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ACCUMULATION OF SOME TRACE METALS AND FLUORIDE IN ECONOMICALLY IMPOTANT FISH SPECIES FROM COASTAL WATERS OF ALEXANDRIA, EGYPT DURING SUMMER 2006

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ABSTRACT

Concentrations of trace metals (Zn, Fe, Ni, Mn , Cu, Cd , Co and Cr) and fluoride were determined in different organs (brain, muscle, liver and skin) of some economically important fish species from three of the most important fishing localities of the Alexandria coastal water (Abu-Qir bay, the Eastern Harbour, and El-Mex bay) during summer 2006. Our results show that there is a preferential accumulation of metals by different organs. Liver is a target organ for Cu accumulation (0.40 – 58.40 µg/g wet wt), whereas the brain tissue clearly accumulates more levels of Zn (21.16 – 1042.4 µg/g wet wt) than the other studied metals. Amongst the studied organs, the flesh tissue nearly accumulated the lowest levels of some of the investigated elements especially those of Fe, Zn and fluoride (2.95 – 12.47 µg/g wet wt, 4.82 – 13.54 µg/g wet wt, respectively) and (8.17 – 15.83 µg/g wet wt). Metal Pollution Index (MPI) and Provisional Tolerable Weekly Intake for Cu and Cd (PTWI) were calculated and discussed. The levels of trace metals and fluoride in the edible parts of the investigated fish were in the permissible safety levels for human uses.

1. INTRODUCTION

Increasing water pollution causes contamination of the entire food supply chain. Pollutants accumulating in aquatic organisms, particularly fish consumed by humans in large quantities are of special concern because a high retention of toxic substances in fish tissue may be detrimental to human health. Among such pollutants, trace metals have received widespread attention as, in addition to their toxicity, they are not usually eliminated from the aquatic ecosystems by natural processes, in contrast to most organic pollutants (Förstner and Wittmann, 1981). An essential requirement for the study of trace metal enrichment is that the various metal contents of the entire organism must be brought into relation with one another or, at the least, the individual organs containing the greatest percentage of the total metals. Organs for which the respective metals show the highest affinity can be good indicators for metal contamination of the organism. In Egypt a number of studies were carried out to determine the levels of trace elements in different fish species from different aquatic environments including brackish and marine environments (Masoud *et al.*, 2007 and 2006; Youssef and Tayel, 2004; Shakweer and Radwan, 2004; Khaled, 2004; Abdel Baky *et al.*, 1998; Tayel and Shridah, 1996; Emara *et al.*, 1993; Shakweer *et al*., 1993). In spite of the fact that fluoride must be considered as a serious pollutant since its concentration in many aquatic ecosystems is significantly increasing as a consequence of man's activities (Camargo, 1996; Camargo *et al.*, 2000), relatively little is known about fluoride concentration in Egyptian aquatic organisms.

The aim of the present study is to assess metal accumulation (Zn, Fe, Ni, Mn, Cu, Cd, Co and Cr) and fluoride in various fish tissues, to evaluate their possible unfitness for human consumption. The fish species were collected from three of the most important fishing localities of the Egyptian Mediterranean Coast (Abu-Qir bay, the Eastern Harbour, and El-Mex bay), subjected to different kinds of pollutants. Some species were collected from the three regions to follow their spatial variation.

2. MATERIALS AND METHODS

2.1. Study areas

Fig. 1 shows the study areas. Abu-Qir bay (A.Q.) is a semicircular basin in the Mediterranean coast of Egypt, lies between longitudes 30º 4' and 30º 21' E and latitudes 31º 16' and 31º 30' N. It is bordered from the west by Abu-Qir peninsula and from the east by Rosetta branch of the River Nile. Its shore line is about 50 km long and having an area of about 560 km^2, with an average depth of about 12 m (Nessim and El-Deek, 1993). Several rocky ridges are found in the northwestern part of the bay. Due to these rocky ridges, a limited exchange of water exists between the open sea and the northwestern part of the bay (Aboul-Naga, 2000). Abu-Qir bay receives different kinds of water from three sources: (1) considerable amounts of fresh water from the Rosetta branch of the River Nile, (2) brackish water from Lake Edku (~3.3 x 10^6 m^3 daily, Aboul-Naga, 2000) through El-Maadyia Inlet and (3) drainage waste water from El-Tabia pumping station (~2 x $10^6 m^3$ daily , Said *et al.*, 1995). The drainage water includes water from El-Behera province as well as different factories representing major industrial activities (food processing, canning paper industry, fertilizers industry and textile manufacturing (Tayel, 1992).

The Eastern Harbour (E.H.) is a semi-enclosed area with its mouth protected from the sea by an artificial break water barrier leaving two openings to the sea, namely El-Boughaz and El-Silsila. The water exchange between the Harbour and the open sea takes place through the two openings. The Harbour has a surface area of about 2.8 km^2 and its average depth is about 5 m while the deepest part (12 m) is found near El-Boughaz inlet. The bottom slopes down gradually towards El-Boughaz opening. Coastal currents enter the Harbour through El-Boughaz and exit through El-Silsila following a counterclockwise, while clockwise current during winter season (Youssef and Lees-Gayed, 2003). For a long time, E.H. has been affected by sewage waste disposal through many outfalls. During February 2003, the sewage disposal was diverted to Lake Mariut.

El-Mex bay extends for about 15 km between El-Agamy headland in the west and the Western Harbour in the east, with a mean depth of 10 m. It receives huge volumes of drainage water via El-Umum Drain as well as mixed wastes from Lake Mariut (~10 x $10^6 m^3$ daily, Youssef, 2001). The bay is subjected to large temporal and spatial salinity fluctuations (from less than 20 to higher than 38 part per thousand, Youssef and Less-Gayed, 2003).

