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Heavy Metals in Some Fish Species and Bivalves from the Mediterranean Coast of Egypt

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Abstract

Biota samples were collected seasonally during three consecutive years from the Egyptian costal region along the Mediterranean Sea for analysis of Zn, Cu, Cd, Pb and Hg. In addition to bivalve Donax, seven commercially important species of fish were examined to provide a comprehensive assessment for the concentrations of these metals in the Mediterranean coastal region of Egypt. Despite of the presence of several land-based sources of contamination, particularly at El-Mex Bay and El-Maadiya, the results showed very weak increase in the concentration of copper, lead and mercury revealing no accumulation of these metals in the biological material, even in non-migrant bivalve species such as Donax. However, an increase in the concentration of zinc and cadmium in fish tissues was measured from 1993 to 1995. Regardless of the fish species, no significant differences were observed in concentrations of most metals between different locations and from season to season. Regarding concentrations of most metals, no interspecies differences could be also measured in either fish tissues or in bivalve Donax. The study indicated that the concentration of these heavy metals were well below the documented toxic levels for human consumption and represent baseline levels against which possible future heavy-metal contamination can be measured.

Keywords

Heavy Metals, Fish, Bivalves, Mediterranean Coast, Egypt

1. Introduction

Contamination of the Egyptian marine environment by heavy metals has become a subject of great deal of re-

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search in recent years [1]-[13]. Although heavy metals in trace concentrations are normal constituents of marine organisms, the continuing and increasing release of man's wastes into the marine environment will affect the characteristics of water, sediments, flora and fauna, and may prove toxic not only to marine life but also to man [14]-[18]. Contaminants accumulation in various fish and other marine species provides an estimate of integrated metal exposure. Muscle (flesh) is the tissue most commonly chosen because of the implications it carries for human consumption and health risk. Such studies are imperative since rapid industrialization and urbanization during the last two decades have affected the quality of the Egyptian coastal environment along the Mediterranean Sea [19]-[24].

A great variety of marine species, which offer most of the requisite features of a biological indicator as it has a world-wide distribution; is a non-migrant species of long life; is of reasonable size and easy to sample and has the ability to concentrate numerous pollutants, occur along the Mediterranean coast of Egypt. Of these Donax are proved to be useful as a monitor of heavy metals contamination. Fish could also be possible indictors in areas affected by human activities to describe the state of the environment to the public and the politicians [16] [25] assuming that they meet the other requirements for monitoring organisms, *i.e*. that they are plentiful, sedentary, accessible, of reasonable size and of known taxonomy [26].

The present study is a part of MED-POL programme, concerning with the evaluations of pollutants in the Mediterranean coastal regions of Egypt. It assessed the concentrations of heavy metals (Zn, Cu, Cd, Pb, and Hg) in the tissues of some commercial fish species and Donax.

2. Material and Methods

Sampling

Triplicate biota samples were collected seasonally during three consecutive years (1993, 1994 and 1995) from local commercial fishermen at six locations from Damietta in the east to El-Max Bay in the west (**Figure 1**) close to the sources of industrial contamination on the Egyptian coastal region along the Mediterranean Sea. Samples were also collected from Fuka which is substantially free from unnatural sources of contamination. These samples were analyzed for Zn, Cu, Cd, Pb, and Hg. In addition to Donax, which was the primary target species of the MED-POL international environmental monitoring programme for the Mediterranean countries, six fish species deemed commercially important in Egypt were examined (**Table 1**).

Samples were stored in polyethylene bags at −20˚C until brought to the laboratory for analysis. In order to obtain representative samples, composite samples were prepared. The extraction of these metals was performed by using acid digestion bombs (with a Teflon cup) and concentrated nitric acid [27]. Measurements were carried out by using a Varian Spectra AA-10 plus Atomic Absorption was equipped with GTA furnace and VGA-76 cold vapor units. The measurements of Zn and Cu were carried out by using the flame mode where Cd and Pb were measured using graphite furnace (GFAAS) Varian 10 plus, equipped with a deuterium background corrector. Cold vapor atomic absorption spectrophotometry (CV-AAS) was applied for Hg. Glassware utilized were

