EGYPTIAN JOURNAL OF AQUATIC RESEARCH **ISSN: 1687-4285**
VOL. 33 NO. 1, 2007: 85-97

ASSESSMENT OF HEAVY METALS AND NONESSENTIAL CONTENT OF SOME EDIBLE AND SOFT TISSUES

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Keywords: Heavy metals, Crustacea, Cephalopoda, Bivalve, Fish, Mediterranean Sea.

ABSTRACT

The level concentrations of heavy metals (essential and nonessential) were measured in different marine biota including *cephalopoda, bivalve, crustacean* and fish. The results reveal that these organisms show more or less the same order of distribution for each of the metals studied. The average concentrations of heavy metals exhibited the following decreasing order: cephalopoda > bivalve > crustacean > fish. The levels of metals in all studied samples are still comparable to those in their corresponding in the Mediterranean Sea. K (98-181µg/g) and Ca (547-1472 µg/g) were present at the highest concentrations in all investigated samples. Octopus and Sepia do not follow the general pattern. The highest value of Metal Pollution Index (MPI) in cephalopod was recorded in *octopus* (9.55) followed by *sepia* (7.62). Among investigated bivalve, the highest values of MPI were recorded in *Mactra coralline* (2.87).

1. INTRODUCTION

Many marine organisms have the potential to bio-concentrate high levels of metals from their environment (Szeffer *et al.,* 1999). Metal bioaccumulation by marine organisms has been the subject of considerable interest in recent years because of serious concern that high levels of metals may have detrimental effects on the marine organisms and may create problems in relation to their suitability as food for humans. Several organizations have pointed out the need for monitoring heavy metals concentrations in the environment (UNEP/FAO, 1996) because of their toxicity, persistence and accumulation in the biota.

Metal pollution of the sea is less visible and direct than other types of marine pollution but its effects on marine ecosystems and humans are intensive and very extensive. As an indirect measure of the abundance and availability of metals in the marine environment, the bioaccumulation of metals by the tissues of marine organisms had studied. The bioaccumulation studies led to adoption of the bio-indicator concept. Fish are widely used as bio-indicators of marine pollution by metals (Evans *et al.,* 1993).

Fish provide omega-3(n-3) fatty acids that reduce cholesterol levels and the incidence of heart disease, stroke, and preterm delivery (Daviglus *et al.,* 2002 and Patterson, 2002). So levels of contaminates in fish are of particular interest because of the potential risk to humans who consume them.

2. MATERIAL AND METHODS

Four species of vertebrate; (*Mugil capito, Siganus rivulatus, Sparus auratus & Sardina pilchardus*), two species of bivalve (*Mactra spp., Mytilus* spp.); two species of crustaceans {*Portunus spp.*

(Crab) *Penaeus spp.* (Prawn)}; and two species cephalopod (*Sepia spp., Octopus* *spp.)*, were collected from local fishermen at Alexandria region (during October 2005) and kept frozen (-20°C) prior to analysis. Species were identified and prepared for analysis according to Bernhard (1976) and UNEP (1984). One gm (dry weight) of composite samples (about 0.2 gm, triplicate) was placed in each of the Teflon digestion vessel and concentrated HNO_3 was added in amount needed for digestion. The vessels were placed in a steel block oven at 50-60°C for three hours. In case of incomplete digestion, the above experiment was repeated till the solution becomes clear, which is then transferred into clean 25 ml volumetric flask and brought up to volume with DDW. Vials were tightly stopperd until analysis by AAS. The digestion of bivalve was made by the same experiment but with the addition of a mixture of hydrochloric and perchloric acid and heating in the oven for 5 hours (Harms, 1982). All laboratory equipment and containers were washed in 10% HNO_3 solution and deionized water rinse prior to each use (Burger *et al.*, 2001).

All the digested samples were analyzed by Flame Atomic Absorption Spectrophotometer (AAS) for determine Cu, Fe, Se, Zn and Cr and by Graphite furnace Atomic Absorption Spectrophotometer for determine Pb and Cd (National Research Central Laboratory, Cairo).

The method for total mercury measurement was occurred after dissolving the fish tissue in concentrated nitric acid under high pressure and temperature using a microwave digestion system. The mercury in solution was analyzed using a non-dispersive atomic fluorescence spectrometer. Digestion procedure for samples is described by Feng *et al*., (1994) and the procedure for instrumental measurement of mercury is given by Bloom and Fitzgerald (1988).

Procedures for collection, homogenization, and data reporting are covered by other appropriate NBS/GLSC methods. The trapped mercury is subsequently desorbed thermally and measured on a Tekran CVAFS Mercury Analyzer Model 2500.

The concentrations of all metals expressed by µg/g dry weight (DW). For each 10 analyzed samples, one parallel blank was preceded.

3. RESULTS AND DISCUSSION

The precision of technique was tested by replicate analysis of heavy metals (Table 1), using DORM-2 (dogfish muscle). Average recoveries were ranged from 81 to 102%. Number of sample, scientific, common name and feeding habits of each sample are summarized in Table (2). The mean concentrations of trace metals Ca, K, Cu, Fe, Se, Sr, Zn, Cr, Cd, Hg and Pb and their ranges in four groups (bivalve, crustaceans, cephalopod and vertebrate) as µg/g dry weight for all the species studied are presented in Tables 3 – 5.

