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BIOACCUMULATION OF MERCURY IN SOME MARINE ORGANISMS FROM LAKE TIMSAH AND BITTER LAKES (SUEZ CANAL, EGYPT)

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ABSTRACT

The present work is devoted to determine the level of total mercury in the different tissues of fish *Mugil seheli*, crab *Portunus pelagicus*, shrimp *Metapenaeus stebbingi*, and bivalves *Paphia undulata* and *Gafrarium pectinatum* collected from Lake Timsah and Bitter Lakes during spring 2003. In addition, factors affecting the accumulation of mercury in these organisms were studied. Levels of Hg in the edible parts of the investigated organisms showed the ranges 2.62 – 25.45 and 0.94 – 7.94 ng/g wet wt. in fish, 16.02 – 117.26 and 9.86 – 64.18 ng/g wet wt. in crab, 4.55 – 14.67 and 5.76 – 15.58 ng/g wet wt. in shrimp, and 1.06 – 36.31 and 5.38 – 69.59 ng/g wet wt. in bivalves from Lake Timsah and Bitter Lakes, respectively. High accumulation of Hg was recorded in Lake Timsah organisms which receives wastewaters from different polluted sources. Also, high concentration of Hg was detected in the internal organs of the organisms, especially liver compared with a lower one for the edible tissues. Regression curves and ANOVA analysis were used to study the effect of growth rate, species, sex and sites variation on the accumulation of mercury in the edible parts of the studied organisms. The results obtained from the regression curves and inter-spatial variation indicated that the bivalve *Paphia undulata* could be used as bioindicator for mercury pollution.

1- INTRODUCTION

Mercury naturally occurs in the environment as a result of the volcanic degassing of the Earth's crust and weathering of mercury rich geology. While water from areas rich in mercury ores may exhibit high local mercury concentrations, industrial processes, agriculture, and the combustion of fossil fuel are the most significant sources of aquatic contamination. Common sources include caustic soda, pulp and paper, and paint manufacturing. Mercury is also used in batteries, dental amalgam, and in bactericides (FAO, 1992; Munthe 1993; OECD, 1994 and Johannesson, 2002). Mercury has as, far as we know, no necessary function in any living organism and is considered as a nonessential metal. On the contrary, mercury is among the most toxic elements to man and many higher animals (Steinnes, 1995; Landner and Lindestrom, 1998). Mercury has caused more problems to the consumers of fish than any other inorganic contaminant. In extreme cases, consumption of mercury-tainted fish has led to the onset of a serious neurological disease, termed Minamata disease. In other cases, entire fisheries have been either restricted or significantly curtailed because of mercury contamination (Moore, 1991).

In addition to that the concentrations of total mercury in fish muscle tissues are generally low, aquatic invertebrates, also, accumulate mercury to high concentrations. Although total Hg in invertebrates is highly variable, levels in marine waters are typically

< 1 µg/g (Surma-Aho *et al*., 1986; Sanzgiry *et al*., 1988; Lopez-Artiguez *et al*., 1989; Khan *et al*., 1989 and Otchere, 2003). As for most metals, factors known to influence mercury concentrations and accumulation in the marine organisms include metal bioavailability, season of sampling, hydrodynamics of the environment, size, sex, and changes in tissue composition and reproductive cycle (Boyden and Phillips, 1981). Metal concentrations in organisms at the same location differ between different species and individuals due to species-specific ability/capacity to regulate or accumulate metals (Reinfelder *et al*., 1997; Otchere *et al*., 2003).

Studies on the level of mercury in marine organisms from the Suez Canal were scarcely; therefore, the present study is mainly aimed to determine the concentration of total mercury in different marine organisms collected from Lake Timsah and Bitter Lakes (Suez Canal), as well as to study the factors affecting its accumulation.