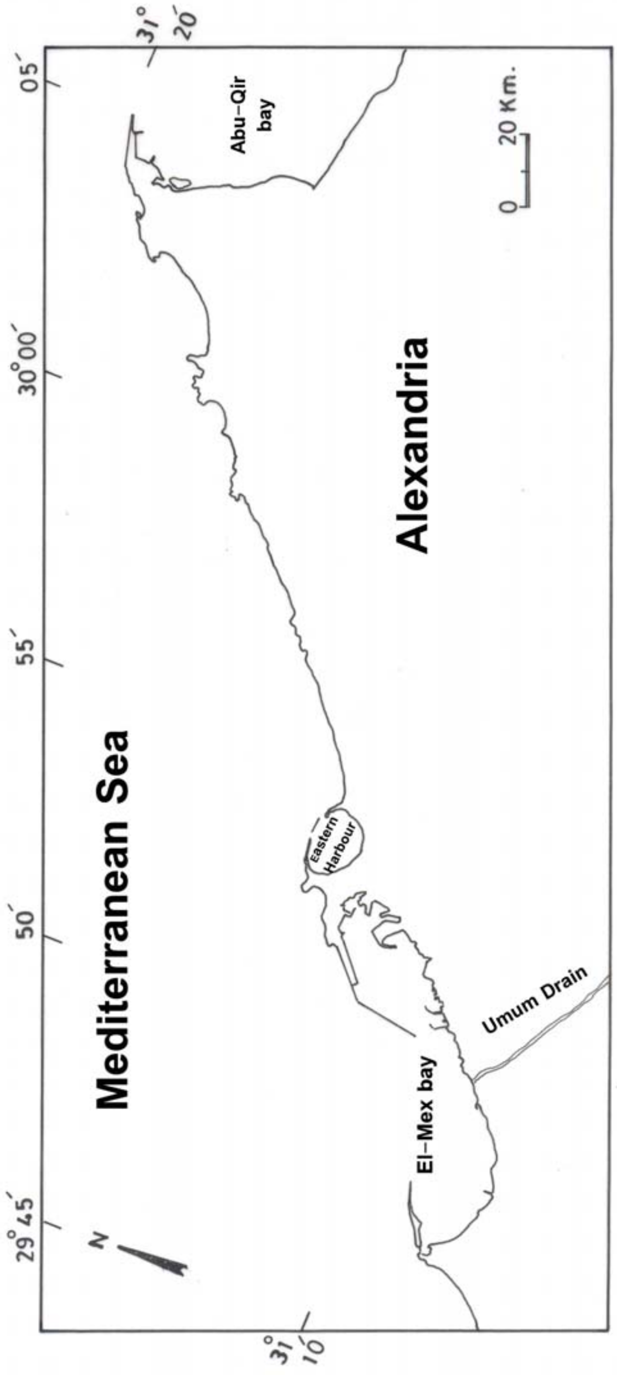

Fig. (1): Sampling location during summer 2006.

2.2. Sampling and methods

During August 2006, different fish samples were captured from three of the most important fishing localities of the Alexandria coastal water (Abu-Qir Bay, the Eastern Harbour, and El-Mex Bay). 15 different species were sampled from Abu-Qir Bay, four species were trapped from the Eastern Harbour and five fish samples were collected from El-Mex Bay (Table 1). A number of species were collected from the two and/or the three investigated regions. The samples were wrapped and double-bagged in polyethylene and chilled on ice for transport to the laboratory. In the laboratory, total weight and total length were measured for each fish (Table 1). For the same species from the same region, triplicate samples (for most of the species) were taken. Different organs (muscle, liver, brain and skin) were dissected, homogenized and kept frozen for analysis. For each organ, a weight of composite tissue was digested by HNO_3 in a closed teflon cups on a hot plate with thermostatic control (Oregioni and Aston, 1984). The digestion was carried out three times for each sample. The digested organ was dissolved in a known volume of metal-free distilled water and preserved in acid-clean PVC bottles for analysis. For each batch, blank determinations were done using the same procedure. Concentrations of the metals (Zn, Fe , Ni, Mn, Cu, Cd, Co and Cr) were determined using a Perkin Elmer 2830 flame atomic absorption spectrophotometer. Working standards of studied metals were prepared by diluting concentrated stock solutions (Merck, Germany) of 1000 mg/l in metal-free distilled water. Each metal concentration was estimated quantitatively according to the standard conditions described in the instrument manual. For each sample, the mean concentrations of the studied metals were calculated and the results were expressed in µg/g wet weight. The accuracy and precision of our results were checked by analyzing standard reference material (DORM-1 for dogfish) from the National Research Council, Canada. A triplicate analysis of the reference material showed a good accuracy; with recovery rates for metals between 93.02% and 106.56 % (Table 2).

For fluoride, each 1.0 gm of composite flesh and skin tissues was digested by HNO_3 inside closed teflon cups at room temperature. The digestion was carried out three times for each sample. The digested organ was dissolved in 25 ml of distilled water and preserved in clean PVC bottles for analysis. Fluoride ion concentration was determined following the procedure of zirconium alizarin red S (Zr-ARS) (Courtenary and Rex, 1951). 1.5 ml of 1 mol/l NaOH solution was added to each sample before the addition of Zr-ARS reagent to avoid the interferences of some metals especially calcium and magnesium. The samples were warmed and filtered after cooling. 1 ml of the filtered sample was treated with 1.5 ml (0.004 mol/l) ARS, 1 ml of standardized $ZrCl_4$ (0.004 mol/l) and then diluted to 25 ml by distilled water. The pH of samples was adjusted as that of the blank. The absorbance was measured at λ=420 nm after two hours where Zr-ARS was used as a blank with Shimadzu Double-Beam spectrophotometer UV-150-02. The concentration of the unknown sample (mg/l) was obtained using the calibration curve in which the standard NaF was of 10 µg F^-/ml. For each sample, the mean concentrations were calculated and the results were expressed as µg/g wet weight. Throughout the study, all reagents used were of analytical grade.

Table (1): Ranges of Total length and Weight of Studied fish

Region	Species	Total length (cm)	Total weight (g)
Abu-Qir bay	***Ariosoma balearicum***	**41 - 54** [a]	**90 - 127.2**
	Coris julis	**13 - 14.5** [a]	**23.3 - 33.7**
	Diplodus puntazzo	**15 - 17** [a]	**68.7 - 92.2**
	Diplodus vulgaris	**18** [b]	**120,6**
	Liza aurata	**20 - 24** [a]	**70.9 - 139.9**
	Sargocentron rubrum	**14 - 14.5** [a]	**57.7 - 64.3**
	Sebastpists nuchalis	**14.5 - 18** [a]	**70.5 - 122.4**
	Serranus cabrilla	**12** [b]	**24,2**
	Serranus scriba	**17 - 18** [a]	**73.6 - 86**
	Siganus luridus	**15.5 - 17** [a]	**51.8 - 77**
	Siganus rivulatus	**15.5** [b]	**48,9**
	Solea aegyptiaca	**17.5 - 20** [a]	**35.7 - 59.7**
	Sphyraena sphyraena	**20.5 - 25** [a]	**45.2 - 68.8**
	Symphodus ocellatus	**17 - 18.5** [a]	**72.7 - 89.7**
	Trichiurus lepturus	**47** [b]	**85,1**
Eastern Harbour	***Diplodus vulgaris***	**10 - 10.2** [a]	**18.6 - 20.6**
	Morone punctatus	**10** [b]	**50,6**
	Mugil capito	**22.8 - 24.3** [a]	**140.3 - 154**
	Siganus rivulatus	**15 - 16.7** [a]	**35.4 - 56.4**
El-Mex bay	***Dentex dentex***	**16 - 17.2** [a]	**61 - 82.2**
	Diplodus puntazzo	**12.5** [b]	**43,4**
	Serranus scriba	**14.5** [b]	**65,8**
	Siganus rivulatus	**16 - 17.5** [a]	**52.2 - 75.9**
	Sparisoma cretense	**18.5 - 19** [a]	**107.1 - 126**

[a] **triplicate samples**
[b] **one sample**

Table (2): Concentrations of metals found in Standard Reference Material DORM-2 (dogfish muscle) from the National Research Council, Canada (all data as means ± standard divisions, in mg kg^{-1} dry wt).