Table (1): Replicate analysis for DORM-2 (dogfish muscle) using UNEP (1984) technique.

	Essential elements µg/g					Heavy metals µg/g		
Element	Cu	Fe	Se	Zn	Cr	Cd	Hg	Pb
Certified value	2.34	142.00	18.00	25.60	34.70	0.004	4.64	0.066
Measured value	2.35	130.33	17.62	65.10	32.50	0.036	4.00	0.057
Recovery	100.43	91.78	97.89	101.95	93.66	81.192	86.21	86.758

Table (2): number of samples and its common name and feeding habits of studied organisms.

Sample species	Common name	Feeding	No.
Bivalve			
Mactra spp.	Mediterranean mussel	filter-feeding	25
Mytilus spp. (Lamarck,1819)	Mediterranean mussel	filter-feeding	25
Crustacean			
Portunus spp. ((Linnaeus1758)	Blue pelagic swim crab	carnivorous fish and other animals	15
Penaeus spp. (leach 1815)	Shrimp (prawn)	mussel and crustacean	17
Cephalopod			
Sepia spp. (Linnaeus1758)	Cuttle fish	Small mollusks, shrimp, crabs, other crustaceans	8
Octopus spp. (Cuvier, 1797)	Common octopus	Small mollusks, shrimp, crabs, other crustaceans	4
Vertebrate			
Mugil capito (Cuvier,1829)	Black sea mullet	Epiphytic algae, detritus, small benthic or planktonic organism	7
Siganus rivulatus (Frosshääl, 1775)	Marbled spine foot Rabbit fish	Brown, red, green algae, phytoplankton, seaweeds	9
Sparus auratus (Linnaeus,1758)	Gilthead sea-bream	Carnivores: molluscus, mainly mussels, crustaceans, fish	8
Sardina pilchardus (Walbaum,1792)	European pilchard	Mainly planktonic crustaceans, larger planktonic animals	9

Burger *et al.,* (2001) found that the dry weight ranged from 23% to 33% of the corresponding wet weight (i.e., water content of 67 – 77%). A perusal of Fig. (1) shows that; *Octopus spp.* and *Sepia spp.* (cephalopod) were consistently highest for all studied metals except Se and Hg. These high levels were may be due to the food habit where cephalopod eats small moluscan, shrimp, crabs and other crustaceans. *Portunus spp.* had the highest levels of selenium which recorded 3.9 (1.7-4.3) µg/g. On the other hand, vertebrate represented the least abundant of all studied metals except Se and Hg, which recorded 2.4 and 0.12 µg/g, respectively, (Tables 3-5). Also, there was insignificant difference between the averages in bivalve and crustacean of all studied metals. There were interspecific differences in levels of these metals. Zinc recorded the highest values of these essential metals, on the other hand, chromium recorded the lowest values.

Copper is the most toxic metal after mercury and silver (Clark, 1989). The concentrations of copper fluctuated between 0.9µg/g found in both *Sparus auratus* and *Mugil capito* and 11.7µg/g in *Octopus spp.* (Table 3). Copper ranged from 0.6 to 1.2 with mean value 1.0µg/g in *Siganus rivulatus*.

Iron is the most abundant transition element, and probably the most well known metal in biologic systems (Fr̉stner and Wittmann 1983). Iron concentrations in investigated organisms ranged from 6.4µg/g (*Mugil capito*) to 97.9 µg/g (*Octopus spp.*), this highest amount is higher than those reported in cephalopods by Miramand and Bentley (1992) since Fe values in *Eledone cirrhosa* (25µg/g) and *Sepia officinalis* (14µg/g).

