SOME INDUSTRIAL HEAVY METAL POLLUTANTS IN RIVER NILE AND THEIR EFFECT ON BIOLOGICAL AND NON BIOLOGICAL INHABITANTS I. ESSENTIAL HEAVY METALS

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Abstract

This study involves the determination of levels of four heavy metals: copper, iron, manganese, and zinc in three phases (water, sediment and deboned flesh of tilapia fish) from the upper section of the Rive Nile.

In water, all the values were found beow the detection limit.

In sediment, the concentrations of studied trace elements were 2, 177 to 47, 345 times higher than those in the water.

Tilapia captured in front of Sohag onion manufactory had greater concentrations of Fe and Mn.

Data collected during the present study on sediment and tilapia supported the impression that metal-specific differences in the concentration levels existed between the different localities.

As can be seen from the data, the mean values for the heavy metal residues in fish deboned flesh show correlations with its concentrations in water for iron and manganese and with sediment concentration for zinc.

A significant negative correlation between deboned flesh iron residue and fish length was calculated. The high physiological need for the iron may interpret this observation.

INTRODUCTION

In water, copper, iron, manganese and zinc have been classified as essential heavy metals. These metals are known to help in the growth and production of aquatic life.

Numerous studies Phillips and Russo (1978) and Eisenberg and Topping (1986) have attempted to elucidate the mechanism and problems of bioaccumulation of metals, even though, their concentrations in the water are well below objectionable levels in the aquatic food chain. According to Mathis and Kevern (1975), among the aquatic fauna, fishes are the most sensitive group and serve as an indicator of metal concentrations in polluted waters.

The presence of heavy metals such as Cu, Fe, Mn, and Zn could create health problems if ingested over a long period of time. Water is an important vehicle for transmitting those agents to potential victims. Although this aspect of the water-health relationship has been recognized for many years, it only recently has become the focus of greatly increased attention and concern.

This study involves the determination of levels of four heavy metals, Cu, Fe, Mn, and Zn in water, sediment and a variety of tilapia fish harvested from the upper section of the River Nile and its tributaries over a four month period. Particular emphasis is being given to areas with heavy concentrations of industries. The intent of these studies is twofold, involving a measure of contamination levels of the aquaic ecosystem as well as to provide baseline data of persistent, bioaccumulative trace metals in fish which suffer under environmental stress through man's activities. This may serve as a useful reference measure for the suitability of human consumption of various species of fish harvested from these regions.

MATERIALS AND METHODS

The investigations are spread over a period of four months (Oct., 1990 - Feb., 1991). The sampling network covered the River Nile along the areas between Kena and El-Menia Governorates. Table 1 describes the localities and their indusrial activities.

The six water samples from each locality were collected by a Hydro-Bios TPN water sampler at one meter depth as described by Parker (1972). In each locality, river water's pH were determined (Table 1) by portable Digital Mini-pH meter Model 55 (L.G. NESTER Company).

Plankton and water suspended particles (Sediment) samples were collected by towing a new standard plankton net (20 uM) for five minutes at a depth of one metre. Contents of the plankton nets were immediately transferred to acid-cleaned polystyrene vials, acidified with concentrated nitric acid (analytical grade), kept refrigerated and transferred cold to the laboratory. In laboratory, the sediment samples were dried in a vacuum oven at 50°C. The digestion procedure for both flesh and water sediment was as that described by Engan et al. (1987).

One-hundred- forty-nine tilapia fish were collected using gill nets and the physical characteristics of the fish and length as well location caught were recorded . From time of collection until analysis at Animal Health Research Institute, Cairo, the specimens were kept frozen (at about - 20 °C) in plastic bags. The storage time is about one week. In laboratory, the fish samples were thawed and dissected with a stainless steel scalpel and dissecting scissors. A full length fillet is cut from each fish, extending from head to tail and as deep as the backbone. After skin and larger bones have been removed, the deboned flesh was minced and homogenized. The samples were placed on clean dry glass plates and dried in an oven at 105° C for 48 hours (Bohn and McElroy 1976).