2. MATERIALS AND METHODS

2.1. Samples and analysis

The marine organisms species (fish: *Mugil seheli*, crab: *Portunus pelagicus*, shrimp: *Metapenaeus stebbingi* and bivalves: *Paphia undulata* and *Gafrarium pectinatum*) were collected from two locations at Suez Canal (I- Lake Timsah and II- Bitter Lakes) during spring 2003 (Fig. 1). All samples were handled according to FAO (1976). To determine the concentration of total mercury, wet digestion of subsamples was carried out in Teflon vessels using AR HNO_3 and $HClO_4$ mixture. The digested samples were diluted to known volume with bi-distilled water and analyzed using cold vapor Atomic Absorption technique [Flameless Atomic Absorption Spectrophotometer, Perkin Elmer, model Aanalyst 100, coupled with mercury/hydride system MHs 10]. 3% sodium borohydride solution (3 g in 100 ml 1% free mercury sodium hydroxide) was used to reduce mercury to the elemental form. The obtained data were expressed as ng/g wet wt.

2.2. Quality control

To control the determination of mercury through all the analysis procedure, blanks and reference material (non-defatted lobster hepatopancreas – LUTS-1) were used. The Lowest Concentration-the Criterion of Detection (CD) and Limit of Detection (LOD) for mercury were estimated from the blank measurements according to Lund *et al* (1997) which were 0.13 and 0.26 ppb, respectively. The recovery value of mercury in the analyzed reference material was 97%. The precision of analytical method was checked by replicate measurements for the studied metal in sample of fish muscles, and the obtained results showed precision of 6.2%.

2.3. Data analysis

Regression curves and two-way analysis of variance (ANOVA) were conducted using computer program: STATISTICA for windows (Release 4.5, Copyright© StatSoft, Inc. 1993).

3. RESULTS AND DISCUSSION

3.1. Accumulation of mercury

The concentration of Hg in different organs of fish *Mugil seheli* and crab *Portunus pelagicus*, muscles of shrimp *Metapenaeus stebbingi* and total soft tissue of bivalve *Paphia undulata* and *Gafrarium pectinatum* collected from Lake Timsah and Bitter Lakes is presented in Table (1).

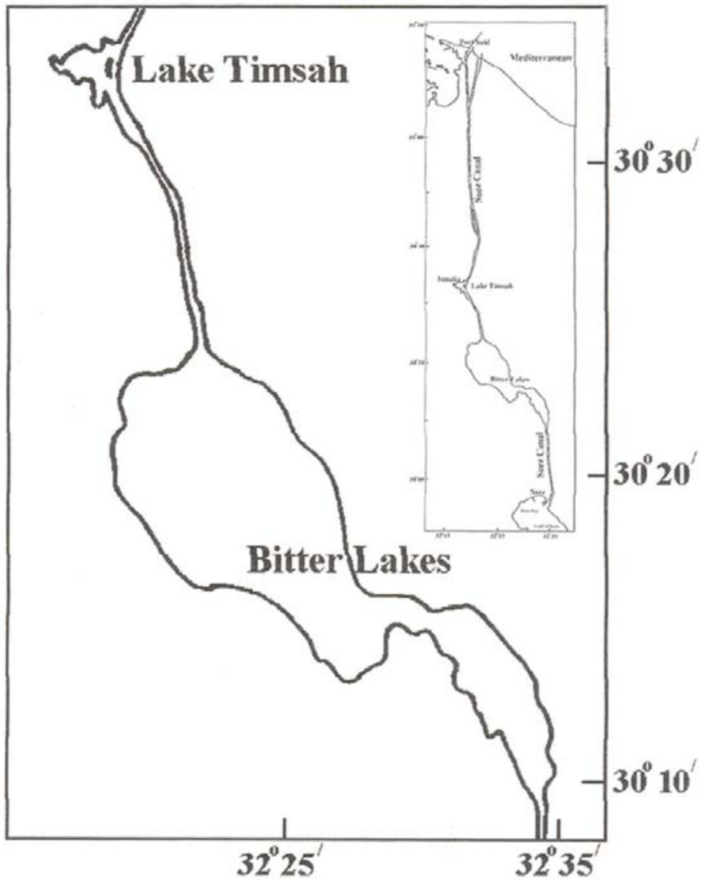

Fig. (1): Map of the Suez Canal showing the sampling sites (Lake Timsah and Bitter Lakes)

Table (1): Levels of mercury (ng/g wet wt.) in some marine organisms from Lake Timsah and Bitter Lakes