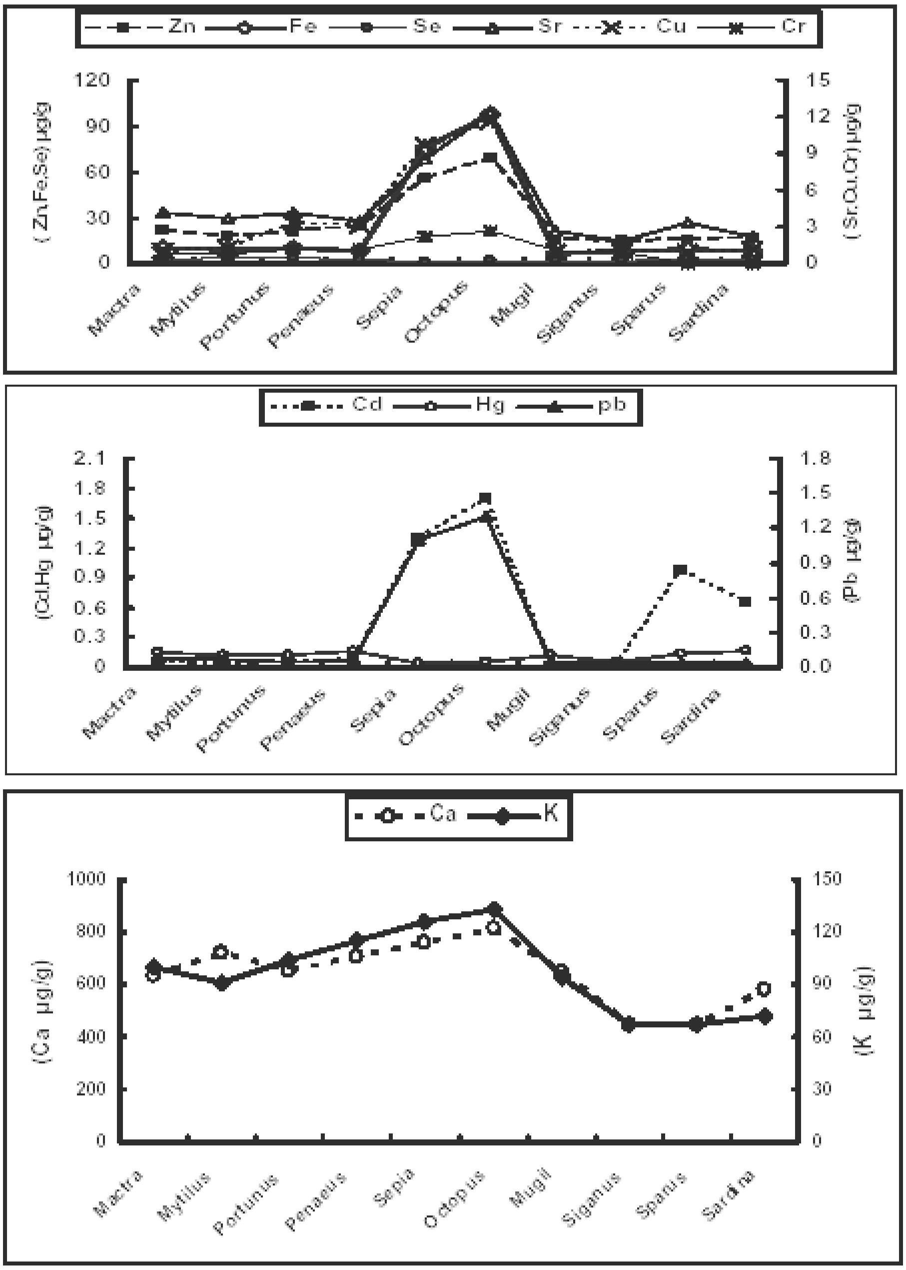

Fig. (1): Mean concentrations of trace metals in present studied marine organisms (µg/g dry weight).

Table (3) Mean concentrations, ranges and MPI of essential elements in studied organisms.

Common name	Cu	Fe	Se	Sr	Zn	Cr	MPI
Bivalve							
Mactra spp.	1.0 (0.5-2.1)	10.5 (7.7-18.7)	2.8 (1.4-4.3)	4.1 (2.4-6.8)	22 (18-35)	0.85 (0.7-1.3)	3.62
Mytilus spp.	1.3 (0.7-2.5)	9.4 (7.2-16.1)	3.4 (1.5-4.7)	3.7 (1.8-4.1)	18 (17-20)	0.79 (0.6-1.1)	3.60
Averages	1.15	9.9	3.1	3.9	20	0.82	
Crustacean							
Portunus spp.	3.4 (1.6-5.3)	10.0 (8.0-11.0)	3.9 (1.7-4.3)	4.1 (1.5-4.7)	21 (19-24)	1.1 (0.84-1.2)	4.82
Penaeus spp.	3.1 (1.4-6.4)	8.4 (6.6-10.4)	2.4 (1.0-2.7)	3.5 (1.2-4.0)	24 (19-27)	1.2 (0.8-1.4)	4.30
Averages	3.25	9.2	3.2	3.8	22	1.15	
Cephalopod							
Sepia spp.	9.7 (5.1-12.7)	75.7 (20-110)	1.1 (0.9-1.7)	8.5 (3.1-20.7)	55 (34-67)	2.2 (1.3-2.9)	9.70
Octopus spp.	11.7 (4.8-15.6)	97.9 (30-210)	1.8 (0.9-2.1)	12.4 (9.0-15.0)	69 (55-84)	2.7 (1.7-3.1)	12.97
Averages	10.7	86.8	1.5	10.5	62	2.45	
Vertebrate							
Mugil capito	0.9 (0.7-1.5)	6.4 (5.5-7.4)	1.9 (1.0-3.1)	2.7 (1.7-3.2)	16 (14-17)	0.99 (0.7-1.4)	2.79
Siganus rivulatus	1.0 (0.6-1.2)	8.2 (7.0-10.0)	2.3 (1.1-2.8)	1.8 (1.3-2.4)	15 (15-16)	0.87 (0.7-1.1)	2.76
Sparus auratus	0.9 (0.7-1.1)	9.1 (7.1-11.4)	3.0 (1.2-4.4)	3.4 (1.9-4.7)	16 (14-19)	0.97 (0.5-1.5)	3.30
Sardina pilchardus	1.1 (0.5-1.8)	8.0 (6.3-9.8)	2.5 (1.2-2.9)	2.2 (0.9-2.8)	17 (15-20)	0.66 (0.2-0.97)	2.86
Averages	0.98	7.93	2.4	2.5	16	0.09	

