mn and Ni). Liver represented the highest site of concentrations of heavy metals followed by kidney then gills and finally muscle tissue. This may be attributed to the major role of liver in detoxification and protection from heavy metal exposure, both by producing metallothionines (metal binding-proteins) and by acting as storage site for bound metals (Pratap *et al.*, 1989). Also, the liver concentrates these metals from the blood circulatory system of the fish. The present results are in agreement with Velcheva (2006) who reported that heavy metals were significantly higher in fish viscera, including liver tissue and kidney than in the edible muscle tissue. The high heavy metal content in gills of fish collected from the three sources of water can be related to accumulation of such heavy metals from the water primarily through fish gill where metallothionine enhances that bioaccumulation in gills and its uptake could be controlled by the amount of water passing through the gills (Saeed, 2000).

Fish collected from area of industrial activity (Muweis canal) and swage areas (Kafr El-Hosr pond and San El-Hagar canal) had significantly greater concentrations of heavy metals than fish collected from areas of agricultural activities (Bilbeis canal and Abbassa canal). These variations in heavy metal concentrations may be due to the nature of water source. Moreover, it is obvious that the average heavy metal concentrations in different tissues of *Clarias gariepinus* were higher than those of *Oreochromis niloticus* and *Bagrus bayad*. This may be due to the difference of feeding habits of the three species, where the former fish is mainly omnivorous feeding on fish, insect larvae, mollusks, planktonic organisms and water weeds (Bishai and Khalil, 1997) which accumulate large amounts of heavy metals (Rizkalla and Abou-Donia, 1996).

Also, *Oreochromis niloticus* feeds mainly on phytoplankton (Schroeder, 1983) which accumulate large amounts of heavy metals while *Bagrus bayad* feeds mainly on fishes, insects and crustaceans. Moreover, *Clarias gariepinus* lives mainly in muddy or semi-muddy bottom (Bishai and Khalil, 1997) and *Oreochromis niloticus* wanders in water from surface to bottom, being frequently in contact with soil particles (Saeed, 2000), while *Bagrus bayad* lives in deep water in crevices of rocks at the daylight (Bishai and Khalil, 1997).

CONCLUSION AND RECOMMENDATION

From the present results, it can be concluded that Conditions at industrial drainage, sewage wastewater and agriculture drainage fish are not safe for human consumption since the heavy metal analysis revealed a public health hazard as the quality of fish grown in such water did not comply with the standards levels recommended by WHO, USEPA and ANZECC. Potential adverse health effects in such application could be avoided if the wastewater is sufficiently treated.

REFERENCES

Abbasi, S. A.; Abbasi, N. and Soni, R. (1997). Heavy metals in the environment. Showroom, pp. 1-297.

Abdel-Hafez, S. M. and El-Caryony, I. A. (2009). An economic study on the production of catfish in the Egyptian fisheries. J. Arab. Aqua. Soc., 4 (1): 19-34.

Akubugwo, I. E.; Ofoegbu, C. J. and Ukwuoma, C. U. (2007). Physicochemical studies on Uburu Salt Lake Ebonyi Staste-Nigeria. Pak. J. Biol. Sci., 10(17): 3170-3174.

Al- Bader, N. (2008). Heavy metal levels in most common available fish species in Saudi market. II J. Food Tech., 6(4): 173-177.

Allinson, G.; Laurenson, L. J. B.; Pistone, G.; Stagnitti, F. and Jones, P. L. (2000). Effects of dietary copper on the Australian freshwater crayfish, Cherax destructor, 46: 117-123.

American Public Health Association (APHA) (1985). Standard methods for the examination of water and wastewater. 16^{th} ed., Washington, D. C.

ANZECC (2000). Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environmental Conservation Council & Agriculture and Resource Management Council of Australian and New Zealand. Canberra.pp. 1-123.

Begum, A.; Harikrishna, S. and Khan, I. (2009). Analysis of heavy metals in water, sediment and fish samples of Madivala Lake of Bangalore, Karnataka. Int. J. of Chem Tech Res., 1(2):245-249.

