African Journal of Biotechnology Vol. 11(77), pp. 14204-14216, 25 September, 2012
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB11.3745
ISSN 1684–5315 ©2012 Academic Journals

Full Length Research Paper

Bioaccumulation of heavy metals in water, sediment and fish (*Oreochromis niloticus* and *Clarias anguillaris),* in Rosetta branch of the River Nile, Egypt

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Accepted 6 June, 2012

Rosetta Branch of the River Nile is exposed to high input of agricultural drainage water, sewage and industrial water that affect living organisms like fish. In the present study, some heavy metals such as iron, copper, lead, cadmium and zinc (Fe, Cu, Pb, Cd and Zn) were seasonally determined in some tissues of tilapia (*Oreochromis niloticus*) and catfish (*Clarias anguillaris*), water sediment and in Rosetta branch of River Nile at the following areas: El-Kanater El-Khairya (I), El-Rahawy drain (II), Tamaly (III) and Kafer El-Zyate (IV), which are an important water source for irrigation and drinking in Egypt. The highest levels of heavy metal accumulated in the liver of *C. anguillaris* were Fe, Cu, Pb, Cd and Zn than accumulated in *O. niloticus.* In gills of *C. anguillaris,* the highest accumulation of metal levels were Zn, Fe, Pb, Cd and Cu than accumulation in gills of *O. niloticus.* In muscles of *C. anguillaris*, the highest accumulation of metal levels were recorded for Fe, Zn, Cd and Cu except Pb was highest in O*. niloticus* muscles. Bioaccumulation factor (BAF) of all heavy metals in organs of *C. anguillaris* was higher than *O. niloticus*. Heavy metal levels in water, sediment and fish samples were analyzed by using atomic absorption. The order of heavy metal accumulation in water was Fe > Pb > Cu > Zn > Cd. Maximum metal index (MI) recorded at station IV for Fe, Cu, Pb and Zn were 2.7, 0.3, 62 and 0.17 mg/L, respectively and Cd was 15.333 mg/L at station III. The order of heavy metal accumulation in sediment was Fe > Zn > Cu > Pb > Cd. It was discovered in the present study that fish can bioaccumulate heavy metals from a polluted environment and could be a risk factor for accumulation of heavy metal in humans after a long time that would lead to dangerous diseases.

Key words: Heavy metals, metal index (MI), bioaccumulation factor (BAF), *Oreochromis niloticus*, *Clarias anguillaris,* gills, liver, muscles.

INTRODUCTION

Rivers and lakes are excessively contaminated with heavy metals, hydrocarbons, pesticides and organic metals released from domestic, industrial mining and agricultural effluents. The most important ingredient of these pollutants is the chemical substances that stay longer and become toxic in water columns. Within them, heavy metals have positive effects on the vital activities of several organisms and impairment in food chain by affecting biological activities of the living organisms in ecosystem (Gundogu and Erden, 2008).

Heavy metals have a great ecological consideration due to their toxicity and accumulation behavior (Purves, 1985). Fishes are located at the end of aquatic food chain

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and may accumulate metals even in water in which they are below the limit of detection in routine water sample (Mason, 1987).

The contamination of fresh water with a wide range of pollutants has become a matter of great concern over the last few decades, not only because of the threats to public water supplies but also the damages caused to the aquatic life (Canli et al., 1998). The natural aquatic systems may extensively be contaminated with heavy metals released from domestic and industrial wastes, agricultural activities, physical and chemical weathering of rocks, soil erosions, as well as sewage disposal and atmospheric deposition (Alloway and Ayres, 1993).

Aquatic organisms such as fish are capable of accumulating heavy metals in their living cells to concentrations much higher than those present in water, sediment and microflora in their environment (Forstner and Wittmann, 1981). The presence of heavy metals in rivers, Lake or any aquatic environment can change both aquatic species diversity and ecosystems due to their toxicity and accumulative behavior (Heath, 1995).

The increasing importance of fish as a source of protein and the interest in understanding the accumulation of heavy metals at the trophic levels of food chain, extend the focus towards fish (Deb and Santra, 1997). Fish is a valuable and cheap food item, and also a source of protein to man. Concern about heavy-metal contamination of fish has been motivated largely by adverse effects on humans, given that consumption of fish is the primary route of heavy metal exposure (Nsikak et al., 2007).

Heavy metals in fishes increase with the increment of metal levels in water, sediment and fish food organism (Arvind, 2002). Heavy metals like Cu, Co, Zn, Fe and Mn at low concentrations are essential metals for enzymatic activity and many biological processes. Other metals such as Cd, Pb, and Hg have no known essential role in the body of living organisms, and are toxic even at low concentrations. The essential metals also become toxic at high concentration (Bryan, 1976; Alloway and Ayres, 1993). Heavy metal contamination may have devastating effects on the ecological balance of the recipient environment and a diversity of aquatic organisms (Farombi et al., 2007; Vosyliene and Jankaite, 2006; Ashraj, 2005).

The toxic effects of heavy metals have been reviewed, including bioaccumulation (Waqar, 2006; Adami et al., 2002; Rasmussen and Anderson, 2000; Aucoin et al., 1999). The organisms developed a protective defense against the deleterious effects of essential and inessential heavy metals and other xenobiotics that produce degenerative changes like oxidative stress in the body (Abou EL-Naga et al., 2005; Filipovic and Raspor, 2003).

The present study was conducted to focus light on the levels of heavy metals (Fe, Cu, Pb, Cd and Zn) concentration in water, sediment and some tissues of tilapia fish (*Oreochromis niloticus*) and cat fish (*Clarias angullaris*) in Rosetta branch of River Nile, in Egypt.

MATERIALS AND METHODS

Area of study

Rosetta branch of River Nile begins from El-Kanater Barrage in the south and ends at Rosetta Esturay in the Mediterranean Sea (Figure 1). Many sources of pollutants are poured into Rosetta branch of River Nile, site I: El-Kanater El-Khairya, site II: El-Rahawy drain, the cross section area of the drain, more than 400.000 m^3 daily including 398.000 m^3 liquid sewage and 2.000 m^3 of sludge from Giza governate pours into the branch at El-Rahawy. Site III: Tamaly, this drain receives untreated domestic sewage from El-Monofya province and villages. Site IV: industrial effluents of El-Malyia Superphosphate Company, salt and Soda Company and Pesticides Company at Kafer El-zyat City which pour directly into the branch without treatments.

Samples

Fish (*O. niloticus* and *C. anguillaris*), water and sediment samples were collected seasonally from the four mentioned sites at Rosetta branch of the River Nile of Egypt during spring, summer, autumn and winter 2010.

Fish samples

O. niloticus and *C. angullaris* samples were collected monthly, place in ice- box, transported to the laboratory of Foods, Faculty of Home Economics, Helwan University and finally frozen at -20°C until analysis. Before analysis, each fish was weighed, measured and dissected. One to three gram (1 to 3 g) from liver, gills and epaxial muscle were put in 25 ml conical flasks.

Digestion of tissues was carried out by wet method (Mason and Barak, 1990; APHA, 1990). In which 5 ml of concentrated nitric acid was added and reaction mixture was maintained on a hot plate at 70°C. After digestion the samples were filtered in 25 ml volumetric flasks and completed to the mark by distilled water. The samples were stored in glass bottles until metals analysis. The digested samples were determined using atomic absorption (Perkin Elemer Model 2380) and results were expressed in mg/L in water, sediment (ppm/kg) and fish tissues (mg/kg/dry.wt).

For each element of heavy metals 96 samples (in triplicate) were obtained from the two kinds of fish (*O. niloticus* and *C. angullaris*), from the three organs (liver, gills and muscles) at four stations (I, II, III and IV) and for the four seasons and its concentration was assessed (mg/kg/dry.wt).

Water samples

Water samples was collected at 0.5 m below the water surface, filtered in pre-cleaned liter bottle acidified by adding 5 ml of concentrated nitric acid (HNO_3) and kept for analysis. For determination of each element of heavy metals, 16 samples (in triplicate) were obtained from four stations (I, II, III and IV), for the four seasons and its concentration assessed (mg/L).