Although selenium is an essential micronutrient, it can be toxic at high levels (Coyle *et al.*, 1993). A concentration of about 1µg/g (wet weight) in prey is the threshold for Se toxicity in some fish, while muscle concentration of 2.6µg/g (wet weight) is associated with adverse in the fish themselves (Lemly 1993a and b). In our study, there is no problem for the fish themselves, hence the values ranged from 1.1µg/g in *Sepia* spp. to 3.9µg/g in *portunus* spp. Burger and Gochfeld (2005) estimated concentrations of selenium in small and large Shrimp ranged from (0.14 - 0.16 & 0.19 – 0.23 µg/g), wet weight, respectively. These were lower than that of the present study; hence the mean in *penaeus spp.* which recorded 2.4 µg/g with averages (1.0-2.7µg/g). There is no significance difference in concentrations of Sr and Se as shown in Table (3), except in *Sepia spp.* and *Octopus spp*., hence recorded high levels (3.1 - 20.7 & 9.0 – 15 µg/g, respectively,). Zinc is responsible for some important biological functions and relatively high level is necessary to maintain these biological functions. It is a constituent of all cells, and of many enzymes (Oehlenschlager, 1997). Zinc was the first abundant essential element in the soft part of studied species. This high values confirms obtaining majority of zinc from dietary sources rather than from water (Kargin, 1996). The highest value was observed in (*Octopus spp.*).

The concentrations obtained for Zn are in agreement with the work of El Nabawi *et al.,* (1987), who studied Zn in fish from the Alexandria region and obtained values ranging from 16.5 µg/g to 40.5 µg/g. However, Prudente *et al.,* (1994) studied metal levels in some commercial fish species from Manila Bay, Philippines, and obtained higher results (39-124 µg/g). Considering cephalopods, Miramand and Bentley, (1992) measured 105 ug/g and 62 µg/g in *E.cirrhasa* and *S.officinalis*, recpectively. These values agree with our obtained data for *octopus spp.* in the present work.

Chromium is essential trace element, although its toxicity at high doses (Burger and Gochfeld, 1995). Levels in our commercial fish were low, suggesting that predators or scavengers would not be at risk from chromium if they ate them in the wild. It is clear from Table (3) that, Cr recorded the least abundance of studied essential elements.

There is no significant difference between averages of Cr in both bivalve and vertebrate. On the other hand, the averages recorded 1.15 and 2.45 µg/g in crustaceans and in cephalopod, respectively. Burger and Gochfeld, (2005) estimated the ranges of Cr in small and large prawn (0.04 - 0.03 & 0.03µg/g, wet weight, respectively). The ranges in the present study were higher than ranges recorded by the previous author.

Cadmium, mercury and lead are toxic heavy metals. There were no consistent differences in these metal levels. This group of toxic reflects an exogenous influence that may be related to environmental pollution.

Adverse effects from cadmium can occur in fish dietary levels of 1.0 µg/g (Eisler, 1985). Whole body burdens of cadmium in fish from the United States overall average 0.03µg/g (wet weight), with the maximum being 0.22 µg/g (Schmitt and Brumbaugh, 1990); current levels can range as high as 0.54 µg/g in free ranging fish (Burger *et al.,* 2002).

Burger and Gochfeld (2005), in small and large prawn, were (00013 - 0.00002 & 0.004–0.001), wet weight, respectively. In contract the present study declared that levels of cadmium were below all these ranges. The lowest concentrations were recorded in the fish and highest in the cephalopod, as shown in Table (4).

Codex Alimentarius Commission (2002) has standards or proposed standards for Cd in mollusks (1.0 µg/g) and crustacean (0.5 µg/g). For cadmium the joint Monitoring Programmed established under the Osla and Paris Commissions set a guideline of 0.2µg/g in fish and below 2 µg/g in mussels.

However, Eisler (1987) concluded that, when the level of Hg in fish muscle was 5µg/g (wet weight) can be associated with emaciation, decreased coordination, loss of appetite, and mortality in fish themselves, while concentrations of 15µg/g are required for adverse effects in predators that eat the fish (Wiener and Spry, 1996). In our study, a concentration of Hg does not reach to this level, so it does not pose a problem for the studied organisms themselves and the consumers. Both of *Penaeus spp.* and *sardina pilchardus* had the highest levels of mercury of magnitude 0.17 (0.08-0.29) & 0.17 (0.13-0.32)µg/g, respectively (Table 4).

This is agreeing with Burger and Gochfeld (2005), the levels varied among species by an order of magnitude for most metals, except for mercury (Table 4). Harmful effects occur at dietary levels 5.5 µg/g (WHO, 1991).

Table (4): Mean concentrations, ranges and MPI of heavy metals in studied organisms.