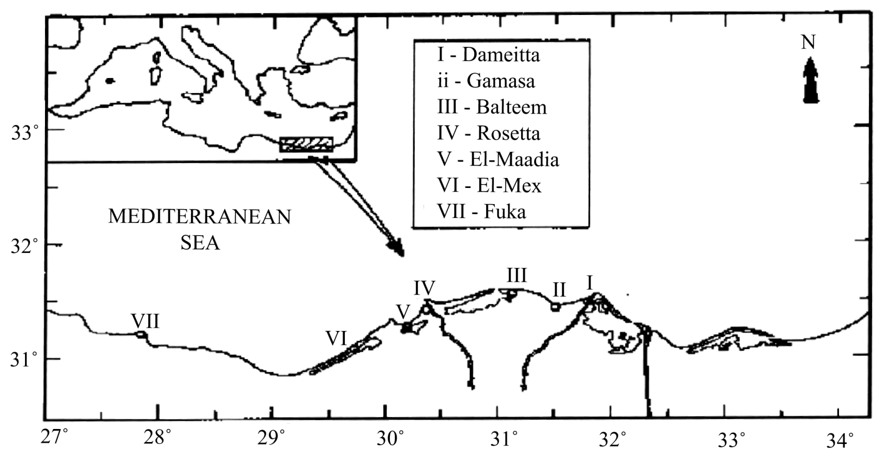

Figure 1. Map for the study area showing locations of sampling stations.

Table 1. Size and general characteristics of fish species and bivalves.

Species	No. of Organism (Composite Sample)	Size		General Characteristics	
		Length (cm)	Weight (g)	Demersal	Pelagic
Fish Species:					
Sardinella	3 - 5	16.5 - 21.0	54 - 106		X
Pagellus	3 - 5	12 - 163.8	27.6 - 36.9	X	
Solea vulgaris	5	19.0 - 26.5	340 - 540	X	
Mugilcephilus	3 - 5	22.5 - 24	160 - 426	X	
Scomber japonicas	3 - 5	22.5 - 24	136 - 169		X
Moron labrox	3 - 5	25 - 27	130 - 170		X
Bivalves:					
Donax sp.	70	1.5 - 3.0	0.3 - 1.1	X	

soaked in aqua-regia, rinsed with Milli-Q water and kept at 110˚C prior to its use. The reagents utilized were of high purity, appropriate for heavy metal analysis [28]. The standards were prepared from commercially available stock solutions (Merck). A calibration curve for each heavy metal was prepared prior to every batch of analysis.

In order to assess the precision and accuracy of the results, a quality control of the analysis was assured by routine analysis of DORM-2 reference material for the examined heavy metals, *i.e*. Zn, Cu, Cd, Pb, and Hg (**Table 2**). The reference material was supplied from the International Atomic Environmental Agency, Monaco (IAEA).

3. Results and Discussion

The results obtained from the analyses of Zn, Cu, Cd, Pb, and Hg in some species, *i.e. Sardinella*, *Pagellus*, *Solea vulgaris*, *Mugilcephilus*, *Scomber japonicas*, and *Moron labrox* in addition to *Donax Sp.* collected from several locations along the Mediterranean coast of Egypt during three consecutive years (**Table 3**).

Despite of the presence of several land-based sources of contamination, particularly at El-Mex Bey and El-Maadiya, and their discharges to the sea might constitute a hazard to marine biota and organisms including fish, shellfish as they will eventually end up in food chain [29] [30], the obtained results of the three years showed that the increase in concentrations of copper, lead and mercury was very little revealing no accumulation of these metals in the biological material, even in a non-migrant species of long life such as Donax (**Figure 2**). However, an increase in the concentration of zinc and cadmium in fish tissues was measured from 1993 to 1995. For example, the concentration of zinc during 1995 was almost 3 times higher than that of 1994 and 4 times higher than that of 1993. In case of cadmium, the concentration of 1995 was 2 times higher than that of 1994 and 4 times higher than that of 1993. Shriadah [31] as well as Shriadah and Emara [32] found no highly trace metals concentrations in the tissues of different fish species that could endanger consumer. Differences in the concentration of most metals, between the different fish species and locations examined, except the increase in Pb concentration during summer which could be a result of human impact and traffic increase. Seasonal variations in the concentration of these metals were also relatively little (**Figure 3**). Moreover, no interspecies differences in the concentration of most heavy metals in fish tissues (**Figure 4**) coincided with the variations in feeding habits and behavior of the different species [33]. Metal contents in tissues of demersal fishes such as *Solea-vulgaris*, *Mugilcephilus* were more or less comparable to those measured in tissues of pelagic fish *Moron labrox* throughout the study period. Habashi *et al*. [34] found also no significant differences in some metal concentrations, such as lead between species, size or age of fish collected from Western area of the Arabian Gulf. Non-parametric rank order correlation between the concentrations of different trace metals in different tissues was assessed by using the software [Minitab-12]. This indicated that the accumulation of metals by marine organisms was affected by several and complicated factors, such as wind, current regime, salinity variation during different months, impact of different pollution sources [35].