Sediment samples

Sediment samples were collected during summer season in plastic bags transported to laboratory air dried at room temperature, ground, sieved and digested with concentrated nitric acid and

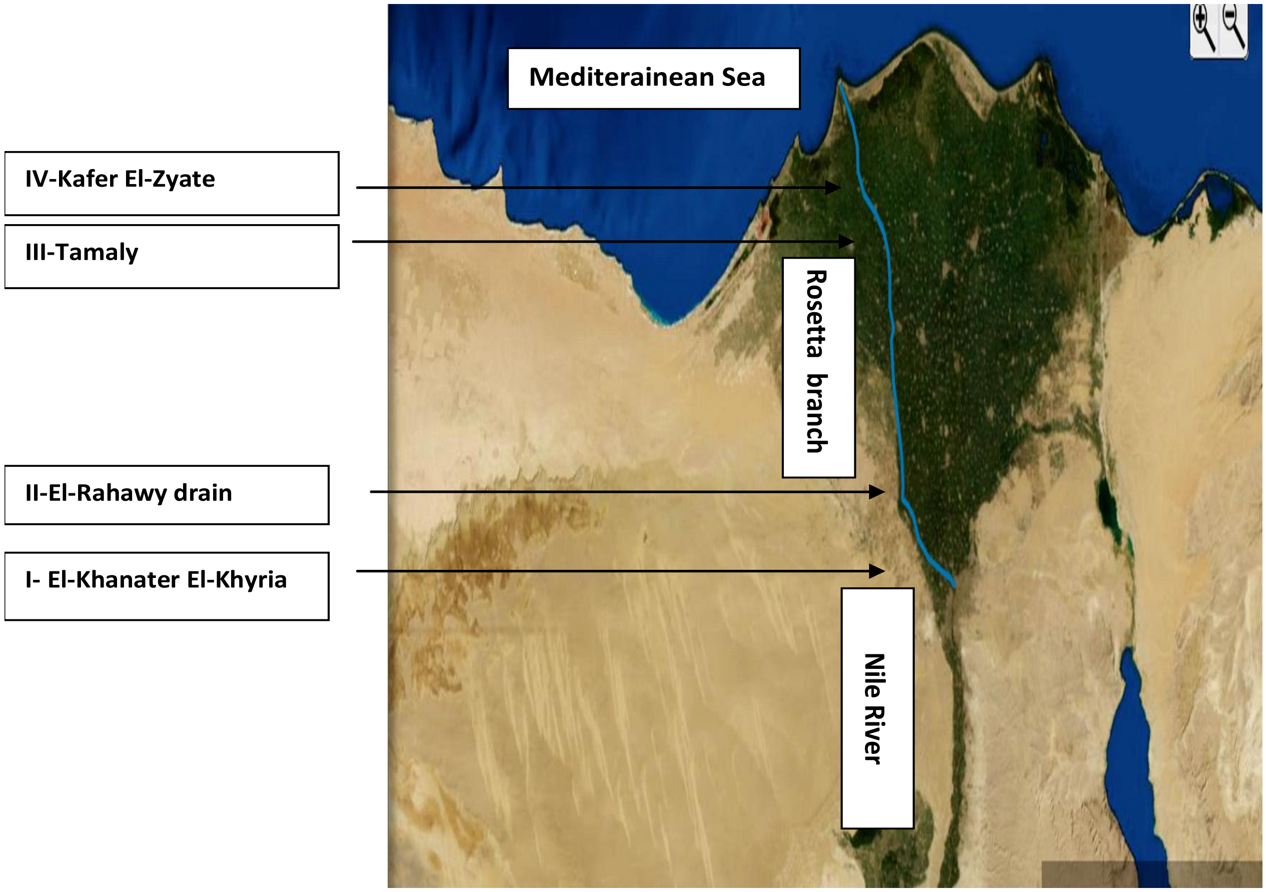

Figure 1. Map showing sampling station.

perchloric acid (2:1) using a hot plate at 70°C.

After complete digestion, the solution was filtered using an acid–resistant filter paper in 25 ml volumetric flask and completed to the mark by distilled water. The solution was kept in a tight-stoppard bottle until analysis. For determination of each element of heavy metals, 16 samples (in triplicate) were obtained from four stations (I, II, III and IV), for the four seasons and concentration was (ppm/kg) assessed.

Bioaccumulation factor (BAF)

The ratio of the contaminant in an organism to the concentration in the ambient environment at a steady state, where the organism can take in the contaminant through ingestion with its food as well as through direct content (U.S. Environmental Protection Agency, 2010). Bioaccumulation factor was calculated according to Klavins et al. (1998) as follow:

BAF = M-tissue/M-sed

Where, M-tissue is the metal concentration in soft tissue and M-sed is the concentration in sediment.

Assessing the contamination of water

In order to assess the contamination of water, the concentration of heavy metals of Fe, Cu, Pb, Cd and Zn compared with World Health Organization (WHO) standard for drinking water were in almost all locations. An index for assessing the water contamination was applied. The index used is metal index (MI). The MI index was preliminarily defined by Tamasi and Cini (2004). This index can be expressed as the following equation:

$$\text{Metal Index (MI)} = \Sigma\, [Ci/(MAC)i]$$

Where, MI is the metal index; C is the concentration of each element solution; MAC is the maximum of allowed concentration for each element, and subscript i is the ith sample. The higher the concentration of metal compared to its respective MAC value, the worse the quality of the water. If the concentration of certain element is higher than respective value (that is, MI > 1), the water cannot be used according to this index.

RESULTS

Water

Results in Table 1 presents the maximum mean concentrations value of Fe, Pb, Cu and Zn in water sample which were 0.81 ± 0.02, 0.62 ± 0.02, 0.60 ± 0.08, 0.51 ± 0.02 mg/L, respectively at station IV, where Cd was 0.061 ± 0.002 mg/L at station III. The lowest mean

Table 1. Seasonal variation of heavy metals concentrations (mg/L) in water from from Rosetta Branch of the River Nile of Egypt.

Metal	Station	Spring (M±SD)	Summer (M±SD)	Autumn (M±SD)	Winter (M±SD)	All (M±SD)	MI
Fe**	I	0.51±0.1	0.50±0.01	0.58±0.02	0.57±0.01	0.54±0.04	1.8
	II	0.56±0.01	0.48±0.1	0.56±0.03	0.58±0.03	0.55±0.05	1.833
	III	0.59±0.2	0.55±0.2	0.40±0.009	0.52±0.00	0.52±0.08	1.733
	IV	0.89±0.1	0.80±0.06	0.78±0.04	0.77±0.01	0.81±0.02	2.7
Cu	I	ND*	ND*	ND*	ND*	ND*	ND*
	II	0.40±0.03	0.48±0.01	0.51±0.03	0.49±0.01	0.49±0.05	0.245
	III	0.62±0.01	0.50±0.03	0.50±0.09	0.51±0.07	0.53± 0.07	0.265
	IV	0.51±0.08	0.66±0.04	0.60±0.01	0.62±0.04	0.60±0.08	0.3
Pb	I	0.14±0.03	0.15±0.04	0.16±0.03	0.12±0.03	0.14± 0.01	14
	II	0.50±0.01	0.48±0.02	0.45±0.07	0.41±0.04	0.46±0.03	46
	III	0.43±0.01	0.40±0.01	0.42±0.02	0.45±0.1	0.42±0.01	42
	IV	0.58±0.03	0.60±0.08	0.62±0.08	0.66±0.08	0.62±0.02	62
Cd	I	ND*	ND*	ND*	ND*	ND*	ND*
	II	ND*	ND*	ND*	ND*	ND*	ND*
	III	0.060±0.001	0.065±0.08	0.061±0.01	0.058±0.008	0.061±0.002	20.333
	IV	0.036±0.003	0.050±0.001	0.052±0.003	0.048±0.007	0.046±0.008	15.333
Zn	I	0.045±0.001	0.040±0.02	0.48±0.002	0.40±0.003	0.24±0.25	0.08
	II	0.25±0.003	0.20±0.03	0.23±0.001	0.18±0.001	0.22±0.025	0.07
	III	0.18±0.01	0.16±0.08	0.18±0.008	0.15±0.008	0.16±0.011	0.05
	IV	0.52±0.06	0.50±0.01	0.53±0.001	0.48±0.004	0.51±0.02	0.17

MI, Metal index = Σ [Ci/ (MAC)i]. WHO lists guideline values (GVs) for drinking waters (2008). WHO GV (mg/L): Fe: 0.3 - Cu: 2.0 - Pb: 0.01 - Cd: 0.003 - Zn: 3.0. **WHO has not fixed a health-based GV for iron, but notes that drinking water containing higher levels than those listed above may be unacceptable to consumers for aesthetic reasons. *ND not determined, I = EL-Qunater Elkhairya (Agricultural drain), II = Tamaly (Sewage and agricultural drain). III = El-Bahawy (Sewage drain). IV = Kafer El-Zyat.

concentration value of Fe was 0.52 ± 0.08 mg/L at station III, Cu was 0.49 ± 0.05 mg/L at II, Pb was 0.14 ± 0.01 mg/L at station I, Cd was 0.046 ± 0.008 mg/L at station IV and Zn were 0.16 ± 0.011 mg/L at station III. The order of heavy metal accumulation in water was Fe > Pb > Cu > Zn > Cd.