Elements	Fe	Mn	Co	Ni	Cr	Cu	Zn	Cd
Certified	**142**	**3,66**	**0,182**	**19,40**	**34,70**	**2,34**	**25,60**	**0,043**
S.D.	**10**	**0,34**	**0,031**	**3,10**	**5,50**	**0,16**	**2,30**	**0,008**
Observed	**135**	**3,90**	**0,185**	**18,80**	**33,00**	**2,30**	**24,50**	**0,040**
S.D.	**11**	**1,22**	**0,080**	**3,40**	**2,00**	**0,23**	**2,50**	**0,090**
Recovery (%)	**95,07**	**106,56**	**101,65**	**96,91**	**95,10**	**98,29**	**95,70**	**93,02**

3. RESULTS AND DISCUSSION

3.1. Levels of trace metals in different organs of studied fish

3.1.1. Zinc

Zinc is an essential trace element for both animals and humans. Zinc toxicity is rare but, at concentrations in water up to 40 mg/kg, may induce toxicity (NAS-NRC, 1974). Zinc appears to have a protective effect against the toxicity of cadmium (Calabrese *et al.*, 1985). Tables 3-6 show the concentration of Zn in different organs of the examined fish species. Considerable ranges of Zn were detected in the brain and the liver organs (21.16 - 1042.41 µg/g and 23.80 - 389.69 µg/g, respectively), whereas Zn concentration fluctuated widely between different species within the same organ. The levels of Zn in the skin tissue were moderate (19.40 - 89.37 µg/g). However, the flesh of studied fish had the lowest levels of Zn (4.82 - 13.54 µg/g). The results show that Zn metabolism seemed to be dependent on the liver and the brain tissues. Fernandesa *et al.*, 2007 stated that the role of liver in zinc metabolism should be considered, but zinc is apparently well regulated in this organ. The low concentrations of Zn in the muscle of the examined fish species may reflect the low levels of these binding proteins (metallothioneins) in the muscle (Allen-Gil and Martynov, 1995). The preferential accumulation of Zn in the brain rather than the muscle of fish agree with that observed by Youssef and Tayel, 2004 for some fish species collected from the Egyptian inland waters. Chipman *et al.*, 1958 pointed out that the internal organs of fish rapidly take up Zn in large amounts. The uptake and rate of loss in these organs is usually rapid. The rate of uptake in muscle and bone may be slow.

Regarding the edible tissue (Table 4), amongst the studied trace metals, Zn had the highest concentration; *Ariosoma balearicum* accumulated the elevated level of Zn (13.54 µg/g). This concentration was nearly three times higher than the minimum value recorded for *Sebastpists nuchalis*. The other different fish species have more or less the same concentration of Zn. The average value in the present study (7.76 ± 1.98 µg/g) was compared with the Canadian food standards (Zn: 100 µg/g), Hungarian standards (Zn: 150 µg/g) and the range of international standards (Zn: 40 – 100 µg/g) and Turkish acceptable limits (Zn: 50 µg/g) (Papagiannis *et al.*, 2004; TFC, 2002). The comparison showed that the values in the investigated fish species are considerably lower than the guidelines.

3.1.2. Iron

Fe is one of the most essential elements for living organisms; its concentration in different tissues of fish is mainly due to the presence and metabolism of hemoglobin (Bryan, 1976). The ranges of Fe in the brain, flesh, liver and skin organs of the studied fish species (Tables 3-6) were 17.64 - 1063.78 µg/g, 2.95 - 12.47 µg/g, N.D. - 41.79 µg/g and N.D. - 308.84 µg/g, respectively. The results show that Fe is the dominant element in the brain tissue, whereas, the edible organ accumulated the lowest concentration of Fe. Concerning flesh tissue, Fe is the second most abundant element (Table 4); its concentration fluctuated greatly between a minimum concentration of 2.95 µg/g (*Coris julis*) and a maximum one of 12.47 µg/g (*Trichiurus lepturus*). For most samples (63%), the concentration of Fe is lower than 5 µg/g.

Table (3): Concentration of trace metals in brain tissue of studied fish species (µg/g wet wt).

Location	Species	Fe	Mn	Co	Cr	Cu	Zn
Abu-Qir bay	*Ariosoma balearicum*	484.38	33.07	N.D.	12.76	0.01	1042.41
	Coris julis	159.90	8.88	N.D.	3.63	0.07	107.66
	Diplodus puntazzo	171.97	3.68	17.40	N.D.	0.01	27.09
	Diplodus vulgaris	97.59	N.D.	8.91	N.D.	0.10	167.95
	Liza aurata	402.15	0.59	4.79	N.D.	0.04	37.15
	Sargocentron rubrum	113.81	2.86	N.D.	1.10	0.11	49.09
	Sebastpists nuchalis	66.19	3.14	N.D.	4.36	0.03	40.73
	Serranus cabrilla	1063.78	3.15	59.52	7.29	0.14	256.38
	Serranus scriba	87.43	2.40	5.75	N.D.	0.09	30.99
	Siganus luridus	125.49	6.07	2.18	N.D.	0.02	43.74
	Siganus rivulatus	318.87	9.15	10.59	24.21	0.10	134.53
	Solea aegyptiaca	N.d.	N.d.	N.d.	N.d.	N.d.	N.d.
	Sphyraena sphyraena	99.54	3.70	17.03	2.52	0.04	82.28
	Symphodus ocellatus	22.24	1.65	1.72	N.D.	0.01	21.16
	Trichiurus lepturus	199.14	12.38	2.39	81.87	0.02	69.13
Eastern Harbour	*Morone punctatus*	320.93	5.51	41.34	2.83	0.03	77.88
	Mugil capito	17.64	5.51	41.34	2.83	0.03	77.88
El-Mex bay	*Dentex dentex*	91.76	1.39	9.88	0.40	0.08	21.95
	Sparisoma cretense	206.14	1.39	9.88	0.40	0.08	21.95
	Range	17.64 - 1063.78	N.D. - 33.07	N.D. - 59.52	N.D. - 81.87	0.01 - 0.14	21.16 - 1042.41

N.d. not determined
N.D. not detected

Table (4): Concentration of trace metals in flesh tissue of studied fish species (µg/g wet wt) and their metal pollution index (MPI).