The studied heavy metals were determined in deboned flesh, water suspended particles (sediment) and water samples using Atomic Absorption Perkin-Elmer

Table 1.. Industrial activities, abbreviations and water pH of different localities of Upper Egypt studies (6 samples each).

No.	Locality	Manufacture	Abbreviation	Water pH
1	Armant	Sugar	A.S.	7.9±0.15
2	Deshna	Sugar	D.S.	7.7±0.26
3	Nagi Hamady	Sugar	N.H.S.	8.1±0.04
4	Girga	Sugar	G.S.	8.2±0.25
5	Sohag	Onion	S.O.	6.5±0.05
6	Sohg	Soap	S.S.	8.3±0.27
7	Sohag	Soap (1 Km. north)	S.S.N.	8.5±0.01
8	Mangabad	Fertilizer*	M.F.	3.6±0.15
9	Mangabad	Fertilizer (1Km. north)	M.F.N.	---
10	Bany Kora	Soap	B.K.S.	8.3±0.15
11	El-Menia	Fish hatchery	E.F.H.	9.0±0.05

Model 2380 with air/acetylene burner. Optimum conditions for each element were obtained within the guidelines of the instrument manufacturer. A minimum of one blank were analyzed in each sample run to account for any analytical and instrumental errors. All chemicals used in the sample pre-treatment were of reagent-grade quality. Determination of trace metals were measured as absorbance and were converted to micrograms per gram dry weight or per litre.

The data on trace metals have been subjected to necessary statistical treatment (Snedecor and Cochran 1976) and hance, only the reliable values have been reported.

RESULTS

In tables 2, 3 and 4 the analytical data obtained are summerized. The presentation of mean values and concentration ranges have been chosen because of the locality induced variability of data undoubtedly present in all samples.

The mean concentration (ug/L) of water elements are detected in table 2. The Fe and Mn values shown in table 2 indicate significant variations with region ($P<0.01$). An obvious signficant Fe-specific differences between Sohag areas could be identified.

Values of the metals in sediment are given in table 3. Our data are related to dry weight. Mangabad area showed the maximum average heavy metal concentration except for Mn (248.2 ±26.54 ug/g) at S.S.N. Significant comparison was detected in all elements, except copper, between the two localities of Sohag (S.P. and S.S.N). At the third locality in Sohag (S.S.), in front of soap manufactory, heavily sewage colloidal particles contained in the water, so, it was difficult to collect sediment from this area. The same significant observtion for all metals was shown between the two localities of Mangabad (M.F. and M.F.N.) except iron. Obvious significant differences ($P<0.01$) between the ten localities studied for all trace elements were calculated (Table 3).

Results for the determination of heavy metal residues in tilapia samples (deboned flesh) are shown in Table 4. All values are reported as ug/g dry weight. Fish investigated had Zn values between 11.00 ± 0.09 and 99.83±27.91 ug / g at S.S. and M.F.N., respectively. After zinc, iron is the most common metallic trace element in fish. Most iron values lie between 11.85±0.083 ug/g at D.S. and 39.08± 4.57 ug/g at S.O. The scale of Cu values ranged from 6.95 ± 0.39 to 15.81 ±2.28 ug/g at S.S. and N.H.S., respectively. Manganese content lies between 0.438 ± 0.059 ug/g at S.S. and 2.299 ± 0.528 ug/g at S.O. Tilapia captured in front of Sohag onion manufactory (S.O.) has significantly greater concentrations of all elements,

Table 2. Levels of essential heavy metals in water from River Nile in the different localities of Upper Egypt.