Species		Organ	Lake Timsah		Bitter Lakes	
			Range	Mean ± SD	Range	Mean ± SD
Fish:	Male	Muscles	2.62 – 25.45	10.22 ± 7.87	4.04 – 6.34	5.19 ± 1.63
Mugil seheli		Gills	4.06 – 9.12	6.26 ± 1.98	4.61 – 10.32	7.47 ± 4.04
		Liver	52.80 – 268.94	102.53 ± 83.73	102.32 – 117.02	109.67 ± 10.39
		Gonads	1.13 – 30.32	10.39 ± 11.17	22.18 – 85.01	53.60 ± 44.43
	Female	Muscles	3.51 – 12.40	7.96 ± 4.99	0.94 – 7.94	4.67 ± 2.22
		Gills	2.21 – 6.41	3.74 ± 1.85	2.54 – 9.93	5.43 ± 2.67
		Liver	30.64 – 94.44	56.42 ± 33.62	37.70 – 298.01	112.90 ± 82.13
		Gonads	1.74 – 8.06	5.27 ± 3.28	3.98 – 44.39	19.48 ± 12.29
Crab:	Male	Muscles	16.02 – 30.95	24.39 ± 6.23	9.86 – 19.18	14.52 ± 6.59
Portunus pelagicus		Gills	13.03 – 22.69	16.99 ± 5.06	1.95 – 3.56	2.76 ± 1.14
		Hepatopancreas	28.09 – 54.92	41.12 ± 13.43	13.43 – 20.45	16.94 ± 4.96
		Gonads	107.82 – 125.00	113.81 ± 9.70	7.41 – 11.35	9.38 ± 2.79
	Female	Muscles	39.02 – 117.26	85.52 ± 33.60	20.66 – 64.18	42.42 ± 30.77
		Gills	13.21 – 31.01	19.33 ± 10.12	3.24 – 5.05	4.33 ± 0.96
		Hepatopancreas	37.88 – 73.67	55.98 ± 17.90	23.42 – 35.68	28.56 ± 6.37
		Gonads	19.16 – 24.38	21.77 ± 3.69	1.61 – 3.23	2.42 ± 1.15
Shrimp:	Male	Muscles	4.55 – 13.58	7.60 ± 3.56	7.49 – 9.91	8.41 ± 1.31
Metapenaeus stebbingi	Female	Muscles	8.91 – 14.67	12.11 ± 1.82	5.76 – 15.58	9.40 ± 3.54
Bivalves:						
Paphia undulata		Total soft tissue	1.06 – 36.31	17.95 ± 8.97	5.38 – 34.97	11.46 ± 8.30
Gafrarium pectinatum		Total soft tissue	---	---	8.62 – 69.59	29.64 ± 14.48

The obtained data showed that, the highest mean value of Hg in fish *Mugil seheli* was found in liver of females from Bitter Lakes (112.90 ± 82.13 ng/g wet wt.), and the lowest was in gills (3.74 ± 1.85 ng/g wet wt.) of females from Lake Timsah. Previous studies showed that, liver and other internal organs of fish species accumulated mercury higher than those of muscle tissues (EL-Sokkary, 1984; Hornung *et al*., 1984 and Halim *et al*., 1986). For the crab *Portunus pelagicus*, the highest Hg mean contents was recorded in gonads of males from Lake Timsah (113.81 ± 9.70 ng/g wet wt.) and the lowest was in males gills and females gonads from Bitter Lakes (2.76 ± 1.14 and 2.42 ± 1.15 ng/g wet wt., respectively). With respect to shrimp *Metapenaeus stebbingi* from Lake Timsah, mercury varied between 7.60 ± 3.56 and 12.11 ± 1.82 ng/g (wet wt.) in males and females. In bivalve species, the highest mean value of Hg was recorded in *Gafrarium pectinatum* (29.64 ± 14.48 ng/g wet wt.), compared to a lower one for *Paphia undulata* from Lake Timsah (17.95 ± 8.97 ng/g wet wt.) and Bitter lakes (11.46 ± 8.30 ng/g wet wt.).