Location	Species	Fe	Mn	Co	Ni	Cr	Cu	Zn	Cd	MPI
Abu-Qir bay	*Ariosoma balearicum*	4.37	1.20	0.22	0.60	0.33	0.34	13.54	0.11	0.77
	Coris julis	2.95	0.54	0.18	1.13	N.D.	0.16	7.60	0.38	0.78
	Diplodus puntazzo	4.08	0.41	0.04	1.31	N.D.	0.15	7.68	0.22	0.63
	Diplodus vulgaris	3.96	0.37	0.17	1.68	N.D.	0.22	7.74	0.42	0.86
	Liza aurata	4.97	0.49	0.15	0.49	N.D.	0.21	8.88	0.10	0.65
	Sargocentron rubrum	11.12	0.37	0.37	1.41	N.D.	0.29	7.05	0.36	1.06
	Sebastpists nuchalis	3.03	0.19	0.15	0.33	0.07	0.15	4.82	0.07	0.32
	Serranus cabrilla	4.82	0.41	0.21	1.23	0.36	0.40	8.54	0.34	0.83
	Serranus scriba	5.86	0.58	0.43	1.52	N.D.	0.25	7.25	0.34	1.04
	Siganus luridus	10.09	0.27	0.33	0.85	0.30	0.42	8.12	0.23	0.80
	Siganus rivulatus	8.44	0.15	0.40	0.49	0.07	0.45	9.71	0.09	0.53
	Solea aegyptiaca	3.02	0.15	0.10	0.18	0.07	0.26	5.09	0.16	0.32
	Sphyraena sphyraena	6.52	1.44	0.06	1.02	N.D.	0.35	7.49	0.33	0.91
	Symphodus ocellatus	3.05	0.34	0.23	1.10	0.10	0.19	6.00	0.25	0.54
	Trichiurus lepturus	12.47	1.02	0.23	0.57	0.28	0.58	9.41	0.11	0.86
Eastern Harbour	*Morone punctatus*	4.25	0.13	0.28	0.37	0.08	0.20	9.21	0.09	0.41
	Mugil capito	6.96	0.11	0.09	0.29	0.09	0.25	5.87	0.03	0.32
El-Mex bay	*Dentex dentex*	3.55	0.35	0.36	1.36	0.06	0.35	7.44	0.45	0.67
	Sparisoma cretense	3.92	0.24	0.08	1.34	0.22	0.10	5.96	0.24	0.48
	Range	2.95 - 12.47	0.11 - 1.44	0.04 - 0.43	0.18 - 1.68	N.D. - 0.36	0.10 - 0.58	4.82 - 13.54	0.03 - 0.45	0.32 - 1.06

N.D. not detected

Table (5): Concentration of trace metals in liver tissue of studied fish species (µg/g wet wt).

Location	Species	Fe	Mn	Co	Ni	Cr	Cu	Zn	Cd
Abu-Qir bay	*Ariosoma balearicum*	32.36	0.83	0.35	0.31	N.D.	7.12	56.07	0.23
	Coris julis	N.d.	N.D.	2.31	2.35	N.D.	2.87	106.04	3.29
	Diplodus puntazzo	4.36	2.13	0.58	0.61	N.D.	10.12	92.29	0.68
	Diplodus vulgaris	N.d.	0.49	1.17	0.72	N.D.	4.10	65.98	0.94
	Liza aurata	5.30	1.22	0.26	0.13	0.17	58.23	50.35	0.12
	Sargocentron rubrum	24.51	0.83	0.78	0.64	1.05	5.51	74.51	0.73
	Sebastpists nuchalis	1.16	0.61	0.11	0.06	N.D.	3.18	45.84	0.12
	Serranus cabrilla	N.d.	N.D.	6.76	3.99	0.17	24.40	238.85	4.08
	Serranus scriba	9.25	1.16	0.19	0.14	1.05	1.00	23.80	0.25
	Siganus luridus	N.d.	N.d.	N.d.	N.d.	N.d.	N.d.	N.d.	N.d.
	Siganus rivulatus	N.d.	N.D.	2.43	3.52	N.D.	58.40	398.69	6.58
	Solea aegyptiaca	N.d.	N.d.	N.d.	N.d.	N.d.	N.d.	N.d.	N.d.
	Sphyraena sphyraena	41.79	2.61	1.44	0.87	N.D.	3.72	74.26	0.52
	Symphodus ocellatus	20.85	1.95	0.26	0.30	0.26	4.59	35.72	0.12
	Trichiurus lepturus	10.82	3.86	0.21	0.25	N.D.	2.14	39.13	0.22
Eastern Harbour	*Morone punctatus*	N.D.	N.D.	1.14	N.D.	N.D.	0.40	78.34	0.35
	Mugil capito	11.03	1.22	0.31	0.36	0.19	5.91	136.97	0.05
El-Mex bay	*Dentex dentex*	6.97	1.25	0.66	0.61	0.14	0.97	47.97	0.90
	Sparisoma cretense	9.68	0.89	0.37	0.46	0.54	25.66	35.44	0.58
	Range	N.D. - 41.79	N.D. - 3.86	0.11 - 6.76	N.D. - 3.99	N.D. - 1.05	0.40 - 58.40	23.80 - 389.69	0.05 - 6.58

N.d. not determined
N.D. not detected

Table (6): Concentration of trace metals in skin tissue of studied fish species (µg/g wet wt).

Location	Species	Fe	Mn	Co	Ni	Cr	Zn
Abu-Qir bay	*Ariosoma balearicum*	61.56	N.D.	N.D.	36.81	N.D.	22.42
	Coris julis	N.D.	8.11	21.91	28.00	N.D.	51.03
	Diplodus puntazzo	101.32	4.60	12.42	9.35	N.D.	40.83
	Diplodus vulgaris	308.84	13.11	35.39	25.94	2.53	89.37
	Liza aurata	N.D.	56.13	151.55	28.22	N.D.	77.06
	Sargocentron rubrum	N.D.	3.88	10.47	15.17	N.D.	23.57
	Sebastpists nuchalis	21.30	3.96	10.70	10.06	N.D.	19.40
	Serranus cabrilla	39.88	7.63	20.60	20.34	N.D.	31.59
	Serranus scriba	N.D.	N.D.	N.D.	12.60	2.09	88.42
	Siganus luridus	N.D.	N.D.	N.D.	N.D.	N.D.	78.00
	Siganus rivulatus	N.D.	12.90	34.84	N.D.	N.D.	77.27
	Solea aegyptiaca	66.84	0.44	1.18	15.85	N.D.	20.86
	Sphyraena sphyraena	190.44	9.68	26.12	9.01	N.D.	32.52
	Symphodus ocellatus	18.62	1.23	3.31	N.D.	N.D.	34.62
	Trichiurus lepturus	N.d.	N.d.	N.d.	N.d.	N.d.	N.d.
Eastern Harbour	*Morone punctatus*	N.D.	5.27	14.23	N.D.	N.D.	39.07
	Mugil capito	43.47	8.96	24.19	N.D.	N.D.	60.66
El-Mex bay	*Dentex dentex*	52.16	7.77	20.98	11.37	3.43	56.65
	Sparisoma cretense	39.45	4.70	12.70	9.38	N.D.	25.31
	Range	N.D. - 308.84	N.D. - 56.13	N.D. - 151.55	N.D. - 36.81	N.D. - 3.43	19.40 - 89.37