Location	Mean ± S.E. and Range of Metals concentration (ug/Litre)			
	Copper	Iron	Manganese	Zinc
A.S.	0.028±0.011 (0.00-0.07)	0.175±0.070 (0.00-0.38)	0.068±0.036 (0.00-0.18)	0.297±0.232 (0.01-1.45)
D.S.	0.060±0.014 (0.03-0.10)	0.158±0.034 (0.00-0.21)	0.030±0.017 (0.00-0.10)	0.193±0.040 (0.00-0.26)
N.H.S.	0.082±0.023 (0.01-0.15)	0.180±0.037 (0.00-0.24)	0.042±0.015 (0.00-0.08)	0.260±0.047 (0.12-0.40)
G.S.	0.083±0.041 (0.00-0.21)	0.185±0.031 (0.10-0.27)	0.113±0.040 (0.03-0.24)	0.183±0.048 (0.04-0.32)
S.O.	0.055±0.002 (0.05-0.06)	2.270±0.137***a (1.79-2.75)	0.460±0.021 (0.38-0.54)	0.260±.057*a (0.04-0.48)
S.S.	0.075±0.025 (0.00-0.14)	0.587±0.125**b (0.27-0.95)	0.782±0.415 (0.06-2.09)	0.083±0.044 (0.00-0.22)
S.S.N.	0.035±0.008*c (0.00-0.06)	0.103±0.031***c (0.00-0.22)	0.087±0.036***c (0.00-0.20)	0.145±0.059 (0.02-0.39)
M.F.	0.032±0.010 (0.00-0.05)	0.308±0.113 (0.09-0.79)	0.100±0.036 (0.01-0.24)	0.133±0.030 (0.02-0.19)
M.F.N.	0.050±0.005 (0.03-0.07)	0.387±0.018 (0.32-0.45)	0.118±0.004 (0.10-0.13)	0.078±0.011 (0.04-0.11)
B.K.S.	0.072±0.010 (0.05-0.12)	0.087±0.018 (0.00-0.12)	0.010±0.006 (0.00-0.04)	0.290±0.049 (0.09-0.41)
E.F.H.	0.067±0.012 (0.04-0.12)	0.290±0.008 (0.026-0.31)	0.35±0.022 (0.00-0.14)	0.150±0.029 (0.06-0.27)
Mean F-test	0.058 P>0.05	0.430 P<0.01	0.168 P<0.01	0.188 P>0.01

* Significant at P< 0.05 ** Significant at P < 0.01

*** Significant at P< 0.001 Number of samples for each location = 6

a : Comparison between means of S.O. and S.S. groups.

b : Comparison between means of S.S. and S.S.N. groups.

c : Comparison between means of S.O. and S.S.N groups.

Table 3. Levels of essential heavy metals in water from River Nile in the different localities of Upper Egypt.

Location	Mean ± S.E. and Range of Metals concentration (ug/Litre)			
	Copper	Iron	Manganese	Zinc
A.S.	205.45±9.62 (162.93-227.44)	12.92±2.13 (7.22-20.38)	173.66±9.13 (149.29-205.98)	172.33±13.62 (131.97-209.57)
D.S.	186.92±14.41 (148.34-237.15)	13.73±3.43 (4.34-23.50)	134.57±34.10 (41.18-227.98)	132.26±19.47 (81.73-206.85)
N.H.S.	171.17±13.39 (125.94-207.27)	6.22±0.62 (4.42-7.92)	69.29±12.51 (34.54-103.54)	65.81±3.46 (58.74-81.80)
G.S.	353.03±36.96 (252.18-465.99)	10.49±3.21 (1.73-20.92)	(153.90±22.71) 91.73-218.66	91.58±17.55 (47.31-162.29)
S.O.	241.75±1.07 (237.62-245.88)	15.52±0.29 (14.39-16.66)	117.71±1.75 (110.94-124.47)	306.31±20.25 (227.89-384.72)
S.S.	------- -------	------- -------	------- -------	------- -------
S.S.N.	261.34±19.52 (212.18-340.24)	3.99±0.73***c (1.99-6.02)	248.02±26.54***c (175.54-328.25)	68.68±8.34***c (46.01-95.28)
M.F.	381.65±43.72 (261.93-501.37)	14.03±3.30 (5.07-24.53)	130.63±13.13 (94.74-169.87)	118.98±21.75 (63.94-206.23)
M.F.N.	155.21±3.49***d (141.70-168.72)	16.77±0.25 (15.82-17.72)	161.29±3.70*d (146.95-175.63)	1202.62±133.20***d (686.73-1718.51)
B.K.S.	182.99±20.07 (103.60-234.23)	5.62±1.17 (2.44-9.43)	144.97±26.28 (67.60-216.83)	178.15±37.70 (75.07-289.49)
E.F.H.	210.34±7.54 (189.82-244.81)	6.50±0.77 (4.46-9.23)	172.60±43.01 (55.73-310.26)	176.19±27.22 (103.15-270.38)
Mean F-test	234.99 P<0.01	10.58 P<0.01	150.66 P<0.01	251.29 P<0.01