The results indicated that the Fe was maximally accumulated in water whereas Cd got the least concentration. Also noted that the greatest values of heavy metal in water were found at station IV except Cd which was found at station III. Maximum Metal Index (MI) was recorded at station IV for Fe, Cu, Pb and Zn were 2.7, 0.3, 62 and 0.17, mg/L respectively and for Cd was 20.333 mg/L at station III.

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Sediments

Results presented in Table 2 indicate that the average of maximum mean concentration value of Fe, Zn, Cu, Pb and Cd in sediment were 115.63 ± 9.51, 102.15 ± 34.04, 94 ± 16.18, 51.36 ± 7.90, and 33.45 ± 3.68 ppm, respectively. The minimum mean concentration of Fe, Zn, Pb and Cd was 101.38 ± 7.2, 58.587 ± 4.3, 41.22 ± 3.33 and 28.66 ± 3.11 ppm, respectively at station III and for Cu was 71.33 ± 9.76 ppm at station I. The descending order of heavy metals accumulation in sediment was Fe > Zn > Cu > Pb > Cd. The data indicate that the Fe was maximally accumulated in sediment whereas Cd got the least concentration.

Fishes

In the obtained results (Table 3) indicated, the mean concentration value (mg/kg/wt) of Fe in various organs (liver, gills, and muscles) of two kinds of fish C*. anguillaris and O. niloticus* at four stations is as follows: In the liver

Table 2. Heavy metals concentrations (ppm) in sediments from Rosetta branch of River Nile of Egypt.

Metal	Station			
	I (Mean±SD)	II (Mean±SD)	III (Mean±SD)	IV (Mean±SD)
Fe	112.42 ± 8.2	120.33 ± 8.9	101.38 ± 7.2	128.38 ± 6.60
Cu	71.33 ± 9.76	103.68 ± 5.22	88.31 ± 1.2	112.68 ± 0.77
Pb	50.99 ± 5.35	56.88 ± 4.89	41.22 ± 3.33	56.36 ± 2.56
Cd	30.22 ± 3.82	35.68 ± 4.42	28.66 ± 3.11	39.22 ± 4.45
Zn	92.68 ± 0.37	126.68 ± 0.37	58.587 ± 4.3	130.67 ± 5.10

I = EL-Khanater El-Khairya (Agricultural drain), II = Tamaly (Sewage and agricultural drain), III = El-Bahawy (Sewage drain), IV = Kafer El-Zyat.

of C*. anguillaris* Fe recorded its highest mean concentration at station IV, 69.07 ± 1.57 and in *O .niloticus* was 21.84 ± 3.39 mg/kg/wt at station II. The lowest mean concentration value of Fe in liver of *C. anguillaris* was 35.22 ± 0.55 and in *O. niloticus* was 16.03 ± 0.49 mg/kg/wt at station III. Also at station IV, the gills of *C. anguillaris* recorded the highest mean concentration value of Fe 48.87 ± 1.0 and in *O. niloticus* was 16.63 ± 0.94 mg/kg/wt at station II. The lowest mean concentration of Fe in the gills of *C. anguillaris* and *O. niloticus* were 32.27 ± 1.79 and 9.58 ± 0.92 mg/kg/wt, respectively at station I.

In muscles of *C. anguillaris* and *O. niloticust* the highest concentration of Fe recorded was 27.4 ± 1.07 and 9.22 ± 1.13 mg/kg/wt at station IV respectively, the lowest mean concentration Fe in muscles of *C. anguillaris and O. niloticus* was 10.45 ± 0.55 and 2.85 ± 0.90 mg/kg/wt at station I, respectively.

The maximum BAF concentration of Fe in the liver of *C. anguillaris* and *O. niloticus* were 0.5380 and 0.1815 mg/kg/wt. at station IV and II, respectively, the minimum BAF concentration for *C. anguillaris* and *O. niloticus* were 0.3474 and 0.1462 mg/kg/wt at station III and IV, respectively. In gills of *C. anguillaris and O. niloticus,* maximum BAF concentration of iron was 0.4456 and 0.1382 mg/kg/wt at station III and II, respectively, but the lowest concentration was 0.2870 and 0.0852 mg/kg/wt at station I, respectively. In muscles of *C. anguillaris* and *O. niloticus,* the maximum BAF was 0.2134 and 0.0739 mg/kg/wt at station IV, III, respectively; whilst the lowest BAF was 0.0929 and 0.0253 mg/kg/wt at station IV for the two kinds of fish's *C. anguillaris* and *O. niloticus,* respectively.

Results in Table 4 show comparison between the two kinds of fish tissues of *C. anguillaris* and *O. niloticus* in its content (mg/kg/wt) of Cu at four stations. The highest mean concentration of Cu in the liver of C*. anguillaris* and *O. niloticus* were 22.87 ± 0.45 and 18.37 ± 0.47 mg/kg/wt recorded at station IV.

The lowest mean concentration of Cu in the liver of *C. anguillaris and O. niloticus* was 5.05 ± 0.21 and 2.46 ± 0.13 mg/kg/wt respectively at station I. The highest mean concentration of Cu in gills of *C. anguillaris* and *O. niloticus* recorded was 6.52 ± 0.32 and 4.01 ± 0.1 mg/kg/wt at station III and IV respectively, the lowest mean concentration of Cu in the gills of *C. anguillaris and O. niloticus* was 2.05 ± 0.1 and 1.27 ± 0.14 mg/kg/wt, respectively at station I.

In muscles of *C. anguillaris* the highest concentration of Cu recorded was 0.02 ± 0.002 mg/kg/wt at station IV where the lowest mean of concentration was 0.001 ± 0.001 mg/kg/wt at the same station. Cu was not detected in any concentration in the muscles of *O. niloticus.* The maximum mean BAF concentration of Cu in liver of *C. anguillaris* and *O. niloticus* were 0.2023 and 0.1630 mg/kg/wt respectively; at station IV, the minimum mean BAF concentration for *C. anguillaris and O. niloticus* was0.0489 and 0.0345 mg/kg/wt at station II and I, respectively.

In gills of *C. anguillaris and O. niloticus,* maximum mean concentration BAF of Cu at station III was 0.0738 and 0.0438 mg/kg/wt, respectively but the lowest mean concentration was 0.02873 and 0.0178 mg/kg/wt, respectively at station I.

In muscles of *C. anguillaris* the maximum mean BAF concentration of Cu was 0.0002 at station IV and the lowest mean concentration of BAF was 0.00001 mg/kg/wt at station I. No data was determined for *O. niloticus.*

Results in Table 5 determined the mean concentration (mg/kg/wt) of Pb in various organs (liver, gills, and muscles) for the two kinds of fish *O. niloticus* and *C. anguillaris* at four stations. The highest mean concentration of Pb in the liver of C*. anguillaris* and *O. niloticus* were 47.77 ± 1.40 and 33.52 ± 0.49 mg/kg/wt respectively recorded at station IV. The lowest mean concentration of Pb in liver of *C. anguillaris and O. niloticus* was 15.7 ± 0.2 and 13.75 ± 1.70 mg/kg/wt, respectively at station I.