N.d. not determined
N.D. not detected

3.1.3. Nickel

The concentration of Ni was measured in the flesh, liver and skin tissues of studied fishes (Tables 4-6). In spite of Ni was not detected in the skin tissue of a number of species, the ranges of Ni for most species in this tissue are the highest (9.01- 36.81 µg/g). For liver organ, the maximum concentration reached 3.99 µg/g. The concentration of Ni in the muscle tissue varied within narrow range (0.18 - 1.68 µg/g). *Solea aegyptiaca* accumulated the lowest concentration. However, *Diplodus vulgaris* had the highest one. The major source of nickel for humans is food and uptake from natural sources, as well as food processing (NAS-NRC, 1975). The human health action level for Ni contaminant is 13 µg/g wet weights (USFDA, 1993). The edible tissues analyzed in the present study showed concentrations only up to 1.68 µg/g.

3.1.4. Manganese

In general, the ranges of Mn in various tissues; brain, liver, flesh and skin were N.D. - 33.07 µg/g, N.D. - 3.86 µg/g, 0.11 - 1.44 µg/g and N.D. - 56.13µg/g, respectively (Tables 3-6). It was observed that, for most samples, there is a preferential accumulation of Mn in the skin tissue (external organ) rather than the other studied organs (internal organ). The preferential accumulation of Mn in the external organs was also observed by Khaled (2004) for some fish species collected from El-Mex bay, who stated that Mn concentration are highest in gills and lowest in muscle for all the studied species.

The flesh accumulated the lowest ranges for most samples, whereas the maximum concentration of Mn 1.44 µg/g was in the flesh tissue of *Sphyraena sphyraena*. However, the lowest one was found in the tissue of *Mugil capito* (0.11 µg/g). Most of the studied species (84 %) have less than 1 µg/g Mn. It was reported that manganese is an essential element for both animals and plants and deficiencies result in severe skeletal and reproductive abnormalities in mammals (NAS-NRC, 1977). It activates many enzymes in the muscle (Satoch *et al.*, 1983; Satoch *et al.*, 1983).The total daily intake varies from 2.5 to 7 mg (NAS-NRC, 1977).

3.1.5. Copper

The ranges of Cu in the brain, flesh and liver organs of the studied fish species (Tables 3-5) were 0.01 - 0.14 µg/g, 0.10 - 0.58 µg/g and 0.40 - 58.40 µg/g, respectively. For each species, the trend of Cu accumulation in different organs was: liver > flesh> brain. Of the investigated species, the liver of *Siganus rivulatus* contained not only elevated concentration of Cu (58.40 µg/g) but also had elevated concentration of Zn and Cd (398.69 µg/g and 6.58µg/g, respectively). The results suggest that liver might be a target organ for accumulation of Cu. Indeed, it was stated that the liver of fish is a major storage organ for Cu (Buckley *et al.*, 1982 ; Salanki *et al.*, 1982). The preferential accumulation of Cu in liver organ of different fish species from the Egyptian water is extensively observed (Shakweer *et al.*, 1993; Shakweer and Abbas, 1996; Shakweer and Abbas, 1997; Youssef and Tayel, 2004).

Concerning the edible part (Table 4), *Sparisoma cretense* had the lowest concentration (0.10 µg/g). Amongst the studied species, *Trichiurus lepturus* accumulated not only the highest concentration of Cu (0.58 µg/g) but also the highest concentration of Fe (12.47 µg/g). Copper is essential element and is carefully regulated by physiological mechanisms in most organisms; accumulate in porphyrins and enzymes (Bowen, 1979). However, it is regarded as potential hazards that can endanger both animal and human health. The low concentrations of Cu in the muscle of the examined fish species may reflect the low levels of these binding proteins (metallothioneins) in the muscle (Allen-Gil and Martynov, 1995). We compared our average values with the Canadian food standards (Cu: 100 µg/g), Hungarian standards (Cu: 60 µg/g) and the range of international standards (Cu: 10 – 100 µg/g) and Turkish acceptable limits (Cu: 20 µg/g) (Papagiannis *et al.*, 2004; TFC, 2002). The comparison showed that our values are lower than the guidelines. Therefore we can conclude that Cu have posed no threat for consumption of these fishes.

3.1.6. Cadmium

Cadmium is non essential element (CIESM, 2002). It can be accumulated with natural compounds as metallothioneins and 1.5 – 9 mg/day is lethal to man (Bowen, 1979). The levels of Cd in flesh and liver tissues of examined fishes were given in Tables 4 and 5, where the ranges were found to be 0.03 - 0.45 µg/g and 0.05 - 6.58 µg/g, respectively. Concerning liver, for most samples, the concentration of Cd was less than 1 µg/g. However, the liver of *Siganus rivulatus* accumulated the highest level (6.58µg/g). Regarding flesh, the concentration of Cd varied within a narrow range. The lowest concentration of 0.03 µg/g was recorded in *Mugil capito*, however, the highest level of 0.45 µg/g was found in the flesh tissue of *Dentex dentex*. The levels of Cd in the muscle tissue are much lower than the human health action level for Cd contaminant (3.7 µg/g wet weight; USFDA, 1993).

In the present study, it seems that the bioaccumulation of Cd is mainly in the liver rather than in the flesh. Ray and Mcleese, 1987 pointed out that, in most organisms, whether vertebrates or invertebrates, muscle tissue contains only negligible amounts of Cd. The preferential accumulation of Cd in the liver rather than in the flesh was also observed by Masoud *et al.*, 2007. It was mentioned that Cd accumulates in liver, kidney rather than in muscle and may be replacing Zn in some enzymes and has a long half-life time 10 – 30 yr (Kotsonis and Klaassen, 1977 and 1978)

3.1.7. Cobalt

Co is accumulated in some enzymes as vitamin B12 (Bowen, 1979).The concentrations of Co detected in the brain, flesh, liver and skin samples (Tables 3-6) showed different capacities for accumulating. In general, for most of the samples, the highest metal concentrations were found in the skin followed by brain. The highest level of Co reached 151.55 µg/g, observed in the skin of *Liza aurata*. The level of Co in the liver tissue was in the range 0.11 - 6.76µg/g. The muscle tended to accumulate less metal, where the concentration of Co fluctuated between a minimum value of 0.04 µg/g (*Diplodus puntazzo*) and a maximum one of 0.43 µg/g (*Serranus scriba*). Indeed, Accumulation of Co is mostly in the viscera and skin of the fish, not the edible parts of the fish (Smith and Carson, 1981).The largest source of exposure to cobalt for the general population is the food supply. The estimated intake from food is 5 – 40 µg/day, most of which is inorganic and 500 mg/day toxic to man (Bowen, 1979; Barceloux, 1999). According to Smith and Carson (1981), bio-magnification of cobalt up the food-chain does not occur.