* Significant at P< 0.05 *** Significant at P < 0.01

Number of samples for each location = 6

b : Comparison between means of S.O. and S.S.N. groups.

c : Comparison between means of M.F. and M.F.N. groups.

Table 4. Levels of essential heavy metals in water from River Nile in the different localities of Upper Egypt.

Location (Number of fish)	Fish length (cm)	Mean ± S.E. and Range of Metals concentration (ug/Litre)			
		Copper	Iron	Manganese	Zinc
A.S. (17)	19.0±0.61 (16.0-22.8)	11.10±1.00 (3.52-20.49)	20.08±4.31 (5.83-83.20)	0.969±0.135 (0.00-1.98)	53.36±11.79 (5.32-158.18)
D.S. (10)	18.5±1.10 (15.3-24.0)	7.20±1.59 (4.18-20.42)	11.85±0.83 (7.64-15.61)	0.644±0.173 (0.00-1.64)	27.33±4.49 (13.06-52.56)
N.H.S. (3)	17.7±0.37 (16.7-19.2)	15.81±2.28 (9.58-18.96)	19.89±2.34 (12.76-31.46)	1.144±0.124 (0.78-1.94)	26.09±2.48 (18.42-39.25)
G.S. (24)	18.8±0.30 (16.3-21.3)	14.23±3.82 (6.92-63.58)	20.48±1.74 (8.69-40.21)	1.407±0.368 (0.01-8.42)	28.66±3.26 (8.33-69.74)
S.O. (14)	13.9±0.30 (12.5-15.4)	6.95±0.39 (5.45-8.45)	39.08±4.57**a (21.93-78.08)	2.299±0.528*a (0.83-8.28)	27.47±2.57***a (15.89-51.12)
S.S. (6)	19.9±0.11 (19.5-20.2)	9.66±0.94 (3.37-19.10)	14.00±0.07***b (13.80-14.20)	0.438±0.059**b (0.24-0.64)	11.00±0.09**b (10.74-11.26)
S.S.N.(20)	17.6±0.62 (14.4-23.4)	11.87±0.55 (7.66-14.15)	29.99±1.72*c (19.75-52.09)	1.792±0.200 (0.78-4.18)	28.41±2.71 (10.55-51.51)
M.F. (11)	18.2±0.48 (16.6-20.7)	10.38±0.86 (8.06-13.68)	17.26±1.65 (6.000-23.74)	1.225±0.180 (0.16-2.19)	22.67±2.80 (11.48-43.09)
M.F.N(7)	14.0±1.06 (11.6-18.0)	11.40±0.86 (5.78-25.84)	22.63±4.03 (13.36-41.31)	0.954±0.341 (0.00-1.97)	99.83±2.37 (37.92-248.72)
B.K.S.(7)	17.1±1.31 (12.3-23.0)	10.38±0.86 (8.06-13.68)	16.73±2.39 (8.75-29.55)	0.723±0.100 (0.48-1.19)	19.42±2.37 (12.83-31.73)
E.F.H.(24)	16.3±0.54 (14.1-24.4	10.84±1.41 (5.80-16.94	22.00±1.85 (7.80-44.64)	1.110±0.161 (0.00-3.01)	41.17±4.50 (1.05-91.53)
Mean		10.820	21.272	1.067	35.040
F-test		P<0.05	P<0.01	P<0.01	P<0.01