The concentrations of studied heavy metals in Donax, on the other hand, were found to increase with time and

Table 2. Concentration values ($\mu g \cdot g^{-1}$) of elements in DORM-2 reference materials of mussel homogenate.

Metal	DORM-2		
	Concentration Found	Certified Value	Accuracy %
Zn	27.5 ± 2.5	25.6 ± 2.3	107.4
Cu	2.40 ± 0.17	2.43 ± 0.16	98.8
Cd	0.047 ± 0.003	0.043 ± 0.008	109.3
Pb	0.070 ± 0.003	0.065 ± 0.007	107.6
Hg	4.65 ± 0.12	4.64 ± 0.26	102.1

Table 3. Concentrations ($\mu g \cdot g^{-1}$ dry wt) of Zn, Cu, Cd, Pb and Hg in different fish species and Donax.

Year→		1993		1994		1995	
Metal↓		Fish	Donax	Fish	Donax	Fish	Donax
Zn	Range M ± SD	12.5 - 40.1 18.9 ± 8.00	42.1 - 78.6 58.8 ± 12.50	17.2 - 32.6 25.0 ± 6.10	54.9 - 93.0 70.8 ± 11.2	18.7 - 72.6 31.5 ± 15.9	51.7 - 73.0 66.8 ± 10.00
Cu	Range M ± SD	1.8 - 17.8 7.3 ± 5.50	8.93 - 84.8 33.3 ± 27.90	2.0 - 16.7 6.4 ± 3.80	19.7 - 66.6 34.9 ± 15.00	1.9 - 9.4 5.3 ± 2.50	14.9 - 36.0 24.2 ± 7.00
Cd	Range M ± SD	0.03 - 0.07 0.05 ± 0.01	0.01 - 2.60 0.50 ± 0.90	0.03 - 0.34 0.09 ± 0.08	0.06 - 0.34 0.15 ± 0.09	0.03 - 0.92 0.19 ± 0.25	0.03 - 0.06 0.05 ± 0.00
Pb	Range M ± SD	0.6 - 3.5 1.5 ± 0.80	0.11 - 10.0 4.5 ± 3.80	0.2 - 1.8 0.9 ± 0.60	0.19 - 3.66 1.91 ± 1.20	0.3 - 1.6 0.6 ± 0.40	0.18 - 2.4 1.03 ± 0.70
Hg	Range M ± SD	0.11 - 0.87 0.49 ± 0.30	0.07 - 0.88 0.58 ± 0.30	0.03 - 1.67 0.45 ± 0.48	0.18 - 1.08 0.42 ± 0.33	0.17 - 0.87 0.34 ± 0.28	0.20 - 0.60 0.39 ± 0.10

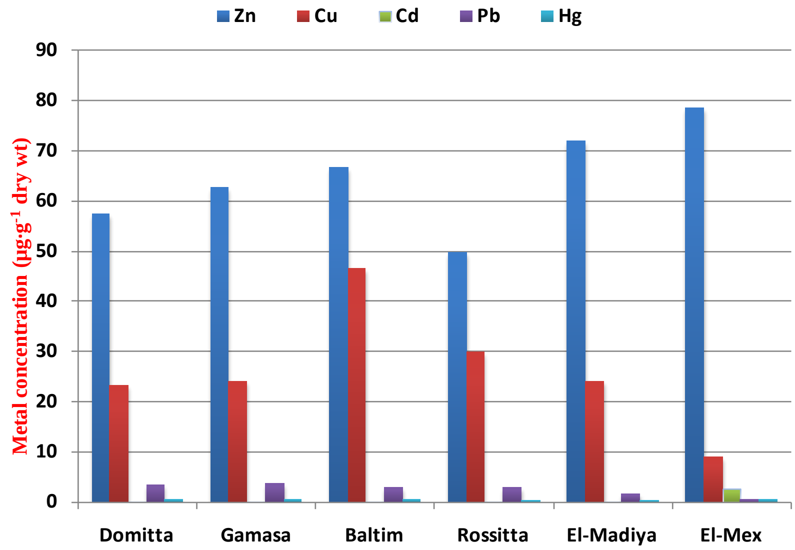

Figure 2. Regional changes of heavy metals concentration in Donax.

they were several times higher than those observed in the tissues of investigated fish species (**Table 3**). The increase was in the following order: Zn > Cu > Pb > Hg > Cd.