3.1.8. Chromium

In spite of chromium was not detected in a number of investigated tissues (brain, flesh, liver and skin, Tables 3-6), the highest levels of Cr were observed in the brain tissues of studied fish species. Thus, the brain tissue of *Trichiurus lepturus* had the elevated concentration (81.87 µg/g). For flesh, liver and skin tissues, the maximum concentrations did not exceed 0.36 µg/g (*Serranus cabrilla*), 1.05 µg/g (*Sargocentron rubrum* and *Serranus scriba*) and 3.43 µg/g *(Dentex dentex*), respectively. Chromium is an essential trace element and the biologically usable form of chromium plays an essential role in glucose metabolism (Mertz, 1969). It has been estimated that the average human requires nearly 1 µg/day. Deficiency of chromium results in impaired growth and disturbances in glucose, lipid, and protein metabolism (Calabrese *et al.*, 1985).

3.2. Spatial variation in the concentration of studied trace metals in the flesh and liver tissues of some species

The results of spatial variation in the concentration of the studied trace metals in both flesh and liver tissues are represented in Tables 7 and 8, respectively. The liver of *Diplodus puntazzo* from El-Mex had considerable higher levels of Co, Ni, Cr, Zn, and Cd than that from Abu-Qir. The liver of *Siganus rivulatus* accumulated higher levels of Co, Ni, Cu, Zn, and Cd compared with that from EH and El-Mex bay. Generally, concerning the non essential element Cd, it was observed that the liver of the both species *Diplodus puntazzo* and *Serranus scriba* collected from El-Mex bay contained respectively about 17 and 23 times higher Cd than those from Abu-Qir bay. The results show an obvious trend of spatial variation in the concentration of Cd in the liver of the studied species. Indeed, the liver has a key role in basic metabolism (Moon *et al.*, 1985) and is the major site of accumulation, biotransformation, and excretion of contaminants in fish (Triebskorn *et al.*, 1994 and 1997). In spite of the muscle tissues are not considered as an active site for metal accumulation (Romeo *et al.*, 1999), the concentration of Cd in the flesh tissue of *Siganus rivulatus* from El-Mex bay was about 22 and 5 times higher than those from E.H. and Abu-Qir bay, respectively. For both liver and flesh, *Diplodus vulgaris* from Abu-Qir bay contained not only the highest levels of Cd but also the highest level of Cu and Ni, if compared with that from E.H. Generally, the species of E.H. are the lowest contaminated with Cd compared with those from Abu-Qir and El-Mex bays. Indeed, during February 2003, the sewage disposal was diverted from E.H. to Lake Mariut.

3.3. Level of fluoride in different organs of studied fish and its spatial variation

Of all chemical elements in the Periodic Table, fluorine is the most electronegative and the most reactive. Because of its great reactivity, fluorine cannot be found in nature in its elemental state. It exists either as inorganic fluorides (including the free anion F^-) or as organic fluoride compounds (e.g., freons). In the global environment, inorganic fluorides are much more abundant than organic fluoride compounds (Greenwood and Earnshaw, 1984). The first major natural source of inorganic fluorides is the weathering of fluoride minerals. Volcanoes are the second major natural source through the release of gases with hydrogen fluoride (HF) into the atmosphere. Marine aerosols are the third major natural source (Camargo, 2003). Human activities, such as aluminum smelters, discharges of fluoridated municipal waters, and plants manufacturing brick, ceramics, glass and fluoride chemicals, may cause significant increases in the fluoride concentration of surface waters (Camargo, 1996; Roy *et al.*, 2000). Aquatic animals such as fish and invertebrates can take up fluoride directly from the water or to a much lesser extent via food. This fluoride uptake is a function of fluoride concentration in the aquatic medium, exposure time and water temperature (Nell and Livanos, 1988).

In the present study, fluoride concentration was detected in the flesh, brain and skin tissues of the studied species (Table 9). The concentration of fluoride in the edible part of studied fish lies within a narrow range (8.17 - 15.83 µg/g). In the contrast, for brain tissue, fluoride was fluctuated widely between a minimum concentration of 9.39 µg/g and a maximum one of 110.41 µg/g. Elevated concentration of fluoride was recorded in the brain tissue of *Ariosoma balearicum* and *Serranus cabrilla* (110.41 µg/g and 96.01 µg/g, respectively). For skin tissue, considerable range of fluoride was observed (16.15 - 40.94 µg/g). Generally, for most studied species (79%), the flesh tissue accumulated the lowest fluoride concentration. The lower muscle fluoride levels were observed in a number of studies (Milhaud *et al.*, 1981; Oehlenschlager and Manthey, 1982; Gikunju, 1992; Masoud *et al.*, 2006). It was stated that fluoride tends to be accumulated in the exoskeleton of invertebrates and in the bone tissue of fishes. Fluoride accumulation in hard tissues may be viewed as a defense mechanism against fluoride intoxication because of the removal of fluoride from body circulation (Sigler and Neuhold, 1972; Kessabi, 1984). This may be explaining the lowest muscle fluoride levels, observed in the present study.

Concerning the spatial variation (Table 10), *Siganus rivulatus* from Abu-Qir bay accumulated the highest levels of fluoride in both brain and skin tissues compared with that from E.H. and El-Mex bay. Again, the brain tissues of *Diplodus vulgaris* from Abu-Qir bay and *Serranus scriba* from El-Mex bay have the highest level of fluoride compared with those from E.H. and Abu-Qir bay, respectively. For brain, the species collected from E.H. have the lowest levels of fluoride. These results may indicate that the brain may be considered as a bio-indicator organ for fluoride accumulation.

A number of studies were carried out to determine the accumulation of fluoride in different fish organs. As examples, Milhaud *et al.*, (1981) compared fluoride levels in mullet species (*Mugil auratus, M. cephalus* and *M. labrosus*) from Gabes Gulf (South Tunisia), where inorganic fluoride rich effluents were discharged (fluoride concentration in seawater was about 2 – 3 mg F^-/l). Fluoride levels in mullets from the Tunis Bay, which is remote from point sources (fluoride concentration in seawater was about 1.4 mg F^-/l) were detected. They found that the mullets from Gabes Gulf had mean fluoride levels (as mg F^-/kg wet weight) of 320 for bone and 9.6 for muscle. However, the mullets from Tunis Bay had mean fluoride levels (as mg F^-/kg wet weight) of 73 for bone and 1.8 for muscle. Oehlenschlager and Manthey (1982) studied inorganic fluoride levels in tissues of marine fishes (*Micromesistius australis, Notothenia gibberifons, N. rossii, N. neglecta* and *Chaenocephalus aceratus*). They found that vertebra fluoride levels were in the range 865 – 1207 mg F^-/kg wet weight and muscle fluoride levels were in the range 1.3 – 3.7 mg F^-/kg wet weight. Gikunju (1992) examined the fluoride concentration in tilapia fish (*Oreochromis leucostictus*) from Naivasha lake (mean freshwater fluoride concentration of 2.5 mg F^-/l), in Kenya. He found fluoride levels (as mg F^-/kg wet weight) of 210.6, 143.1, 4.96 and1.97 for bone, gills, skin and muscle, respectively. The fluoride content in the wet weight of the muscle tissue of *Gadus morrhua* and *Gadus aeglifinus* from the North Sea was 1.7 and 1.8 mg/ Kg (Grave, 1981). Comparing these results with the results presented in Table 9 from the present study, it was concluded that the levels of fluoride in flesh tissue of the studied species are the highest. This may be attributed to the nutritional behavior for each species as well as the level of fluoride in the ambient aquatic environment (Grave, 1981; Masoud *et al.*, 2006). Indeed the Egyptian Mediterranean coastal waters contain high levels of fluoride. According to Masoud *et al.*, (2006) the average concentration of fluoride during 2001 in the coastal water of Abu-Qir was 5.2 ± 0.3 mg/l.