Common name	Cd	Hg	Pb	MPI
Bivalve				
Mactra spp.	0.06 (0.03-0.19)	0.15 (0.011-0.33)	0.085 (0.03-0.17)	0.091
Mytilus spp.	0.048 (0.031-0.18)	0.12 (0.061-0.270)	0.07 (0.06-1.80)	0.074
Averages	0.054	0.135	0.078	
Crustacean				
Portunus spp.	0.59 (0.44-0.133)	0.13 (0.066-0.22)	0.05 (0.02-0.11)	0.073
Penaeus spp.	0.088 (0.04-0.147)	0.17 (0.08-0.29)	0.06 (0.03-0.14)	0.096
Averages	0.074	0.15	0.055	
Cephalopod				
Sepia spp.	1.3 (0.6-1.9)	0.044 (0.031-0.066)	1.1 (0.8-2.7)	0.40
Octopus spp.	1.7 (0.8-2.1)	0.053 (0.02-0.08)	1.3 (0.7-2.8)	0.49
Averages	1.50	0.049	1.2	
Vertebrate				
Mugil capito	0.02 (0.01-0.03)	0.125 (0.055-0.24)	<0.03	0.042
Siganus rivulatus	0.03 (0.02-0.05)	0.052 (0.044-0.11)	<0.03	0.036
Sparus auratus	0.04 (0.03-0.07)	0.14 (0.05-0.29)	<0.03	0.055
Sardina pilchardus	0.02 (0.01-0.04)	0.17 (0.13-0.32)	<0.03	0.047
Averages	0.028	0.12	<0.03	

Lead is a neurotoxin that cause behavioral deficits in vertebrates (Weber and Dingel, 1997) and an cause decreases in survival, growth rates and metabolism (Eisler, 1988; Burger and Gochfeld, 2000). Dietary levels as low as 0.1-0.5 µg/g (wet weight) is associated with learning deficits in some vertebrates (Eisler, 1988). In our study, the levels of lead in some species averaged within this range, suggesting that some sensitive predatory vertebrates may be impacted by the levels of lead in these fish. Lead, in the studied organisms (<0.03 to 2.8 µg/g), this may be explained by the relatively low rate of binding the lead metal to the SH groups in the muscles. In addition, the low solubility of salts restricts movement across the cell membranes (Moore and Ramamoorthy, 1984). There is no difference between mean concentrations of lead in all species of fish. This is agrees with Moore & Ramamoorthy (1981), where the residues of fish muscle can not be related to the concentrations in water, in addition no correlation was found between the feeding habit and tissues levels. In prawn same author recorded 0.17 (0.08 - 0.29) µg/g were lower than recorded as wet weight (0.29-0.24 µg/g) in small prawn and (0.17-0.15 µg/g) by Burger and Gochfeld, (2005). The Codex Alimentarius Commission, (2002) specifies levels for Pb in fish (1.0 µg/g) and in mollusks 2.5 µg/g.

Contaminations in marine organisms can pose a health risk to the fish themselves, to their predators, and to humans who consume them. The concentrations of Se, Zn, Cr, Cd, Hg and Pb in the studied organisms were below the risk international standards (Se: 0.3–2.0 with median 1.5; Zn: 40–100 with median 50; Cr: 1.0; Cd: 0.05–2.0 with median 0.3; Hg: 0.1–1.0 with median 0.5 and Pb:

0.5–10.0 with median 2.0µg/g, wet weight) given by United Nations Food and Agriculture Organization for Reference Dose (risk-based); Environmental Protection Agency (EPA, 2004).

Potassium and calcium are the most abundant major elements. However, large variations between individuals were found. It is clear from Table (5) that, average values of calcium in all organisms were recorded highest and fluctuated between 529 µg/g in vertebrate and 788 µg/g in cephalopod.

While potassium ranged from 67 µg/g in both *Siganus rivulatus* and *Sparus auratus* to 133 µg/g in *octopus* spp.

Concentrations do not constitute a hazard for consumer. People should not only eat smaller quantities of fish known to accumulate metals but also should eat a diversity of fish to avoid consuming unhealthy quantities of metals. Also consumers should bear in mind that standards have a margin of safety but, conversely, that action levels are not necessarily risk based. The dose of toxic metal that one obtains from fish depends on the quantity of fish consumed.

To compare the total metal content in the different sampling sites investigated in this study, the metal pollution index (MPI) was used with the formula (Usero *et al.*, 1996 and 1997).

Table (5): Mean concentrations, ranges & MPI of major element in studied organisms.

Common name	Ca	K	MPI
Bivalve			
Mactra spp.	635 (421-1531)	100 (77-145)	251.99
Mytilus spp.	720 (365-1760)	91 (71-119)	255.70
Averages	668	96	
Crustacean			
Portunus spp.	651 (490-891)	104 (88-136)	260.20
Penaeus spp.	710 (545-1190)	115 (94-148)	285.75
Averages	681	110	
Cephalopod			
Sepia spp.	760 (550-1310)	126 (99-168)	309.45
Octopus spp.	815 (547-1472)	133 (98-181)	329.23
Averages	788	130	
Vertebrate			
Mugil capito	644 (575-945)	94 (77-123)	246.04
Siganus rivulatus	447 (360-545)	67 (59-93)	173.06
Sparus auratus	444 (285-610)	67 (54-89)	172.48
Sardina pilchardus	580 (310-742)	72 (54-81)	204.35
Averages	529	75	

$MPI = (M_1 \times M_2 \times M_3 \times \ldots \times M_n)^{1/n}$ where, M_n is the concentration expressed in µg/g in dry weight (dw) of any investigated metals. From Fig. (2), it is clear that MPI in major, essential and heavy metals recorded higher in Sepia and octopus (cephalopod) and followed by crustacean followed by bivalve and the lower occurred in vertebrate. On the other hand MPI of essential metals were higher than of heavy metals.