Also, at station IV, the gills of *C .anguillaris* recorded that the highest mean concentration of Pb was 25.1 ± 0.64 and in *O. niloticus* was 18 ± 0.15 mg/kg/wt, the lowest mean concentration of Pb in the gills of *C. anguillaris and O. niloticus* was 10.3 ± 0.52 and 8.15 ± 0.23 mg/kg/wt, respectively at station I. In muscles of *O. niloticus the* highest Pb concentration was 10.37 ± 0.35 mg/kg/wt at station IV and was 9.75 ± 0.21 mg/ kg/ wt. in

Table 3. Seasonal variation of iron (Fe) concentration (mg/kg) in tissues of *O. niloticus* and *C. anguillaris* from Rosetta Branch of the River Nile in Egypt (mean ±SD).

Site	Organ	*O.niloticus*					*C.anguillaris*				
		Spring (M±SD)	Summer (M±SD)	Autumn (M±SD)	Winter (M±SD)	All (M±SD)	Spring (M±SD)	Summer (M±SD)	Autumn (M±SD)	Winter (M±SD)	All (M±SD)
I	Liver	19.88 ±8 .10	20.82 ± 6.20	17.75 ± 7.2	16.22 ± 3.2	18.66±1.57	41.2 ± 1.2	45.9 ± 3.5	40 ± 3.1	39.1 ± 1.1	41.55±3.11
	BAF	0.1768	0.18	0.16	0.14	0.16	0.3665	0.4082	0.3558	0.3478	0.3696
	Gills	10.11 ± 3.50	11.18 ± 1.1	9.33 ± 1.2	7.72 ± 1.10	9.58 ± 0.92	32.1 ± 1.9	35.1 ± 3.6	31.9 ± 2.6	30 ± 1.8	32.27±1.79
	BAF	0.0899	0.0994	0.08299	0.0686	0.0852	0.2855	0.31222	0.2837	0.2668	0.2870
	Muscles	4.10 ± 1.12	3.1 ± 0.08	2.3 ± 0.08	1.9 ± 0.02	2.85±0.90	10.2 ± 3.1	11.2 ± 1.6	10.3 ± 0.9	10.1 ± 1.1	10.45±0.55
	BAF	0.0364	0.0275	0.0204	0.0169	0.0253	0.0907	0.0996	0.0916	0.0898	0.0929
II	Liver	24.55 ± 7.68	24.22 ± 4.3	18.52 ± 2.3	20.1 ± 1.10	21.84±3.39	52.1± 2.2	55.1 ± 3.1	53.10 ± 4.1	49.1 ± 0.5	52.35±1.52
	BAF	0.2040	0.2012	0.1539	0.1670	0.1815	0.4329	0.4579	0.4412	0.4080	0.4350
	Gills	16.22 ± 1.20	17.11 ± 1.10	18.10 ± 0.08	15.1 ± 0.09	16.63±.94	48.6 ± 1.9	49.2 ± 4.1	48 ± 1.9	47.2 ± 1.5	48.3±0.50
	BAF	0.1347	0.1421	0.1504	0.1254	0.1382	0.4038	0.4088	0.3989	0.3922	0.4013
	Muscles	8.11 ± 1.2	9.30 ± 0.09	7.12 ± 1.9	8.12 ± 1.2	8.16±1.09	16.1 ± 1.1	16.6 ± 0.5	15.8 ± 1.0	14.7 ± 1.1	15.8±0.40
	BAF	0.0674	0.0772	0.0592	0.0675	0.0678	0.1338	0.1379	0.1313	0.1222	0.1313
III	Liver	16.12 ± 3.15	17.10 ± 1.90	16.60 ± 2.2	14.33 ± 1.08	16.03±0.49	35.9 ± 1.9	36 ± 3.2	35 ± 4.7	34.1 ± 0.9	35.22±0.55
	BAF	0.1590	0.1687	0.1637	0.1413	0.1581	0.3541	0.3550	0.3452	0.3363	0.3474
	Gills	12.19 ± 1.01	13.10 ± 0.09	10.1 ± 0.10	8.10 ± 0.05	10.87±1.54	45.1 ± 5.2	47.1 ± 1.2	44.7 ± 1.3	43.8 ± 0.8	45.17±1.28
	BAF	0.1202	0.1292	0.0996	0.0798	0.1072	0.4449	0.4646	0.4409	0.4320	0.4456
	Muscles	7.10 ± 0.06	8.32 ± 1.6	8 ± 0.09	6.6 ± 0.055	7.50±0.63	15.2 ± 3.1	16.1 ± 1.1	15.8 ± 1.5	15.1 ± 0.3	15.55±0.45
	BAF	0.0700	0.082	0.0789	0.0651	0.0739	0.1499	0.1588	0.1558	0.1489	0.1534
IV	Liver	23.10 ± 2.90	25.10 ± 1.8	25.6 ± 1.7	21 ± 1.9	18.78±1.32	70.1 ± 4.2	71.2 ± 5.2	68.1 ± 3.1	66.9 ± 0.9	69.07±1.57
	BAF	0.1799	0.1955	0.1994	0.1635	0.1462	0.5460	0.5546	0.530	0.5211	0.5380
	Gills	17.18 ± 1.9	18.20 ± 2.2	15.6 ± 2.60	14.12 ± 2.88	16.16±1.54	48.1 ± 4.2	50.1 ± 3.9	49.1 ± 1.3	48.2 ± 1.0	48.87±1.0
	BAF	0.1338	0.1417	0.1215	0.1099	0.1259	0.3746	0.3902	0.3824	0.3754	0.3806
	Muscles	9.10 ± 0.01	10.9 ± 1.2	8.8 ± 0.8	8.1 ± 0.36	9.22±1.13	28.8 ± 3.1	26.8 ± 1.0	27.1 ± 0.7	26.9 ± 0.9	27.4±1.07
	BAF	0.0708	0.0849	0.0685	0.0631	0.0718	0.2243	0.2087	0.2111	0.2095	0.2134

BAF = M_Tissue / M_sed. I = EL-Khanater El-Khairya (Agricultural drain). II = Tamaly (Sewage and agricultural drain). III = El-Bahawy (Sewage drain). IV = Kafer El-Zyate.

C. anguillaris at station III, where the lowest mean of concentration was 3.45 ± 0.06 and 2.36 ± 0.17 mg/kg/wt for *O. niloticus and* C. *anguillaris* at station II, and I, respectively.

The maximum mean concentration of BAF for Pb in liver of *C. anguillaris* and *O. niloticus* were 0.8476 and 0.5947 mg/kg/wt, respectively at station IV; the minimum mean concentration of BAF for *C. anguillaris* and *O. niloticus* were 0.3079 and 0.2631 mg/kg/wt at station I and II, respectively.

In gills of *C. anguillaris* and *O. niloticus*, the

Table 4. Seasonal variation of copper (Cu) concentration (mg/kg) in tissues of O. niloticus and C. anguillaris from Rosetta branch of the River Nile in Egypt (mean ±SD).