Bishai, H. M. and Khalil, M. T. (1997). Freshwater fishes of Egypt. Publication of National Biodiversity Unit, 9:1-229.

Bishop, O. V. (1980). A practical guide for the experimental biologist. In ‘‘Statistics for Biology’’, Bishop, O. V. (ed.), 3rd edition, Longman group limited., 28 pp.

Boyd, C. E. (1990). Water quality in ponds for aquaculture. Alabama Agriculture Experiment Station, Auburn Univ., Alabama, U. S. A.

Burger, J.; Gaines, K. F.; Boring, S.; Stephens, L.; Snodgrass, J.; Dixon, C.; McMahon, M.; Shukla, S.; Shukla, T. and Gochfeld, M. (2002). Metal levels in fish from the Savannah River: Potential hazards to fish and other receptors. Environ. Res., 89: 85-97.

Dallinger, R.; Prosi, F.; Segner, H. and Black, H. (1987). Contaminated food and uptake of heavy metals by rainbow trout (*Salmo gairdneri*): A field study. Oecologia. 73: 91-98.

Dobaradaran, S.; Naddafi, K.; Nazmara, S. and Ghaedi, H. (2010). Heavy metals (Cd, Cu, Ni and Pb) content in two fish species of Persian Gulf in Bushehr Port, Iran. Af. J. of Biotech., 9(37):6191- 6193.

Fernandez,-Leborans, G. and Olalla-Herrero, Y. (2000). Toxicity and bioaccumulation of lead and cadmium in marine protozoa communities. Ecotoxicol. and Environ. Saf.. 47: 266-276.

Forstner, U. and Wittman, G. T. W. (1979). Metal pollution in aquatic environment. Springer-Verlag Berlin, Heidelerg, PP. 486.

Gabriel, O.; Rita, O.; Clifford, A.; Cynthia, O.; Harrison, N. and Kennedy, K. (2006). Metal pollution of fish of Qua-Iboe River Estuary: Possible implications for neurotoxicity. The Int. J. of Toxicol., 3(1): 1-6.

Gupta, P. K. (2000). Methods in environmental analysis water, soil and air.Agrobios, 5: 1- 400.

Hamilton, S. J. and Buhl, K. J. (2003). Selenium and other trace elements in water, sediment, Aquatic plants, Aquatic invertebrates, and fish from streams in southeastern Idaho near phosphate mining operations: September 2000. USGS science for a changing world, pp. 1-67.

Langston, W. J.; Burt, G. R. And Pope, N. D. (1999). Bioavailability of metals in sediments of the dogger bank (Central North Sea): A mesocosm study. Estuarine, Coastal and Shelf Science. 48: 519-540.

Linnik, P. M. and Zubenko, I. B. (2000). Role of bottom srdiments in the secondary pollution of aquatic environments by Heavy-metal compounds. Lakes and Reservoirs: Res. and Man., 5: 11-21.

McCreadie, J. W.; Alder, P. H.; Grillet, M. E. and Hamada, N. (2006). Sampling and statistics in understanding distributions of black fly larvae (Diptera: Simuliidae). Acta Entomological Serbica, 11: 89-96.

Miclean, M. I.; Ştefãnescu, L. N.; Levei, E. A.; Şenilã, M.; Mãrginean, S. F.; Romam, C. M. and Cordoş, E. A. (2009). Ingestion induced health risk in surface waters near tailings ponds (North-Western Romania). AACL Bioflux, 2(3): 275-283.

Mohamed, F. A. S. (2008). Bioaccumulation of selected metals and histopathological alterations in tissues of *Oreochromis niloticus* and *Lates niloticus* from Lake Nasser, Egypt. Glob. Vet., 2(4): 205-218.

Mohan, B. S. and Hosetti, B. B. (1999). Aquatic plants for toxicity assessment. Environ. Res., 81: 259-274.

Morshdy, A.; El-Dosky, K. E. and El-shebaie, S. (2007). Some heavy metal residues in mackerel and saurus fish. Zag. Vet. J., 35(4): 114-120.