Moreover, the risk to man from consumption of metals in fish/sea food has been discussed by Bernhard (1982); WHO (1972 and 1989); USPA (1991) and ANSFA (1998). This can be estimated by comparing the metal intake from an observed consumption rate of seafood with a Provisional Tolerable Weekly Intake (PTWI). For the metals Selenium, copper, mercury, cadmium and lead PTWI values were calculated to be 2450, 245000, 350, 490 and 1750 µg per 70 kg man, respectively.

Consumption rate were 260.04, 1.04, 3.12, 1.55, 0.414 and 0.96 gm weekly for 70 kg human from fishes, *Portunus spp.*, *Penaeus spp.*, *Sepia spp.*, *Octopus spp.* and bivalves, respectively; General authority of fish resources and development (2004). The percentage of the present concentrations to that of PTWI was estimated for these metals (Table 6), which illustrated that the reported concentrations of trace metals in fish were low except for Se and Hg, so there is no risk from the human consumption of these fish. Although sea foods reported in the present study

(cephalopod, crustacean and bivalves) had higher concentrations for trace content in their bodies than that of fish studied, they showed lower values of PTWI because their human consumption rate was very low compared with that of fishes.

Table (7) showed the averages of condition factors of the different fish species. These averages were calculated, as shown by Le Cren (1951). The most species have an average condition factor higher than one, except Sardine species (= 0.563). This means that the measured fishes were healthy and the environment did not affect their activities (Table 7).

According to Aboul-Nagah and Allam (1997), CF for the different size groups of Sardine were (0.65-0.85).

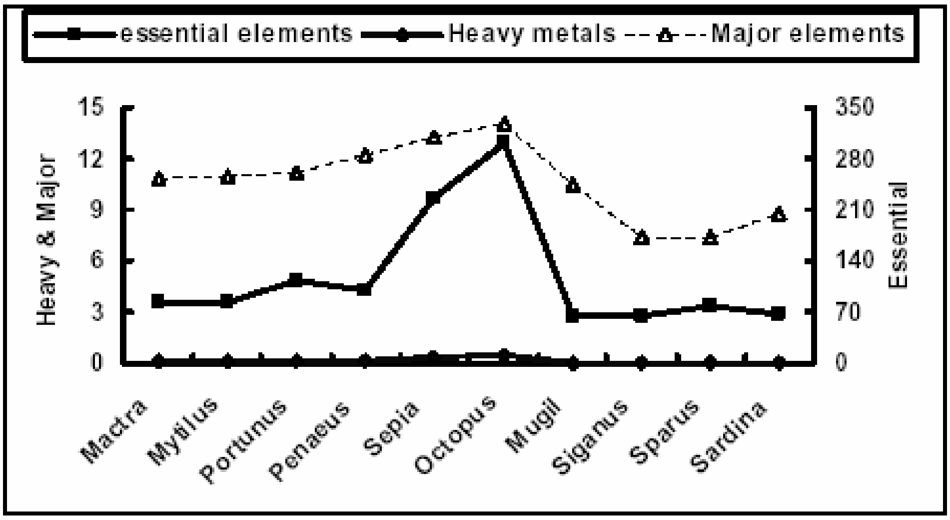

Fig. (2): Mean MPI in the present studied marine organisms.

Table (6): Mean concentrations of Trace metals studied in some fish species and their of percentage Provisional Tolerable Weekly Intake (PTWI).

	Concentrations µg/g					% of the present concentrations to that of PTWI				
Fish species	Se	Cu	Hg	Cd	Pb	Se	Cu	Hg	Cd	Pb
Mactra spp.	2.8	1.0	0.150	0.060	0.085	0.110	0.0004	0.041	0.012	0.0047
Mytilus spp.	3.4	1.3	0.120	0.048	0.070	0.133	0.0005	0.033	0.009	0.0038
Portunus spp.	3.9	3.4	0.130	0.590	0.050	0.223	0.0020	0.052	0.169	0.0040
Penaeus spp.	2.4	3.1	0.170	0.088	0.060	0.306	0.0039	0.152	0.056	0.0107
Sepia spp.	1.1	9.7	0.044	1.300	1.100	0.070	0.0061	0.020	0.411	0.0974
Octopus spp.	1.8	11.7	0.053	1.700	1.300	0.030	0.0020	0.006	0.144	0.0308
M. capito	1.9	0.9	0.125	0.020	0.030	20.166	0.0955	9.287	1.061	0.4458
S. rivulatus	2.3	1.0	0.052	0.030	0.030	24.412	0.1061	3.863	1.592	0.4458
S. auratus	3.0	0.9	0.140	0.040	0.030	31.842	0.0955	10.402	2.123	0.4458
S. pilchardus	2.5	1.1	0.170	0.020	0.030	26.535	0.1168	12.631	1.061	0.4458

Table (7): Ranges of lengths and weights of the tested individuals of the different species of fish and condition factor (CF).