Site	Organ	*O.niloticus*					*C.anguillaris*				
		Spring (M±SD)	Summer (M±SD)	Autumn (M±SD)	Winter (M±SD)	All (M±SD)	Spring (M±SD)	Summer (M±SD)	Autumn (M±SD)	Winter (M±SD)	All (M±SD)
I	Liver	2.6 ± 0.142	3.10 ± 1.60	2.51 ± 1.3	2.35 ± 0.92	2.46±0.13	5.2 ± 1.2	5.3 ± 1.2	4.9 ± 1.12	4.8 ± 1.30	5.05±0.21
	BAF	0.0365	0.0434	0.0352	0.0329	0.0345	0.0729	0.0743	0.0687	0.0673	0.0708
	Gills	1.1± 0.2	1.31 ± 0.20	1.368 ± 0.80	1.30 ± 1.0	1.27±0.14	2.1 ± 0.08	2.2 ± 2.0	2.0 ± 0.06	1.9 ± 0.008	2.05±0.1
	BAF	0.0154	0.0184	0.0191	0.0182	0.0178	0.0294	0.0308	0.0280	0.0266	0.02873
	Muscles	ND*	ND*	ND*	ND*	ND*	0.001± 0.001	ND*	ND*	ND*	0.001±0.001
	BAF	-	-	-	-	-	0.00001	-	-	-	0.00001
II	Liver	5.8 ± 0.7	5.9 ± 0.8	5.3 ± 0.7	5.1 ± 0.42	5.52±0.32	5.1 ± 0.5	5.4 ± 1.01	5.0 ± 1.02	4.8 ±1.1	5.07±0.21
	BAF	0.0559	0.0569	0.0511	0.0492	0.0532	0.0492	0.0521	0.0482	0.0463	0.0489
	Gills	3.2 ± 0.15	3.4 ± 0.12	3.1 ± 0.08	2.9 ± 1.0	3.15±0.15	4.10 ± 0.3	4.3 ± 0.1	4.0 ± 0.001	3.5 ± 1.0	3.97±0.15
	BAF	0.03086	0.0328	0.0298	0.0280	0.0304	0.0395	0.0415	0.03858	0.0338	0.0383
	Muscles	ND*	ND*	ND*	ND*	ND*	0.003 ± 0.001	ND*	ND*	ND*	0.003 ± 0.001
	BAF	-	-	-	-	-	0.00003	-	-	-	0.00003
III	Liver	13.0±1.2	12.1 ± 1.0	12.8 ± 0.9	11.1 ± 1.30	12.25±0.47	14.3 ± 1.2	15.3 ± 2.2	15.1 ± 1.3	14.0 ± 1.2	14.67±0.53
	BAF	0.1472	0.1370	0.1449	0.1257	0.1386	0.1619	0.1733	0.1799	0.1585	0.1661
	Gills	4.1±0.3	4.2 ± 0.11	3.91 ± 0.08	3.3 ± 0.09	3.87±0.15	6.8 ± 0.1	6.9 ± 0.01	6.3 ± 0.03	6.1 ± 0.01	6.52±0.32
	BAF	0.0464	0.0476	0.0443	0.0374	0.0438	0.0770	0.0781	0.0713	0.0690	0.0738
	Muscles	ND*	ND*	ND*	ND*	ND*	0.004± 00.2	ND*	ND*	ND*	0.004± 00.2
	BAF	-	-	-	-	-	0.00004	-	-	-	0.00004
IV	Liver	18.8 ± 3.2	19 ± 1.8	18.1 ± 1.3	17.6 ± 0.08	18.37±0.47	22.8 ± 0.4	23.7 ± 0.5	23.1 ± 0.8	21.9 ± 0.8	22.87±0.45
	BAF	0.1668	0.1686	0.1606	0.1562	0.1630	0.2023	0.2103	0.2050	0.1944	0.2023
	Gills	4 ± 0.8	4.1 ± 0.50	4.2 ± 0.05	3.77±1.600	4.01±0.1	3.9 ± 0.08	4.0 ± 0.09	3.8 ± 0.02	3.7 ± 0.3	3.85±0.1
	BAF	0.0354	0.0364	0.0364	0.0335	0.0355	0.0346	0.0354	0.0337	0.0328	0.0342
	Muscles	ND*	ND*	ND*	ND*	ND*	0.02 ± 0.002	ND*	ND*	ND*	0.02 ± 0.002
	BAF	-	-	-	-	-	0.0002	-	-	-	0.0002

BAF = M_tissue / M_sed. I = EL-Kanater El-Khairya (Agricultural drain). II = Tamaly (Sewage and agricultural drain). III = El-Bahawy (Sewage drain). IV = Kafer El-Zyate. *ND = Not Determined.
Upper level of intake of copper in food for human consumption according to WHO (2008) = 10 mg/day.

maximum mean concentration of BAF for Pb was 0.4454 and 0.3193 mg/kg/wt, respectively at station IV, but the lowest concentration was 0.2020 and 0.1598 mg/kg/wt, respectively at station I.

In the muscles of *O. niloticus* and *C. anguillaris,* the maximum mean of BAF concentration for Pb was 10.37±0.35 and 9.75±0.21 mg/kg/wt at station IV and III, respectively; whilst the lowest BAF concentration was 0.0606 and 0.0463 mg/kg/wt at station I and II, respectively.

Results in Table 6 showed the mean concentra-

Table 5. Seasonal variation of Lead (Pb) concentration (mg/kg) in tissues of *O. niloticus* and *C. anguillaris* from Rosetta branch of the River Nile in Egypt (Mean±SD).

Site	Organ	*O. niloticus*					*C. anguillaris*				
		Spring (M±SD)	Summer (M±SD)	Autumn (M±SD)	Winter (M±SD)	All (M±SD)	Spring (M±SD)	Summer (M±SD)	Autumn (M±SD)	Winter (M±SD)	All (M±SD)
I	Liver	11.8±1.8	15.1±1.01	14.2±0.9	13.9 ± 0.7	13.75±1.70	15.9 ± 0.82	16.1 ± 1.3	15.7 ± 1.2	15.1± 2.2	15.7±0.2
	BAF	0.2314	0.2961	0.2784	0.2726	0.2696	0.3118	0.3157	0.3079	0.2961	0.3079
	Gills	8.1 ± 1.2	8.5 ± 0.9	8.1 ± 0.8	7.9 ± 0.1	8.15±0.23	10.1 ± 0.3	11 ± 1.2	10.1 ± 2.3	10 ± 1.3	10.3±0.52
	BAF	0.1588	0.1667	0.1588	0.1549	0.1598	0.1980	0.2157	0.1980	0.1980	0.2020
	Muscles	4 ± 0.1	4.1 ± 0.2	3.9 ± 0.3	3.7 ± 0.2	3.92±0.1	2.25 ±0.08	2.6 ± 0.09	2.4 ± 0.9	2.2 ± 0.09	2.36±0.17
	BAF	0.0784	0.0804	0.0764	0.0726	0.0768	0.0441	0.0510	0.0471	0.0431	0.0463
II	Liver	15.8 ± 0.8	15.1± 0.7	14.7 ± 0.6	14.3± 0.8	14.97±0.55	19.1 ± 0.6	20.1 ± 0.7	18.8 ± 1.2	18.2 ± 1.6	19.5±0.68
	BAF	0.2777	0.2654	0.2584	0.2514	0.2631	0.3358	0.3533	0.3305	0.3110	0.3428
	Gills	10.2 ± 0.3	10.3 ± 0.2	9.9 ± 0.3	9.8 ± 1.0	10.05±0.21	13.1 ± 2.3	14.3 ± 0.88	13.6 ± 0.9	12.6 ± 1.2	13.4±0.60
	BAF	0.1793	0.1811	0.1741	0.1720	0.1767	0.2301	0.2514	0.2391	0.2268	0.2356
	Muscles	3.5 ± 1.1	3.6 ± 0.9	3.5 ± 0.7	3.2 ± 0.7	3.45±0.06	5.5 ± 1.3	5.8 ± 0.08	5.6 ± 0.7	5.1 ± 1.3	5.5±0.15
	BAF	0.0615	0.0633	0.0615	0.0563	0.0606	0.0967	0.1019	0.0985	0.0897	0.0967
III	Liver	20.1 ± 0.8	19.9 ± 0.6	19.1 ± 0.9	19 ± 0.08	19.52±0.53	35.1 ± 2.1	34.1 ± 3.2	33.9 ± 1.8	32.8 ± 1.2	33.97±0.6
	BAF	0.4876	0.4827	0.4634	0.4609	0.4736	0.8515	0.8273	0.8224	0.7957	0.8241
	Gills	11.8 ± 1.6	11.9 ± 1.2	10.8 ± 0.8	10.3 ± 1.0	11.2±0.61	14.5 ± 0.8	14.8 ± 0.9	14.2 ± 0.7	13.9 ± 1.4	14.35±0.3
	BAF	0.2862	0.2887	0.2620	0.2498	0.2717	0.3517	0.3590	0.3444	0.3372	0.3461
	Muscles	6.1 ± 1.5	6.3 ± 1.2	5.9 ± 0.9	5.8 ± 0.8	6.03±0.2	10.3 ± 1.6	10 ± 1.8	9.9 ± 1.7	9.7 ± 1.2	9.75±0.21
	BAF	0.1480	0.1528	0.1431	0.1407	0.1462	0.2499	0.2426	0.2401	0.2353	0.2365
IV	Liver	33. 2 ± o.5	34.1 ± 0.4	34 ± 1.2	32.8 ± 1.2	33.52±0.49	49.1 ± 1.6	47.9 ± 2.3	46.3 ± 1.2	47.8 ± 2.5	47.77±1.40
	BAF	0.5891	0.6050	0.6032	0.5820	0.5947	0.8711	0.8498	0.8215	0.8481	0.8476
	Gills	18.1 ± 0.8	18.2 ± 0.4	17.9 ± 1.3	17.8 ± 0.6	18±0.15	25.1 ± 1.3	26.1 ± 2.4	24.9 ± 2.1	24.3 ± 1.9	25.1±0.64
	BAF	0.3211	0.3229	0.3176	0.3158	0.3193	0.4453	0.4630	0.4418	0.4311	0.4454
	Muscles	10.1 ± 0.9	10.8 ± 0.3	10.4 ± 0.4	10.2 ± 0.6	10.37±0.35	9.1 ± 0.23	9 ± 0.25	8.7 ± 1.0	8.8 ± 0.99	8.9±0.21
	BAF	0.1792	0.1916	0.1845	0.1809	0.1840	0.1615	0.1597	0.1544	0.1561	0.1579