A great deal of data has been obtained, regardless of fish species, on the concentrations of Zn, Cu, Cd, Pb, and Hg, particularly for locations where heavy metal concentrations were already recognized as a problem (**Table 4**). From this table one can notice that the obtained levels of these metals in different tissues of fish species are within the reported values. Moreover the present concentrations are well below the documented toxic levels for human consumption. The National Health and Medical Council recommended that the standard concentration of Cu and Pb are 30 and 2 $\mu g \cdot g^{-1}$ wet weight respectively as well as the Western Australian Food and Drug Regu-

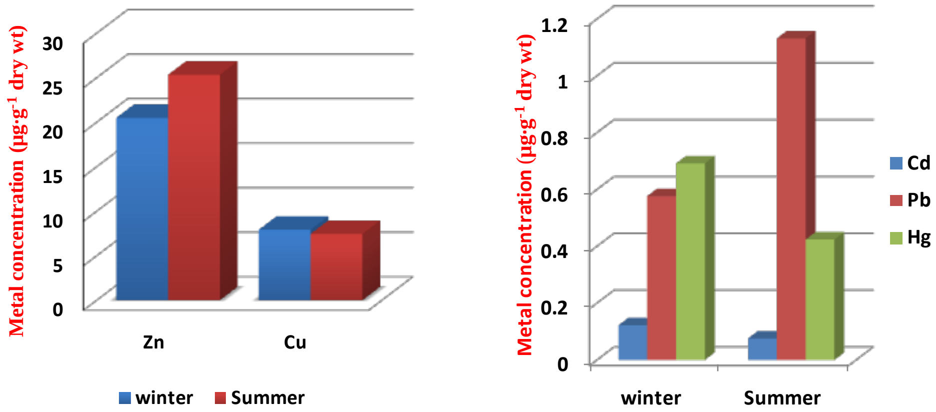

Figure 3. Seasonal changes of heavy metals concentration in fish.

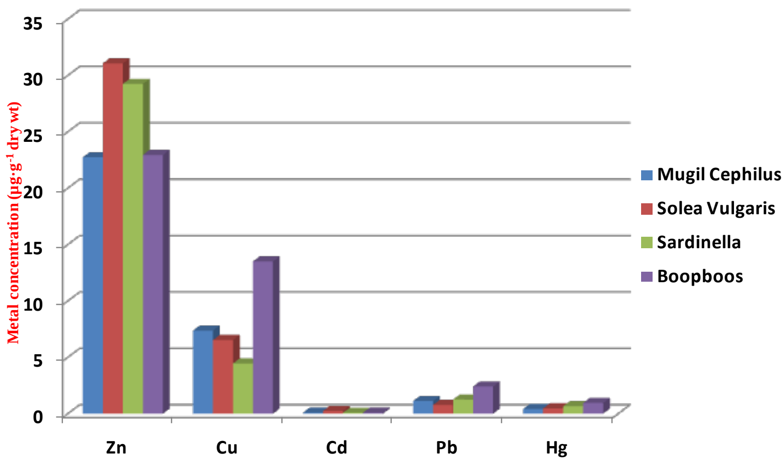

Figure 4. Inter-species changes of heavy metals concentration in fish.

lation listed a level of 40 μg·g^{-1} wet weight of zinc for human consumption [34]. According to WHO [36] the maximum permitted levels of Pb and Cd in humans are 2 and 0.3 μg·g^{-1} wet weight, respectively. Accordingly the present data concluded that these values represent base line levels against which possible future heavy metals contamination can be measured and the Egyptian coastal region is unpolluted one with respect to these metals.

The human health risk assessment has been estimated by comparing the metal intake from the consumption rate of seafood with the Provisional Tolerable Weekly Intake (PTWI) according to the calculation made by Bernhard [37]. For the metals Cu, Pb, Cd and Hg the PTWI were calculated to be 245,000, 2800, 300, 350 μg/70 kg man, respectively. According to General Authority for Fish Resource Development [38] the man whose weight 70 kg eats about 12 kg fish/year, thus the amount of Cd, Cu, Pb and Hg taken weekly by a person (**Table 5**) can be calculated according to the following equation:

Amount of heavy metal taken by person/week = concentration of heavy metal in muscles (μg·g^{-1}) × **Average consumption (g)**

The calculation in **Table 5**, demonstrated that, concentrations of Cd, Cu, Pb, and Hg in the muscles of different fish species from the Mediterranean coast line in Egypt are much lower than the PTWI values and accordingly there is no risk for the human consumption of these species in accordance with the findings of Tayel and Shriadah [39] who found that the concentrations of trace metals in different fish species from the Western Harbor of Alexandria were much lower than the PTWI values.