Scientific name	Length (cm)	Weight (gm)	Condition Factor	Averages of CF
Mugil capito	14.1 – 20.2	56.7 – 88.4	2.22 - 1.07	1.438
Siganus rivulatus	11.3 – 13.2	49.2 – 60.1	3.41 - 2.61	2.973
Sparus auratus	9.5 - 14.4	23.1 – 29.4	2.69 - 0.98	1.538
Sardina pilchardus	9.6 - 16.8	11.4 – 14.5	1.288 - 0.306	0.563

REFERENCES

Aboul-Nagah, W.M. and Allam, S.W.: 1997, Comparison studies of some trace metals in Tilapia spp. from Lake Mariut, Egypt. *Mar. Sci. JKAU*, **8**: 111-125.

Australia New Zealand Food Authority (ANZFA): 1998, The Australian Market Basket Survey 1996, Aus. Info, Caneberra.

Bernhard, M.: 1976, Manual of methods in aquatic environment research. Part 3. Sampling and analysis of bio; ogical material. FAO Fish. Tech. pap. No. 158

(FIRI/T158), pp: 124. FAO, Rome. Bernhard, M.: 1982, Levels of trace metals in the Mediterranean (Review paper). *Ves J. Etud. Pollut., Cannes, C.I.E.S.M.*, 237-243.

Bloom, N.S. and Fitzgerald, W.F.: 1988, Determination of volatile mercury species at the pictogram level by low-temperature gas chromatograph with cold-vapor atomic fluorescence detection. *Anal. Chim. Acta* **208**: 151-161

Burger, J. and Gochfeld, M.: 1995, Growth and behavioral effects of early postnatal chromium and manganese exposure in herring gull (Larus argentatus) chicks. *Pharmacol. Biochem. Behav.* **50**: 607 – 612.

Burger, J. and Gochfeld, M.: 2000, Effects of lead on birds (Laridae: a review of laboratory and field studies. *J. Toxicol. Environ. Health* **3**: 59 – 78.

Burger, J. and Gochfeld, M.: 2005, Heavy metals in commercial fish in New Jersey. *Enviromental Research* 99: 403-412.

Burger, J.; Gaines, K.F. and Gochfeld, M.: 2001, Ethnic differences in risk from mercury among Savannah River fishermen. *Risk Anal*. **21**: 533 – 544.b

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

Clark, R.B.: 1989, Marine Pollution, 2 nd Edn. Oxford. Codex Alimentarius Commission: 2002, Codex Committee on Food Additives and Contaminants: Maximum level for lead in fish. Joint FAO/WHO Food Standards Programme. Document CL-2002 10 - FAC. United Nations, Rome.

Coyle, J.J.; Ingersoll, D.R.; Fairchild, C.G. and May, T.W.: 1993, Effects of dietary selenium on the reproductive success of bluegills (Lepomis) macrochirus). *Environ. Toxicol. Chem.* **12**: 551 - 565.

Le Cren, E.D.: 1951, the length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). *J. Anim. Ecol.,* **20 (2)**: 201-219.

Daviglus, M.; Sheeshka, J. and Murkin, E.: 2002, Health benefits from eating fish. *Comments Toxicol.* **8**: 345 -374.

Eisler, R.: 1985, Cadmium—hazards to fish, wildlife and invertebrates: a synoptic review. US Fish and Wildlife Service Reports, No. 85 (1–2), Washington, DC.

Eisler, R.: 1987, Mercury Hazards to Fish, Wildlife and Invertebrates: A Synoptic Review. US Fish and Wildlife Service Report, No: 85: 1-10, Washington, DC.

Eisler, R.: 1988, Lead Hazards to Fish, Wildlife and Invertebrates: A Synoptic Review. US Fish and Wildlife Service, Washington, DC.

El Nabawi, A.; Heinzow, B. And Kruse, H.: 1987, As, Cd, Cu, Pb, Hg, and Zn in fish from the Alexandria region, Egypt. *Bull Environ Contam Toxicol.* **39(5)**: 889-97.

Environmental Protection Agency (EPA): 2004, Update: National listing of fish and wildlife consumption advisories. Cincinnati, Ohio, US Environmental Protection Agency.

Evans, D.W.; Dodoo, D.K. and Hanson, P. J.: 1993, Trace elements concentrations in fish livers Implications of variations with fish size in pollution monitoring. *Mar. pollut Bull*: **26(6)**: 29 –34.

Fr̉stner, U. and Wittmann, G.T.W.: 1983, Metal pollution in the aquatic environment. Springer-Verlag, Berlin, pp: 30-61.

Feng, Y. and Barratt, R.S.: 1994, Digestion of dust samples in a microwave oven. *Sci. total Environ.* **143**: 157-161.

General authority of fish resources and developments, Egypt: 2004, 135pp.

Harms, U.: 1982, A methodological approach for trace analysis of lead and cadmium in organic matrices submitted for publication of ICES leaflets on "Techniques in Marine Chemistry".