I = BAF = M_tissue / M_sed. EL-Kanater El-Khairya (Agricultural drain), II = Tamaly (Sewage and agricultural drain)' III = El-Bahawy, (Sewage drain), IV = Kafer El-Zyate. Upper level of intake of lead in food for human consumption according to WHO (2008) = 0.25 mg/day.

tion (mg/kg/wt) of Cd in various organs (liver, gills, and muscles) of the two kinds of fish *O. niloticus* and *C. anguillaris* at four stations. The liver of C. *anguillaris* recorded the highest mean concentration of Cd in station IV and was 8.13 ± 0.1 and in *O. niloticus* was 6.07 ± 0.16 mg/kg/wt at station III. The lowest mean concentration ofCd in liver of *C. anguillaris* was 4.1 ± 0.1 at station II and 2.1 ± 0.2 mg/kg/wt for *O. niloticus* at station I, respectively.

Also, at station IV, the highest mean concentration of Cd recorded in the gills of *C.*

Table 6. Seasonal variation of Cadmium (Cd) concentration (mg/kg) in tissues of *O. niloticus* and C. *anguillaris* from Rosetta branch of the River Nile in Egypt (Mean ±SD).

Site	Organ	*O.niloticus*					*C.anguillaris*				
		Spring (M±SD)	Summer (M±SD)	Autumn (M±SD)	Winter (M±SD)	All (M±SD)	Spring (M±SD)	Summer (M±SD)	Autumn (M±SD)	Winter (M±SD)	All (M±SD)
I	Liver	2.1 ± 0.6	2.3 ± 0.08	1.9 ± 0.01	2.1 ± 0.02	2.1±0.2	5.1 ± 0.3	5.3 ± 0.7	5.0 ± 0.8	4.9 ± 1.0	5.07±0.15
	BAF	0.069	0.0761	0.0628	0.0695	0.0695	0.1687	0.1754	0.1654	0.1621	0.1677
	Gills	1.5 ± 0.3	1.6 ± 0.08	1.4 ± 0.02	1.3 ± 0.1	1.45±0.1	8.8 ± 1.2	9.1 ± 1.4	9.2 ± 1.5	9.0 ± 1.07	9.03±0.21
	BAF	0.0496	0.05294	0.0463	0.0430	0.0479	0.2912	0.3011	0.3044	0.2978	0.2988
	Muscles	ND	1.0 ± 0.2	0.9 ± 0.15	0.8 ± 0.01	0.9±0.07	1 ± 0.08	1.1 ± 0.09	1.1 ± 0.08	0.98 ± 0.07	1.045±0.06
	BAF	-	0.0331	0.0298	0.0265	0.0298	0.0331	0.0364	0.0364	0.0324	0.0344
II	Liver	5.3 ± 0.4	5.6 ± 0.12	5.4 ± 0.2	5.3 ± 0.3	5.4±0.15	4.1 ± 0.1	4.3 ± 0.2	4.2 ± 0.22	3.9 ± 0.08	4.1±0.1
	BAF	0.1485	0.1569	0.1513	0.1485	0.1513	0.1149	0.1205	0.1145	0.1093	0.1149
	Gills	2.9 ± 0.7	3.0 ± 0.06	2.88 ± 0.1	2.70 ± 0.4	2.87±0.06	9.1 ± 1.6	9.3 ± 2.1	9.1 ± 1.8	8.9 ± 1.01	9.1±0.11
	BAF	0.0813	0.0840	0.0807	0.0757	0.0804	0.2550	0.2606	0.2550	0.2494	0.2550
	Muscles	2.1 ± 0.1	2.2 ± 0.16	1.99 ± 0.12	1.97 ± 0.3	2.06±0.10	3.9 ± 1.3	4.1 ± 1.05	4.0 ± 1.02	3.99 ± 1.0	3.99±0.1
	BAF	0.0588	0.0616	0.0558	0.0552	0.0577	0.1093	0.1149	0.1121	0.1118	0.1118
III	Liver	6.1 ± 0.51	6.3 ± 0.8	5.99 ± 0.18	5.90 ± 0.2	6.07±0.16	7.8 ± 1.10	7.9 ± 1.02	7.08 ± 0.90	7.88 ± 0.1	7.66±0.44
	BAF	0.2128	0.2198	0.2090	0.2059	0.2118	0.2721	0.2756	0.2470	0.2749	0.2672
	Gills	2.01 ± 0.42	2.2 ± 0.16	2 ± 0.6	2.1 ± 0.09	2.07±0.11	12.6 ± 1.3	13 ± 1.4	12.9 ± 2.3	12.5 ± 2.8	12.75±0.21
	BAF	0.0701	0.0767	0.0698	0.0732	0.0722	0.4396	0.4536	0.4501	0.4361	0.4448
	Muscles	1.1 ± 0.08	1.3 ± 0.2	1.2 ± 0.11	1.12 ± 0.10	1.18±0.1	10.1 ± 1.5	10.3 ± 1.8	10.2 ±2.0	9.9 ± 1.6	10.13±0.1
	BAF	0.0384	0.0454	0.0419	0.0390	0.0412	0.3524	0.3594	0.3559	0.3454	0.3534
IV	Liver	5.1 ± 0.1	5.2 ± 0.3	4.99 ± 0.2	4.5 ± 0.4	4.94±0.11	8.3 ± 1.8	8.2 ± 1.9	8.1 ± 1.3	7.90 ± 1.0	8.13±0.1
	BAF	0.1300	0.1326	0.1272	0.1147	0.1260	0.2116	0.2091	0.2065	0.2014	0.2073
	Gills	3.9 ± 0.3	4.0 ± 0.12	3.82 ± 0.3	4.0 ± 0.01	3.93±0.1	18.6 ± 2.3	18.7 ± 3.3	18.1 ± 1.2	17.8 ± 3.1	18.3±0.32
	BAF	0.0994	0.1020	0.0974	0.1020	0.1002	0.4742	0.4768	0.4615	0.4539	0.4666
	Muscles	1.9 ± 0.8	2 ± 0.35	1.88 ± 0.6	1.85 ± 0.3	1.90±0.06	8.9 ± 1.3	9.1 ± 0.87	9.2 ± 0.77	8.8 ± 0.66	9.0±0.15
	BAF	0.0484	0.0510	0.0479	0.0472	0.0484	0.2269	0.2320	0.2346	0.2244	0.2295

BAF = M_tissue / M_sed, I = EL-Kanater El-Khairya (Agricultural drain). II = Tamaly (Sewage and agricultural drain). III = El-Bahawy (Sewage drain), IV = Kafer El-Zyate.

anguillaris and *O. niloticus* were 18.3 ± 0.32 and 3.93 ± 0.1 mg/kg/wt, the lowest mean concentration of Cd in the gills of *C. anguillaris* and *O. niloticus* was 9.03 ± 0.21 and 1.45 ± 0.1 mg/kg/wt, respectively at station I.

In muscles of *C. anguillaris* the highest concentration of Cd recorded was 10.3 ± 1.8 mg/kg/wt at station III and 2.06 ± 0.10 mg/kg/wt for *O. niloticus* at station II, where the lowest mean concentration was 1.045 ± 0.06 and 0.9 ± 0.07 mg/kg/wt for C*. anguillaris and O. niloticus*, respectively at station I.