The data obtained help to assess the state of chemical contamination of several marine species, which is a necessary step in environmental protection [40], and to contribute to understanding the role of biota in accumulation of contaminants (metals) from water, which is a part of biomechanisms in aquatic ecosystems [41].

Table 4. Heavy metals concentration (μg·g^{-1} wet weight) in some fish species and Donax in the present study and other related areas.

Area	Species	Heavy Metals					Ref.
		Zn	Cu	Cd	Pb	Hg	
Mediterranean Coast Which Particular Location?	*Mugilcephilus*	20.85	6.75	0.08	1.02	0.38	Present study
	Solea vulgaris	31.07	6.53	0.24	0.77	0.47	
	Sardinella	29.25	4.45	0.07	1.25	0.60	
	Moron labrox	50.46	5.60	0.07	0.28	0.71	
	Donax	65.6	30.8	0.23	2.48	0.46	
Mediterranean Coast of Egypt							
Ras El-Bar	*Donax Sp.*	9.74	2.1	0.0098	11.08	9.74	[42]
Gamasa		9.54	0.93	0.0466	8.69	9.54	
Balteam		6.92	1.5	0.0108	9.17	6.92	
Rosetta		7.39	1.42	0.0124	9.19	7.39	
Ataturk Damlorie Turkey	*Cypriuscarpio*	9.72	2.23	Nd	Nd	Nd	[43]
	Capoettatrutta	5.32	1.68	Nd	Nd	Nd	
	Chondrostomaregium	7.93	2.29	Nd	Nd	Nd	
	A canthobroma-marmid	34.67	1.13	Nd	Nd	Nd	
Mediterranean Coast of Israel	Dolphins	21	1.2	0.1	-	8.9	[44]
Northeast Mediterranean (Turkey)							
Iskenderum	*Mugilcephalus*	23.5 ± 3.6	4.41 ± 1.71	1.07 ± 0.3	7.33 ± 2.11		[45]
Karatas		24.0 ± 3.87	5.12 ± 1.80	0.83 ± 0.07	5.44 ± 0.83		
Mersin		30.9 ± 9.98	3.92 ± 1.27	0.96 ± 0.44	5.97 ± 2.10		
El-Mex Bay, Egypy	*Mugilcephalus*	6.75	1.22	0.47	0.73		[46]
South Mediterranean Egypt							
Summer	*Mugilcapito (bouri)*	37.12 ± 11.3	1.19 ± 0.85	1.52 ± 0.1	Nd	0.13	[47]
Autumn		33.83 ± 3.64	1.86 ± 0.14	2.04 ± 1.01	Nd	0.06	
Winter		31.20 ± 1.87	0.48 ± 0.12	1.78 ± 0.00	Nd	0.11	
Spring		29.83 ± 9.78	1.07 ± 0.27	1.26 ± 0.27	Nd	0.07	
El-Mex Bay, Egypt	*Siganusrivulatus*	9.1 ± 1.35	1.80 ± 0.43	0.221 ± 0.20	0.22 ± 0.88		[48]
	Sargus	5.16 ± 0.92	1.07 ± 0.43	0.14 ± 0.05	0.59 ± 0.15		

Table 5. Amount of metals (Cu, Cd, Pb and Hg) taken by a person (70 kg/week) and their percentages to that of Provisional Tolerable Weekly Intake (PWTI). (For 250 gm sea food/week)

Species	Amount of heavy metals taken by a person per week (ppm)				Heavy metals intake/PTWI (%)			
	Cu	Cd	Pb	Hg	Cu	Cd	Pb	Hg
Mugilcephilus	1688	20	255	95	0.7	6.7	9.1	27.1
Solea vulgaris	1633	60	192.5	118	0.7	20.0	6.9	33.7
Sardinella	1113	17.5	312.5	150	0.5	6.0	11.2	42.9
Moronllabrox	1400	17.5	70.0	178	0.6	6.0	2.5	50.9
Donax	7700	57.5	620	115	3.14	19.3	22.1	32.9

4. Conclusion

During three consecutive years, results obtained from the analyses of Zn, Cu, Cd, Pb, and Hg in some species, *i.e. Sardinella*, *Pagellus*, *Solea vulgaris*, *Mugilcephilus*, *Scomber japonicas*, and *Moron labrox* in addition to *Donax Sp.* reveal that the levels of these metals in different tissues of fish species are within the reported values. Moreover, the present concentrations are well below the documented toxic levels for human consumption.

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