Kargin, F.: 1996, Seasonal changes in levels of heavy metals in tissues of *Mullus barbatus* and *Sparus aurata* collected from Iskenderun Gulf (Turkey). *Water, Air and Soil Pollut.,* **90**: 557-562.

Lemly, D.A.: 1993a, Guidelines for evaluating selenium data from aquatic monitoring and assessment studies.

Environ. Monit. Assess. **28**: 83- 100. Lemly, D.A.: 1993b, metabolic stress during winter increases the toxicity of selenium to fish. *Aquat. Toxicol*. **27**: 133 – 158.

Miramand, P. and Bentley, D.: 1992, Concentration and distribution of heavy metals in tissues of two cephalopods, Eledone cirrhosa and Sepia officinalis, from the French coast of the English Channel. *Mar. Biol.* **114**: 407-414.

Moore, J.W. and Ramamoorthy, S.: 1981, Heavy metals in naturals. Springer-verlag, New york.

Moore J.W. and Ramamoorthy, S.: 1984, Heavy metals in natural waters. Springer. Verlag. New York, Berlin, Heidelberg, Tokyo.

Oehlenschlager, J.: 1997, Seafood from procedure to consumer: marine fish- a source for essential elements. In: Lutten J.B., Borresen, T., Oehlenschlager, *J. (eds) Elsevier, Amsterdam,* vol.**38**: 587 - 607.

Patterson, J.: 2002, Introductioncomparative dietary risk: balance the risks and benefits of fish consumption. *Comments Toxicol*. **8**: 337 – 344.

Prudente, M.; Ichihasi, H. and Tatsukawa, R.: 1994, Heavy metal concentrations in sediments from Manila Bay, Philippines and inflowing rivers. *Environmental Pollution* **86**: 33 – 83.

Schmitt, C.J. and Brumbaugh,W.G.: 1990, National contaminant biomonitoring program: concentrations of arsenic, cadmium, copper, lead, mercury, selenium and zinc in US Freshwater fish, 1976 – 1984.*Arch. Environ. Contam. Toxicol.* **19**: 731 – 747.

Szeffer, P.; Wolowicz., M.; Kusak, A.; Deslous-Paoli, J.M.; Czar-nowski, W.; Frelek, K. and Belzunce, M.J.: 1999, Distribution of mercury and other trace metals in the cockle *Cerastoderma glaucum* from Mediterranean Lagoon Etange *Thau. Arch. Environ. Contam. Toxicol.* **36**: 56 – 63.

UNEP: 1984, Sampling of selected marine organisms and sample preparation for trace metal analysis. Reference Methods for Marine pollution studies No. 7 Rev. 2 UNEP, Geneva.

UNEP/FAO: 1996, Final Reports on research projects dealing with eutrophication and heavy metal accumulation. UNEP.

Athesis. 1996. MAP Tech. Rep. Ser.104: 238 .

UNEP/FAO/WHO: 1987, Assessment of the state of pollution of the Mediterranean Sea by mercury and mercury compounds.

UNEP. Athesis. 1987. MAP Tech. Rep. Ser.18: 288 pp.

UNEP/FAO/WHO: 1996, Assessment of the state of pollution of the Mediterranean Sea by zinc, copper and their compounds.

UNEP. Athesis. 1990 MAP Tech. Rep. Ser.105: 288 pp. Usero, J.; Gonzales-Regalado, E. and Gracia, I.: 1996, Trace metals in bivalve mollusks *Chameleo gallina* from the Atlantic Coast of southern Spain. *Mar. Pollut. Bull*. **32**: 305 - 310.

Usero, J.; Gonzales-Regalado, E. and Gracia, I.: 1997, Trace metals in bivalve molluscs Ruditapes *decussatus* and *Ruditapes philippinarum* from the Atlantic Coast of southern Spain *Environ. Int.,* **23**: 291 - 298.

United States Environmental Protection Agency (USPA): 1991, Selenium and Compounds, Integrated Risk Information System life CASRN- 7782 - 49 -2.

Weber, D.N. and Dingel, W.M.: 1997, Alterations in neurobehavioral responses in fishes exposed to lead and lead-chelating agents. *Am. Zool.* **37**: 354 – 362.

Wiener, J.G. and Spry, D.J.: 1996, Toxicological significance of mercury in freshwater fish. In: Beyer, W.N., Heinz, G.H., Redmon-Norwood, and A.W. (Eds.), Environmental contaminants in wildlife: interpreting tissue concentrations. SETAC, Lewis Publ., Boca Raton, FL.

World Health Organization (WHO): 1972, Evaluation of mercury, lead, cadmium and food Additives Amaranth, Diethylpyrocarbonate and Octyl Gallate, 16th report of the Joint FAO/WHO Expert Committee on Food Additives Technical Report Series 505, WHO.

World Health Organization: 1989, Toxicological Evaluation of Certain Food Additives and Contaminants 33rd meeting of the joint FAO/WHO. Expert Committee on Food Additives, WHO, Geneva.

World Health Organization, 1991, IPCSInorganicmercury. *Environ. Health Criteria* **101**: 42- 58.