Olaifa, F. E.; Olaifa, A. K.; Adelaja, A. A. and Owolabi, A. G. (2004). Heavy metal contamination of *Clarias gariepinus* from a lake and fish from farm in Ibadan, Nigeria. A f. J. of Biomed. Res., 7: 145-148.

Olubunmi, F. E. (2010). Evaluation of the status of heavy metal pollution of sediment of Agbabu Bitumen Deposit Area, Nigeria. Eur. J. of Sci. Res., 41(3):373-382.

Pratap, H. B.; Lock, R. A. C. and Bonga, S. E. W. (1989). Effect of waterborne and dietary cadmium on plasma ions of the teleost Oreochromis mossambicus in relation to water calcium levels. Arch. Environ. Contam. Toxicol., 18(4): 568-575.

Rakocy, J. E. (2011). *Oreochromis niloticus*. FAO. In Cultured aquatic species fact sheets. Edited and compiled by Valerio Crespi and Michael New. CD-ROM (multilingual).

Ramelow, G. J.; Webre, C. L.; Mueller, C. L.; Beck, J. N.; Young, J. C. and Langley, M. P. (1989). Variations of heavy metals and arsenic in fish and other organisms from the Calcasien River and Lake, Louisiana. Archive of Environ. Contam. and Toxicol., 18: 804-818.

Raymus-Keller, A.; Olson, K. E.; McGaw, M.; Oray, C.; Carlson, J. O. and Beaty, B. J. (1998). Effect of heavy metals on *Aedes aegypti* (Diptera: Culicidea) larvae. Ecotoxicol. and Environ.saf., 39: 41-47.

Rizkalla, E. and Abo-Donia, M. A. (1996). Some industrial heavy metal pollutants in River Nile and their effect on biological and non-biological inhabitants. 1. Essential heavy metals. Egypt, J. Agric. Res., 74 (1): 225-237.

Saeed, S. M. (2000). A study on factors affecting fish production from certain fish farms in the Delta. M. Sc.Thesis. Faculty of Science, Ain Shams University, Egypt.

Saeed, S. M. and Shaker, I. M. (2010). Assessment of heavy metals pollution in water and sediments and their effect on *Oreochromis niloticus* in the northern Delta Lakes, Egypt. 8th Intern. Symp. on Tilapia in Aqua., pp. 475- 489.

Schlotfeldt, H. J. and Alderman, D. J. (1995). What should I do? A practical guide for the freshwater fish farmer. European Association of Fish Pathologists/Warwick Press, Weymouth.

Schroeder, G. L. (1983). Sources of fish and prawn- growth in polyculture ponds as indicated by delta C analysis Aqua., 35: 29-42.

Uluozlu, O. D.; Tuzen, M.; Mendil, D. and Soylak, M. (2007). Trace metal content in nine species of fish from the Black and Aegean Seas, Tur. Food Chem., 104 (2): 835-840.

United States Environmental Protection Agency (USEPA) (1986). Quality Criteria for Water. EPA/ 440/5-86-001.

Van den Broek, J. L.; Gledhill, K. S. and Morgan, D. G. (2002). Heavy metal concentration in the mosquito fish, *Gambusia holbrooki*, in the Manly Lagoon Catchment. In: UTS freshwater ecology report 2002, Department of Environmental Science, University of Technology, Sydney.

Velcheva, I. G. (2006). Zinc content in the organs and tissues of freshwater fish from the Kardjali and Studen Kladenets Dam Lakes in Bulgaria. Turk. J. Zool., 30: 1-7.

Wildianarko, B.; Van Gestel, C. A. M.; Verweij, R. A. and Van Straalen, N. M. (2000). Associations between trace metals in sediment, water and guppy, *Poecilia reticulate* (Peters), from Urban streams of Semarang, Indonesia. Ecotoxicol. and Environ. Saf.. 46: 101-107.

Wong, P. T. S. and Dixon, D. G. (1995). Bioassessment of water quality. Environ. Toxicol.and Water Qual., 10: 9-17.

World Health Organization (WHO) (1984). Guide lines for drinking water quality. Geneva.

World Health Organization (WHO) (1993). Revision of WHO guidelines for water quality.WHO. Geneva.