In general, marine organisms from Lake Timsah accumulated mercury higher than those of Bitter Lakes, probably due to the fact that Lake Timsah is a semi-closed area and receives huge amounts of wastewater from Ismailia City network, industrial effluents from shore-line workshops, domestic sewage from unconnected areas adjoining the shore, and agricultural drainage water (ETPS, 1995). FAO (1992) and Johannesson (2002) stated that considerable amounts of mercury might be released through the agricultural drains and sewage effluents.

By comparing the level of mercury in the marine organisms of the present investigation with those recorded by other studies elsewhere Table (2), it can be noticed that the level of mercury in the animals of the present study was lower than those recorded by other studies as well as the background and typical concentrations. In the same manner, the level of total mercury in the edible parts of the studied animals from the Lake Timsah and Bitter Lakes is lower than the safe concentration for human consumption recorded by FAO 1992.

3.2. Factors affecting the accumulation of mercury

As most trace elements, accumulation of Hg in the marine organisms is affected by abiotic and biotic variables, such as temperature, salinity, pollution sources, growth rate, sexual state, food supply, feeding mechanism, species variation and physiological state of the animals (Joiris *et al.*, 1998, 2000; Otchere *et al*., 2003).

The effect of growth rates (using regression curves), species, sex and sites variation (using ANOVA analysis) on the accumulation of mercury in the edible parts of the investigated organisms was studied. The regression curves of the relationships between length and level of mercury in *Mugil seheli*, *Paphia undulata* and *Gafrarium pectinatum* showed that the accumulation of mercury in *Mugil seheli* from Lake Timsah and Bitter Lakes and in *Paphia undulata* and *Gafrarium pectinatum* from Bitter Lakes is independent of length (r = 0.130, 0.253, -0.153 and –0.010, respectively), while it is dependent on length of *Paphia undulata* from Lake Timsah (r = 0.471). This result may indicate that *Paphia undulata* seems to be an accumulator of Hg and can be used as a bioindicator for mercury pollution. In contrast, the results of the other species from the two studied sites suggest that excretion of mercury equals its uptake. Sadiq and Alam (1992) studied the concentration of mercury in the bivalve (*Meretrix meretrix*) collected from different locations at Arabian Gulf and observed that only specimens from the stations close to oil drilling and port activities gave a positive significant correlation between mercury and their size. Riget *et al*. (1996) recorded that mercury concentration seems to be independent of size in the mussel (*Mytilus edulis*). In many studies, a positive correlation was reported between Hg concentration in marine fish and their size (Barber and Whaling, 1983; Braune, 1987 and Luten *et al*., 1987).

Table (2): Concentration of Hg in the edible parts of the present organisms in comparing to others studies elsewhere.

Species/location	Total Hg (µg/g wet wt.)	References
Fish		
Abu Qir Bay, Egypt	0.130 – 0.346	Emara, 1982
El-Mex Bay, Egypt	0.830 – 1.425	El Sokkary, 1984
El-Mex Bay, Egypt	0.466 – 0.796	El-Sharnouby *et al*., 1986
Alexandria coast, Egypt	0.120 – 0.835	Aboul-Dahab *et al*., 1986
Alexandria coast, Egypt	0.057 – 0.965	El-Rayis *et al*., 1986
Alexandria coast, Egypt	0.058 – 0.996	El-Nady, 1986
Alexandria coast, Egypt	0.609 – 1.018	Moharram *et al*., 1987
Western Mediterranean	0.032 – 0.232	de Leon *et al*., 1984
Izmir Bay, Turkey	0.119 – 0.307	Kucuksezgin and Balci, 1994
Lake Timsah	0.003 – 0.025	Present study
Bitter Lakes	0.001 – 0.008	Present study
Crab		
Alexandria coast, Egypt	0.068 – 0.325	Aboul-Dahab *et al*., 1986
Lake Timsah	0.016 – 0.117	Present study
Bitter Lakes	0.010 – 0.064	Present study
Shrimp		
Alexandria coast, Egypt	0.029 – 0.314	Aboul-Dahab *et al*., 1986
Indian Coast	<0.004 – 0.170	Sanzgiry *et al*., 1988
	0.100 – 0.400	Khan *et al*., 1989
Lake Timsah	0.005 – 0.015	Present study
Bitter Lakes	0.006 – 0.016	Present study
Bivalve		
Arabian Gulf, KSA	0.005 – 0.160	Sadiq and Alam, 1992
Huelva Estuary	0.020 – 1.180	Lopez-Artiguez *et al*., 1989
Portugal	0.022 – 0.248*	Amaral *et al*., 2000
Ghana	0.110 – 0.370*	Otchere, 2003
Ghana	0.040 – 0.840*	Otchere *et al*., 2003
Lake Timsah	0.001 – 0.036	Present study
Bitter Lakes	0.005 – 0.070	Present study
Background concentration (fish)	< 0.2	USPHS, 1997; Johnston *et al*., 2002
Typical values (marine fish)	0.01 – 1.50	Johannesson, 2002
Typical values (shellfish)	0.01 – 1.00	Johannesson, 2002
WHO limit	0.5	FAO, 1992