* Significant at P< 0.05 ** Significant at P < 0.01

*** Significant at P < 0.01

a : Comparison between means of S.O. and S.S. groups

b : Comparison between means of S.O. and S.S.N. groups.

c : Comparison between means of M.F. and S.S.N. groups.

d : Comparison between means of S.O. and M.F.N. groups except copper, than do the tilapia captured at Sohag soap manufactory (S.S.). Also, Fe conentration was significantly higher in S.O. than S.S.N. (Table 4). The Zn concentration was significantly lower at Mangabad fertilizer manufactory (M.F.) than northern it by one kilometre (M.F.N.). Data generated during the present study on tilapia supported the impression that metal - specific differences in the concentration levels existed between the eleven different localities (Fe, Mn, Zn, $P < 0.01$ and Cu, $P < 0.05$).

The studies of the correlation matrix of the heavy metal concentrations between deboned flesh and both water and sediment demonstrate that there are signifcant positive correlations in the levels of iron and manganese between deboned flesh and water and zinc concentration between deboned flesh and sediment (Table 5). Obvious significant negative correlation ($r = -0.632$, $P < 0.05$) could be easily deduced between deboned flesh iron and body length of fish harvested.

Table 5. Correlation of the concentration of the element between deboned flesh and both water and sediment.

	Fe		Mn		Zn	
	Water	Sediment	Water	Sediment	Water	Sediment
Flesh Fe	<0.05	>0.05				
Flesh Mn			<0.05	>0.05		
Flesh Zn					>0.05	<0.05

DISCUSSION

The calculated global averages for river water were presented by Liebman (1960) to be 7 ug Cu/L and 20 ug Zn/L. Copper with a concentration high of 14.5 ug/L is of little concern. The United States Public Health Service limiting value is 1.0 mg/L Cu and the United States Environmental Protection Agency found 220 ug/L Cu in 74.4% of all samples collected in the United States (Kopp and Kroner 1969). However, the values of heavy metals studied in this survey were found below the detection limit.

Forstner and Muller (1974) mentioned that , in surface waters, most heavy metals are associated with the sediments. Iron compounds in effluents from steel mills or abandoned coal mines may react with the alkalinity and oxygen in streams to form precipitates that impact on fish life and may kill fish by clogging their gills (Lamb 1985). Saleh *et al.* (1988) observed that the concentrations of heavy metals in plankton were 4,000 to 10,000 times higher than those in the water. Our results agreed with this observation in all elements studied. It is 47, 345 (Fe); 4,936 (Cu); 3,525 (Mn) and 2,177 (Zn) times higher in sediments than water.

Plankton is a major food source for many of fish species and other aquatic animals. Consequently, bioaccumulation of heavy metals in plankton may, therefore, critically influence the quality of fish produced. Johnels et al. (1967) and Hannerz (1968) postulated that fish can accumulate metals in their flesh from source water and the absorbance may be across the entire surface as well as the gills (Donald 1972). Fast et al. (1990) indicated in their experiment that metal uptake from the water was not of significant concern and the principal source of heavy metals in salmon was from diet. Our results computed that deboned flesh concentrations of iron and manganese were bioaccumulated from water, and zinc from sediment (Table 5). Koli et al. (1978) said that the accumulation of trace metals by fish depends on size, age, species, sex and environment of fish, but Varshney (1983) observed no strict correlation between length, weight, stage of maturity of some of the Arabian Sea and Bay of Bengal fishes and the concentrations of muscle Cu, Fe, Mn and Zn. Saleh et al. (1988) mentioned that heavy metal concentration in Wadi El-Raiyan fish did not change significantly with the season of collection or with the age of the fish. In our survey, the accumulation of iron was negatively correlated with fish length. The younger the length of fish is the more physiological need for it wich is deposited in the head of the kidney, liver, spleen and muscle (Rizkalla 1988).