It is worth mentioning that estuarine and marine fishes appear to be more tolerant to fluoride toxicity than freshwater fishes as a probable consequence of the elevated content of calcium and chloride in estuarine and seawaters. Fish size and water temperature can also affect fish tolerance to fluoride toxicity (Camargo, 2003). Thus, Hemens and Warwick (1972) reported that no mortality was observed in three estuarine fish species (the ambassid *Ambassis safgha*, the crescent perch *Therapon jarbua* and the striped mullet

Mugil cephalus) after exposures of 96 h to a maximum fluoride concentration of 100 mg F^{-}/l (water temperature of 20.5 ^{o}C). Hemens *et al.*, (1975) found that an exposure to 5.5 mg F^{-}/l for 113 days did not cause mortality or obvious physical deterioration in juvenile individuals of the striped mullet *Mugil cephalus* (water temperature in the range 23.5 – 27.0 ^{o}C). Heitmuller *et al.*, (1981) performed marine short-term (4 days) toxicity bioassays, reported a NOEC of 226 mg F^{-}/l for juvenile individuals of the sheepshead minnow *Cyprinodon variegates*. In general, according to these results, it can be concluded that the level of fluoride in the edible parts of studied fish cannot be considered as hazardous levels. Lastly, because inorganic fluoride bioaccumulates in aquatic producers (algae and macrophytes) as well as in aquatic consumers (invertebrates and fishes), studies on the biotransference and biomagnification of fluoride through food chains and food webs would have to be carried out.

3.4. Statistical analysis

Because of the study of fish muscle tissue is one of the means for investigating the amount of trace metals entering the human by food chain enrichment and has therefore been investigated more than other organs, statistical analyses were carried out on this organ.

3.4.1. Correlation matrix

Various degrees of correlations were found between the studied elements in flesh tissues (Table 11). Thus strong positive correlations were observed between Fe & Cu and Cd & Ni (r = 0.718 and 0.880, respectively, with confidence limit 99%). Moderate positive correlations were found between Zn & Mn, Cu & Cr and between Zn & Cu (0.507, 0.495 and 0.478, respectively; with confidence limit 95 %). These correlations may be explained by that some elements have similar sources and having the same behavior. As an example, manganese or zinc binds the acceptor substrate to the enzyme during the carboxylate transfer (Frederick *et al.*, 1972).Positive correlation was observed between F and Zn (r = 0.516, with confidence limit 95 %). It seems that fluoride may affect the biological processes of fish. The same conclusion was obtained by Masoud *et al.*, (2006).

3.4.2. Metal Pollution Index (MPI)

The overall metal contents of the studied fishes were compared, using the metal pollution index (MPI) calculated with the following formula (Usero *et al.*, 1996 and 1997):

$$MPI = (M1 \times M2 \times M3 \times \cdots \times M_n)^{1/n},$$

Where, M_n is the concentration of metal n expressed in µg/g of wet weight. In the present study MPI = $(Zn \times Fe \times Ni \times Mn \times Cu \times Cd \times Co \times Cr)^{1/8}$ and it is presented in Table 4. MPI was in the range 0.32 - 1.06. The lowest value was for *Sebastpists nuchalis, Solea aegyptiaca and Mugil capito* species. However, *Sargocentron rubrum* had the highest level. *Serranus scriba had* also relatively high MPI (1.04). Concerning spatial variation (Table 7), it was observed that the E.H. species have the lowest MPI values compared with those of Abu-Qir and El-Mex bays. This may indicate that the E.H. is the least contaminated environment. The MPI values for *Siganus rivulatus* in the present study (0.53, 0.39, and 1.02 for Abu-Qir bay, E.H. and El-Mex bay, respectively) was compared with those observed for the same species (Khaled, 2004; Masoud *et al.*, 2007). The comparison showed that our values are relatively lower than those observed by Khaled, 2004 (1.51 and 1.85 for E.H. and El-Mex bay, respectively). However our values are more or less close to that observed by Masoud *et al.*, 2007 (0.97 for El-Mex).

3.4.3. Provisional Tolerable Weekly Intake (PTWI).

The human health risk assessment, for certain metals, was estimated by comparing the metal intake from the consumption rate of sea food with the Provisional Tolerable Weekly Intake (PTWI) according to the calculation made by Bernhard, 1982. The PTWI values were found to be 300 and 245000 µg/ 70 kg man, for Cd and Cu, respectively. In Egypt, the man who weighs 70 Kg consumes 7.8 Kg fish/year (CAPMAS). Accordingly, the amount of Cd and Cu taken weakly by a person can be calculated according to this equation:

{Amount of metal taken weakly by a person= Concentration of metal in muscle (µg/g) x Average consumption (g)}.

Table 12 indicates that the concentrations of Cd and Cu in the flesh tissue of the studied species are much lower than the PTWI values.

Generally, this investigation showed that different fish species contained different metal levels in their tissues. Expectedly this variability depends on feeding habits (Romeo, *et al.*, 1999), ecological needs, metabolism (Canli and Furness, 1993), age, size and length of the fish (Linde *et al.*, 1998) and their habitats (Canli and Atli, 2003). In addition, some tissues are strong accumulators for metals (e.g. liver is a target organ for accumulation of Cu) and others are much weaker accumulators (muscle tissue). The trace metal concentrations and fluoride in the edible organ analyzed were well within the prescribed limits set by various authorities, indicating that the fish species are safe for human uses. The level of the investigated metals in the present study is an example of low content of metals in most of the edible part of fish in the Egyptian water (Masoud *et al.*, 2007 and 2006; Youssef and Tayel, 2004).

Table (7): Spatial variation in the concentration of trace metals in flesh tissue of some species (µg/g wet wt) and metal pollution index (MPI).