The maximum BAF concentration of Cd in liver of *C. anguillaris* and *O. niloticus* were 0.2672 and 0.2118 mg/kg/wt, respectively at station III; the minimum mean concentration of BAF for *C. anguillaris* and *O. niloticus* were 0.1149 and 0.0695, mg/kg/wt at station II and I, respectively.

In gills of *C. anguillaris and O. niloticus,* maximum BAF concentration of Cd was 0.4666 and 0.1002, mg/kg/wt respectively at station IV, but the lowest concentration was 0.2550 and 0.0479 mg/kg/wt at station II and I, respectively.

In Muscles of *C. anguillaris* and *O. niloticus,* the maximum BAF concentration of Cd was 0.3534 and 0.0577, mg/kg/wt at station III and II, respectively; whilst the lowest BAF concentration was 0.0344 and 0.0298 mg/kg/wt at station I for the two kinds of fish *C. anguillaris* and *O. niloticus*, respectively.

Results in Table 7 declared the mean concentration (mg/kg/wt) of Zn in various organs (liver, gills, and muscles) of the two kinds of fish *O. niloticus* and *C. anguillaris* at four stations. The highest mean concentration of Zn in the liver of C*. anguillaris* and *O. niloticus* were 78.15 ± 2.04 and 65.63 ± 0.99 mg/kg/wt at station III and IV, respectively, the lowest mean concentration of Zn in liver of *C. anguillaris and O. niloticus* was 38.15 ± 0.31 and 28.33 ± 0.66 mg/kg/wt, respectively at station I. Also at station IV, highest mean concentration of Zn in gills of *C .anguillaris* and *O. niloticus* were 44.57 ± 1.05 and 34.95 ± 0.55 mg/kg/wt, respectively.

The lowest mean concentration in *C. anguillaris* and *O. niloticus* was 39.62 ± 0.26 and 22.7 ± 0.66 mg/kg/wt, respectively at station I. The highest concentration of Zn in muscles of *C. anguillaris* and *O. niloticus* were 25.0 ± 0.17 and 20.4 ± 1.36 mg/kg/wt, respectively at station IV, where the lowest mean concentration was 13.08 ± 0.30 and 14.075 ± 0.26 mg/kg/wt for *C. anguillaris* and *O. niloticus* at station I and II, respectively.

The maximum mean concentration of BAF for Zn in liver of *C. anguillaris* and *O. niloticus* were 1.3338 and 0.8162 mg/kg/wt, respectively at station III, the minimum BAF concentration for *C. anguillaris* and *O. niloticus* were 0.3827 and 0.3056 mg/kg/wt at station IV and I, respectively.

In gills of *C. anguillaris and O. niloticus,* the maximum mean concentration of BAF for Zn was 0.7535 and 0.4199 mg/kg/wt, respectively at station III, but the lowest concentration was 0.3226 and 0.1899 mg/kg/wt at station IV and II, respectively.

In muscles of *C. anguillaris* and *O. niloticus,* the highest BAF concentration of Zn was 0.3720 and 0.3427 mg/kg/wt, respectively at station III, whilst the lowest BAF was 0.1411 and 0.1111 mg/kg/wt at station I and II for the two kinds of fishes *C. anguillaris* and *O. niloticus*, respectively.

DISCUSSION

The contamination of soils, sediments, water resources, and biota by heavy metals is of major concern especially in many industrialized countries because of their toxicity, persistence and bioaccumulative nature (Ikem et al., 2003). From previous mentioned results, it is clear that the distribution of heavy metals at Kafer El-Zyate station (IV) showed increased values and generally had higher contamination when compared to the other areas (station I, II and III).

The relatively higher values obtained for the station of Kafer El-Zyate in water and sediments may be due to the impact of pollution sources in this area coming from industrial effluents of El-Malyia superphosphate Company, Salt and Soda Company and Pesticides Company at Kafer Elzyat City poured directly into the branch without treatments.

The distribution patterns of heavy metals in the water and fish organs increased in the hot seasons (spring and summer) which may be attributed to the release of heavy metals from sediments to the overlying water under the effect of both high temperature and fermentation process resulted from decomposition of organic matter (Elewa et al., 2001). Moreover, these increase in water coincided with the decrease in the same metal values in the sediments.

In addition, the values of heavy metals showed an obvious decrease in the water during cold season (winter and autumn) with a correspondent increase in the sediments due to precipitation of heavy metals from water column to the sediments under high pH values and the adsorption of heavy metals onto organic matter and their settlement downward (Goher, 2002).

Due to the fact that most trace metals tend to accumulate in different body organs, these metals are dangerous for fish and in turn they lead to serious problems in both man and animals (Marzouk, 1994). Fishes may absorb dissolved elements and trace metals from its feeding diets and surrounding water leading to their accumulation in various tissues in significant amounts and exhibit eliciting toxicological effects at target criteria (McCarthy and Shugart, 1990).

The Fe, Cu, Cd, Pb and Zn concentrations in water samples at four sites (I, II, III and IV) at Rosetta Branch of River Nile were compared with international standards. The obtained results showed that Fe, Pb and Cd concentrations in water exceed the maximum allowable limit (0.3, 0.01 and 0.003 mg/L) in drinking water according to WHO (2008) standards.

Metal index value (MI) > 1 for iron, lead and cadmium compared to its respective maximum allowable concentration (MAC) value means the worse of the quality water for drinking. Cu and Zn, concentrations in water do not exceed the maximum allowable limit (2.0 amd 3.0 mg/L) according to WHO (2008). MI < 1 for Cu and Zn. WHO has not fixed a health- based guideline

Table 7. Seasonal variation of zinc (Zn) concentration (mg/kg) in tissues of *O. niloticus* and *C. anguillaris* from Rosetta branch of the River Nile in Egypt (Mean±SD).