* dry wt.

Data of the ANOVA analysis for inter-species, inter-sex and inter-spatial variation in the accumulation of mercury (Table 3) showed that most of the inter-species variations were significantly different ($p < 0.05$). This result means that species with different habitats accumulate different concentrations of mercury. The magnification in the accumulation of mercury in the edible tissues was found in the order Fish < shrimp < bivalve < crab. The variation in the accumulation of Hg between the different studied species mainly attributed to the difference in feeding mechanisms, food supply, habitat and surroundings. For inter-sex and inter-spatial variations, only male and female of crab and shrimp from Lake Timsah showed significant variation in the accumulation of mercury. Also, *Paphia undulata* showed a significant inter-spatial variation. Sadiq and Alam (1992) recorded significant inter-station difference in Hg concentration in the clams *Meretrix meretrix* collected from the Arabian Gulf. Significant spatial variation in Hg concentrations in the cockle *Cerastoderma glaucum* from the Mediterranean Lagoon Etang de Thau was recorded by Szefer *et al*. (1999). The result of the inter-spatial variation confirm the above result of the regression curves which concluded that *Paphia undulata* is a good indicator for mercury.

Table (3): Effect of species, sex and site on the variation of Hg concentrations (ng/g wet t.) in the edible part of the studied organisms (ANOVA).

Effect	Lake Timsah		Bitter Lakes	
	F	p	F	p
Inter – species				
Fish x Crab	11.51	0.004	10.66	0.007
Fish x shrimp	0.25	0.621	14.27	0.001
Fish x Paphia	6.87	0.015	6.16	0.020
Fish x Gafrarium	---	---	28.71	0.000
Crab x shrimp	15.00	0.001	6.95	0.022
Crab x Paphia	11.59	0.003	5.95	0.025
Crab x Gafrarium	---	---	0.02	0.904
Shrimp x Paphia	8.27	0.008	0.74	0.399
Shrimp x Gafrarium	---	---	19.28	0.000
Paphia x Gafrarium	---	---	18.37	0.000
All	12.19	0.000	11.47	0.000
Inter – sex				
Fish	0.25	0.628	0.09	0.768
Crab	12.80	0.012	1.57	0.337
Shrimp	9.32	0.011	0.21	0.661
Inter – spatial	F	p		
Fish	4.28	0.053		
Crab	1.24	0.298		
Shrimp	0.89	0.356		
Paphia	4.51	0.042		

4. CONCLUSION

It can be concluded from the present study that the internal organs of the studied organisms contain mercury higher than the muscle tissues (edible parts) and the later is safe for human consumption according to WHO criteria. The magnification order of mercury in the edible tissues was as follow: Fish < shrimp < bivalve < crab. Statistical analysis of the present data showed variations in the mercury content with the species variation, sex, size of organism and the site of collection. The results of regression curves and inter-spatial variation indicated that bivalve species *Paphia undulata* could be used as bioindicator for mercury pollution in the surroundings. The results of this study suggested that the accumulation of mercury in the aquatic organisms of the present study may be dependent on some factors such as sources of pollution, growth rate of the organism, sex, size, and species variation.

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