Copper and zinc are widely recognized to be essential to animal life (Mertz 1981). The mean tilapia deboned flesh copper (10.820 ug/g dry wt.) and zinc (35.040 ug/g dry wt.)concentations measured in our survey are within the range of 6.95 - 15.81 ug Cu/g dry muscle and 11.0 - 99.83 ug Zn/g dry muscle. These data are obviously greater than those mentioned by Saleh et al. (1988) from Wadi El-Raiyan Lakes (1.3 - 5.3 ug Cu/g dry muscle and 1.8 - 14.1ug Zn/g dry muscle) and Abou Donia (1990) from Manzalla, Maruit and Wadi El-Raiyan Lakes (1.25, 1.22 and 2.11 ug Cu/g wet weight and 6.30, 6.56 and 6.07 ug Zn/g wet weight, respectively). May and McKinney (1981) mentioned that the scond highest copper level between fish species in USA was in Mozambique tilapia (7.58 ug / g wet weight) collected in Hawaii. Lowe et al. (1985) discussed that the high concenration of zinc in common carp in some stations along USA may reflect its tendency to accumulate more zinc than other species rather than indicate that these stations have unusually high environmental levels of zinc. So, care should be taken to maintain species consistency among collection periods within each geographic region. This observation seems to be at variance with that of Underwood (1977) who found zinc concentrations to be fairly consistent among species. Ajmal et al. (1985)

observed that, discharge of copper and zinc into the water can enter the food chain, bioaccumulate in fish and hence become a threat to man.

These results suggest that there are fundamental differences in the manner in which fish metabolize elements. Fish homeostatically regulate internal levels of essential elements within minimum and maximum levels (Wiener and Giesy 1979). Adaptation has been seen in fish with zinc (Spehar 1976) and copper (Dixon and Sprague 1981). Because physiological needs and copper (Dixon and Sprague, 1981). Because physiological needs and environmental pressures encountered by each species have differed, homeosatic boundaries and tolerance limits that evolved also differ among species. Induction of metal-binding proteins such as metallothionein may be a key factor involved.

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استبيان بعض العناصر النادرة الأساسيه فى مياه نهر النيل وعلاقتها بمستواها فى أسماك البلطى بصعيد مصر

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تشمل هذه الدراسة على تعيين مستويات اربعه معادن ثقيله (نحاس - حديد - منجنيز - زنك) فى المياة والرواسب المتعلقه بمياه نهر النيل بالأضافه الى لحوم اسماك البلطى وذلك من صعيد مصر حتى يمكن تتبع قيم هذه العناصر المدروسه.

فى المياه : وجد أن قيمه العناصر المدروسه تحت المستوى المحسوس.

فى رواسب المياه : تركيزات المعادن الثقيله أعلى بمقدار ٢١٧٧ الى ٤٧٣٤٥ مرة عن مثيلتها بالمياة .

تحتوى الأسماك المصادة أمام مصنع البصل بسوهاج على تركيزات كبيرة من الحديد والمنجنيز.

النتائج المجمعه لرواسب المياة ولحم أسماك البلطى دعمت تصور وجود أختلافات خاصه بتركيزات كل معدن من موقع الى أخر.

تم أستبيان علاقات طردية نوعية بين نسبة متبقيات الحديد والمنجنيز فى لحم الأسماك وبين مثيلتهما فى الماء بالأضافه الى وجود نفس العلاقة بين متبقيات الزنك فى لحم السمك ومثيله فى رواسب المياة.

تم حساب علاقه سلبية نوعية بين نسبة متبقيات الحديد فى لحم الأسماك وطول الأسماك . ولقد أعزيت هذه العلاقه الى الأحتياج الفسيولوجى الكبير للحديد مع النمو الطردى للأسماك.