Site	Organ	***O. niloticus***					***C. anguillaris***				
		Spring (M±SD)	**Summer (M±SD)**	**Autumn (M±SD)**	**Winter (M±SD)**	**All (M±SD)**	**Spring (M±SD)**	**Summer (M±SD)**	**Autumn (M±SD)**	**Winter (M±SD)**	**All (M±SD)**
I	Liver	28.2 ± 3.2	29.1 ± 3.1	27.8 ± 0.8	28.2 ± 0.3	28.33±0.66	38. 2 ± 7.1	38.6 ± 6.2	38 ± 5.2	37.8 ± 1.9	38.15±0.31
	BAF	0.3042	0.3140	0.2100	0.3042	0.3056	0.4122	0.4164	0.4100	0.4078	0.4116
	Gills	22.2 ± 4.0	23.5 ± 2.8	22.6 ± 0.1	22.5 ± 0.1	22.7±0.66	40.2 ± 2.8	39.8 ± 3.9	39.7 ± 4.1	38.8 ± 1.9	39.62±0.26
	BAF	0.2395	0.2395	0.2438	0.2428	0.2450	0.4338	0.4294	0.4284	0.4186	0.4274
	Muscles	18.1 ± 2.5	19.3 ± 0.08	17.9 ± 1.2	18 ± 3.2	18.32±0.76	13.5 ± 4.1	13.1 ± 3.5	12.9 ± 3.2	12.8 ± 1.8	13.08±0.30
	BAF	0.1953	0.2082	0.1931	0.1942	0.1976	0.1457	0.1413	0.1392	0.1396	0.1411
II	Liver	45.2 ± 3.2	45.9 ± 1.2	44.1 ± 0.8	43.9 ± 1.4	44.77±0.91	80.1 ± 6.1	77.3 ±7.6	75.1 ± 8.8	74.8 ± 7.2	76.82±2.5
	BAF	0.3568	0.3623	0.3481	0.3465	0.3534	0.6323	0.6102	0.5928	0.5905	0.6064
	Gills	24.25 ± 3.5	25.1 ± 3.1	24 ± 2.6	22.9 ± 1.0	24.06±0.57	40.3 ± 3.2	42.2 ± 4.1	41.1 ± 3.5	39.9 ± 1.2	40.87±0.95
	BAF	0.1914	0.1981	0.1895	0.1808	0.1899	0.3181	0.3331	0.3244	0.3150	0.3226
	Muscles	14.5 ± 3.6	14.6 ± 1.10	14.1 ± 0.5	13.1 ± 1.2	14.075±0.26	18.1 ± 1.7	18.2 ± 2.1	17.9 ±2.9	17.8 ±3.1	18.0±0.15
	BAF	0.1145	0.1153	0.1113	0.1034	0.1111	0.1429	0.1437	0.1413	0.1405	0.1421
III	Liver	48.8 ± 1.8	49.1 ± 1.2	47.1 ± 0.5	46.3 ± 1.1	47.82±1.08	88.2 ± 7.2	89.1 ±8.3	85.2 ± 7.1	86.1 ± 8.1	78.15±2.04
	BAF	0.8329	0.8380	0.8038	0.7902	0.8162	1.5054	1.5207	1.4542	1.4695	1.3338
	Gills	26.1 ± 2.8	25.1 ± 0.1	24.1 ± 0.3	23.1 ± 1.0	24.6±1.0	44.4 ± 3.5	43.8 ± 4.1	45.1 ± 5.1	43.3 ± 4.1	44.15±0.65
	BAF	0.4455	0.4284	0.4113	0.03942	0.4199	0.7578	0.7476	0.7698	0.7390	0.7535
	Muscles	20.2 ± 3.6	18.9 ± 0.2	20.1 ± 1.2	21.1 ± 0.08	20.08±0.72	22.2 ± 1.6	21 ± 2.6	23.1 ± 3.8	20.9 ±1.8	21.8±1.05
	BAF	0.3448	0.3226	0.3431	0.3618	0.3427	0.3789	0.3584	0.3942	0.3567	0.3720
IV	Liver	66.2 ± 3.9	67.1 ± 1.5	65.12 ± 0.8	64.1 ± 0.08	65.63±0.99	52 ± 3.2	48.8 ± 3.5	49.1 ± 1.6	50.1 ± 4.5	50.0±1.76
	BAF	0.5066	0.5135	0.4983	0.4905	0.5023	0.3979	0.3734	0.3757	0.3834	0.3827
	Gills	35.1 ± 1.3	36 ± 4.0	35 ± 0.9	33.7 ± 1.10	34.95±0.55	51 ± 3.8	52.2 ± 4.6	50.1 ± 3.8	49.9 ± 4.1	44.57±1.05
	BAF	0.2686	0.2755	0.2679	0.2579	0.2675	0.3903	0.3994	0.3834	0.3818	0.3411
	Muscles	22.1 ± 2.8	21.1 ± 1.8	19. 4± 1.0	19 ± 0.2	20.4±1.36	25.1 ± 3.3	24.8 ± 4.1	25.1 ±3.6	25 ± 3.2	25.0±0.17
	BAF	0.1691	0.1691	0.1484	0.1454	0.1561	0.1921	0.1898	0.1921	0.1913	0.1913

BAF = M_tissue / M_sed, I = EL-Kanater El-Khairya (Agricultural drain), II = Tamaly (Sewage and agricultural drain, III = El-Bahawy (Sewage drain), IV = Kafer El-Zyate. Upper level of intake of zinc in food for human consumption according to WHO (2008) = 15 to 20 mg/day.

values (GV) for iron (0.3) but notes that drinking water containing higher levels than those listed in the foregoing may be unacceptable to consumers for aesthetic reasons. The high levels of Cd and Pb in water can be attributed to industrial and agricultural discharge (Mason, 2002).

Saeed and Shaker (2008) found that the high level of Pb in water of Lake Manzala and Borollus could be attributed to the industrial and agricultural discharge as well as from spill of leaded petrol from fishing boats and dust which holds a huge amount of lead from the combustion of petrol in automobile cars (Hardman et al., 1994).

Saeed and Shaker (2008) mentioned that the high level of Pb in water of Northern Delta Lakes can be attributed to heavily traveled roads that run along the Lakes. Higher levels of Pb often occur in water bodies near highways and large cities due to high gasoline combustion (Banat et al., 1998).

The obtained metal concentrations from the sediment samples were compared with sediment quality guideline which showed that these concentrations did not exceed the probable effect concentration (PEC) levels.

The average concentrations of Cd and Fe were higher than those reported in Gediz River. Also, Cr, Cu, Fe and Ni concentrations were higher than the Demirköprü Dam Lake and Cu concentration was higher than the Hazar Lake. Ni concentration was lower than the Atatürk Dam Lake (Table 3). Generally, the average concentrations of Cd and Pb in Avsar Dam Lake were found to be lower than the other studies but Ni and Fe were higher. Differences between our data and the literature probably originate from variations in geological mining history of localities and urban and domestic activities.

The highest metal values in sediment recorded at station IV may be due to the fact that when metal pollutants are discharged into aquatic environment, they do not remain in aqueous phase but instead adsorbed onto the sediment. Thus, sediment serves as a sink for pollutants, hence the reason for its higher concentration of these metals. This is similar to the findings of Amoo et al. (2005) where the obtained levels of these metals in sediments were higher than those in the water of Lake Kanji in Nigeria. Other activities include the use of metal gears for fishing, dumping of metal containers of domestic sources, abandoned fishing canoes/boats with metal linings, etc. The lowest levels of heavy metals recorded at station I and III came from agricultural and sewage drain.

The results confirm the differences of heavy metals accumulation in different tissues of fish and the gradual accumulation and increase during summer and spring period in the liver, gills and muscles was higher in *C. anguillaris* than in *O. niloticus* at station IV. Liver of *C. anguillaris* accumulated higher levels of Fe, Cu, Pb, Cd and Zn than *O. niloticus.*

Jent et al. (1998) found that Cd and Cu concentration increased in fish liver. The higher accumulation in liver may alter the levels of various biochemical parameters in liver. This may also cause severe liver damage (Ferguson, 1989).

Ikechukwu and Ajeh (2011) indicates that heavy metal contamination definitely affects the liver *Hoplobatrachus Occipitalis* causing severe bile secretion, dilation of sinusoids and congestion of blood vessels in the liver thereby affecting the function of the liver in detoxification and biotransformation of foreign compounds.

In gills of *C. anguillaris* the highest accumulation of metal levels were Zn, Fe, Pb, Cd and Cu than accumulation in gills of *O. niloticus.* The gill is an important site for the entry of heavy metals that provokes lesions and gill damage (Bols et al., 2001; Lock and Overbeeke, 1981).

In muscles of *C. anguillaris*, the highest accumulations of metal levels were Fe, Zn, Cd and Cu except Pb was highest in *O. niloticus* muscles. According to WHO (2005), the allowable concentration for Pb, Cd, Cu were 200, 50 and 10000 ppb, respectively. However, such food limits are not defined to all the elements (Agah et al., 2009). The element levels of fish muscles in this study were below the allowable concentration suggested by WHO (2005) and have no threat to public health. The results generally confirmed that the liver is the highest organ in accumulation of heavy metals in two types of fishes, followed by gills and less accumulation detected in muscles.

Also, Yousafzia et al. (2012) showed that fish intestine accumulated high heavy metals burden while muscles accumulated the least in comparison to other organs. Fish species living in contaminated waters tend to accumulate heavy metals in their organs and tissues. Various heavy metals are accumulated in fish body in different amount (Jezierska and Witesta, 2001).

Fish species mostly absorbed heavy metals from its feeding diets, sediments and surrounding waters resulting to their accumulation in reasonable amounts (McCarthy and Shugart, 1996). The differences in the level of heavy metals accumulated by the two fish species could be attributed to the differences in their metabolic rates, feeding habits, age, sex and fish species (Kotze et al., 1999). Body size and health which are closely related to growth and metabolism has been shown to attribute most of the variations in heavy metals content of fishes (Moriarty et al., 1984).

Conclusion

In the present study, some heavy metals concentrations exceed the safe recommended value, which suggest that the Rosetta Branch of River Nile is partly a heavy metal polluted river and the water, sediment and fish are not fully safe for human health and ecosystem. With the gradual development of industry, intensive use of pesticides and discharge of untreated domestic sewage may further exacerbate the situation in coming years.

ACKNOWLEDGEMENTS

This project was supported by King Saud University, Deanship of Scientific Research, College of Food and Agriculture Sciences, Research Center.

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