Species	Region	Fe	Mn	Co	Ni	Cr	Cu	Zn	Cd	MPI
Diplodus puntazzo	Abu-Qir bay	4.08	0.41	0.04	1.31	N.D.	0.15	7.68	0.22	0.63
	El-Mex bay	7.62	0.25	0.22	1.48	N.D.	0.18	9.41	0.24	0.84
Diplodus vulgaris	Abu-Qir bay	3.96	0.37	0.17	1.68	N.D.	0.22	7.74	0.42	0.86
	Eastern Harbour	16.66	0.48	0.17	0.56	0.22	0.03	10.83	0.03	0.44
Serranus scriba	Abu-Qir bay	5.86	0.58	0.43	1.52	N.D.	0.25	7.25	0.34	1.04
	El-Mex bay	6.16	0.36	0.35	1.20	0.06	0.27	8.22	0.42	0.70
Siganus rivulatus	Abu-Qir bay	8.44	0.15	0.40	0.49	0.07	0.45	9.71	0.09	0.53
	Eastern Harbour	7.05	0.33	0.19	0.23	0.12	0.30	7.38	0.02	0.39
	El-Mex bay	5.31	0.36	0.26	1.54	N.D.	0.38	8.78	0.45	1.02

Table (8): Spatial variation in the concentration of trace metals in liver tissue of some species (µg/g wet wt).

Species	Region	Fe	Mn	Co	Ni	Cr	Cu	Zn	Cd
Diplodus puntazzo	Abu-Qir bay	4.36	2.13	0.58	0.61	N.D.	10.12	92.29	0.68
	El-Mex bay	N.d.	N.D.	4.46	3.36	1.98	N.D.	332.92	11.38
Diplodus vulgaris	Abu-Qir bay	N.d.	0.49	1.17	0.72	N.D.	4.10	65.98	0.94
	Eastern Harbour	7.29	0.30	N.D.	N.D.	N.D.	1.57	330.12	0.35
Serranus scriba	Abu-Qir bay	9.25	1.16	0.19	0.14	0.24	1.00	23.80	0.25
	El-Mex bay	N.d.	N.D.	7.88	7.58	N.D.	N.D.	284.24	5.65
Siganus rivulatus	Abu-Qir bay	N.d.	N.D.	2.43	3.52	N.D.	58.40	398.69	6.58
	Eastern Harbour	18.15	3.57	0.10	N.D.	0.25	13.60	75.40	0.24
	El-Mex bay	46.74	0.97	0.41	0.49	0.29	0.17	137.85	0.45

N.D. not detected

N.d. not determined

Table (9): Concentration of fluoride in some tissues of studied fish species (µg/g wet wt).

Location	Species	Flesh	Brain	Skin
Abu-Qir bay	*Ariosoma balearicum*	13.98	110.41	26.21
	Coris julis	8.93	20.92	25.36
	Diplodus puntazzo	11.66	13.63	24.96
	Diplodus vulgaris	14.40	23.90	26.64
	Liza aurata	12.47	10.04	31.04
	Sargocentron rubrum	10.36	14.00	21.63
	Sebastpists nuchalis	10.48	21.08	19.61
	Serranus cabrilla	11.65	96.01	18.87
	Serranus scriba	12.28	9.39	22.59
	Siganus luridus	12.00	15.85	28.03
	Siganus rivulatus	11.21	41.01	40.94
	Solea aegyptiaca	8.17	N.d.	21.86
	Sphyraena sphyraena	11.51	10.33	16.15
	Symphodus ocellatus	10.44	10.63	16.81
	Trichiurus lepturus	15.01	30.81	N.d.
Eastern Harbour	*Morone punctatus*	15.83	21.34	28.01
	Mugil capito	10.24	21.34	32.33
El-Mex bay	*Dentex dentex*	10.87	14.27	17.24
	Sparisoma cretense	14.80	14.27	18.29
	Range	8.17 - 15.83	9.39 - 110.41	16.15 - 40.94

N.d. not determined

Table (10): Spatial variation in the concentration of fluoride in some tissues of some fish species (µg/g wet wt).

Species	Region	Flesh	Brain	Skin
Diplodus puntazzo	Abu-Qir bay	11,66	13,63	24,96
	El-Mex bay	12,40	12,54	11,85
Diplodus vulgaris	Abu-Qir bay	14,40	23,90	26,64
	Eastern Harbour	13,17	9,90	26,03
Serranus scriba	Abu-Qir bay	12,28	9,39	22,59
	El-Mex bay	14,85	38,79	17,89
Siganus rivulatus	Abu-Qir bay	11,21	41,01	40,94
	Eastern Harbour	14,80	12,31	24,86
	El-Mex bay	11,77	27,29	22,80

Table (11): Correlation matrix for the studied elements in muscle tissue of different species (n = 19).

	Fe	Mn	Co	Ni	Cr	Cu	Zn	Cd	F
Fe	1,000								
Cr	0,244	0,165	0,052	-0,165	1,000				
Cu	0,720	0,387	0,425	-0,160	0,491	1,000			
Zn	0,236	0,508	0,287	-0,081	0,413	0,481	1,000		
Cd	-0,132	0,152	0,214	0,881	-0,214	-0,043	-0,142	1,000	
F	0,177	0,240	0,065	0,103	0,359	0,134	0,516	-0,140	1,000

Table (12): Amount of heavy metals (Cu and Cd) taken by person and their percentage to that of Provisional Tolerable Weekly Intake (PTWI).

Location	Species	Amount of heavy metals taken weekly by person		Their % to that of PTWI	
		Cu	Cd	Cu	Cd
Abu-Qir bay	*Ariosoma balearicum*	51.00	16.95	0.021	5.644
	Coris julis	23.40	56.70	0.010	18.881
	Diplodus puntazzo	22.58	32.85	0.009	10.939
	Diplodus vulgaris	32.25	62.85	0.013	20.929
	Liza aurata	31.65	14.40	0.013	4.795
	Sargocentron rubrum	43.80	53.40	0.018	17.782
	Sebastpists nuchalis	21.75	10.05	0.009	3.347
	Serranus cabrilla	60.15	51.30	0.025	17.083
	Serranus scriba	37.05	50.25	0.015	16.733
	Siganus luridus	63.53	34.20	0.026	11.389
	Siganus rivulatus	66.75	13.35	0.027	4.446
	Solea aegyptiaca	38.55	23.40	0.016	7.792
	Sphyraena sphyraena	52.95	49.65	0.022	16.533
	Symphodus ocellatus	27.90	36.75	0.011	12.238
	Trichiurus lepturus	87.45	17.10	0.036	5.694
Eastern Harbour	*Morone punctatus*	30.15	13.80	0.012	4.595
	Mugil capito	36.75	4.76	0.015	1.583
El-Mex bay	*Dentex dentex*	52.89	66.90	0.022	22.278
	Sparisoma cretense	14.25	35.85	0.006	11.938

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