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Heavy Metals in Eleven Common Species of Fish from the Gulf of Aqaba, Red Sea

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Abstract

The muscles, livers, gills, gonads, and stomachs of eleven common fish species collected at three sites in the northern Gulf of Aqaba, were analyzed for the heavy metals Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn. Large differences in trace metal concentrations (in µg g^{-1} dry weight) were observed between different tissues or organ parts within each fish. In muscle tissue Cd ranged from 0.5 to 2.0 µg g^{-1} dry weight, while higher concentrations were found in liver, gill, and stomach tissues (up to 7.0 µg g^{-1}). Cobalt concentrations were lowest in muscles (1.7-7.1) and livers (1.9-6.8) and highest in gills (4.3-15.0) and stomachs (1.8-11.0). Similarly, Cr concentrations were highest in gills (4.3-44.2) and stomachs (1.8-22.0), and lowest in livers (1.9-11.5). Copper was also low in muscles (0.5-2.0), but highest in liver tissue (6.7-40.6). Iron levels were highest in liver (30-1031) and lower in other organs (3.9-391.0). Muscle tissues contained lower concentrations of Mn (1.0-3.3) than other organs, particularly the gills (3.8-19.0), which contained also higher concentrations of Ni and Pb (4.5-19.2 and 8.7-35.0, respectively) compared to the livers (1.0-11.4 and 1.9-6.3) and muscles (1.0-5.0 and 2.5-8.3). Gonads contained the highest concentration of Zn (77.5-271.7), while muscles contained the lowest (1.9-35.0).

الملخص

تم تحليل مستوى العناصر الثقيلة (Zn, Pb, Ni, Mn, Fe, Cu, Cr, Co, Cd) في عضلات و كبد و خياشيم و مناسل و معد إحدى عشر نوعاً من الأسماك السائدة في خليج العقبة . لوحظ وجود فروقات كبيرة في تراكيز هذه المعادن في الأنسجة المختلفة لكل نوع من السمك . تراوح تركيز Cd (0.5 – 2.0) ugg^{-1} dry wt. في العضلات بينما وصل إلى 7.0 ugg^{-1} dry wt في الأنسجة الإخرى . أما Co فقد كان تركيزه أقل ما يمكن في العضلات (1.7-7.1) و الكبد (1.9-6.8) و أعلى ما يمكن في الخياشيم (15.0 – 4.3) و المعد (11.0 – 1.0) . و كان تركيز Cr أعلى ما يمكن في الخياشيم (44.2- 4.3) و المعد (22.0 – 1.8) و أقل تركيز كان في الكبد (11.5- 1.9) . كذلك كان النحاس منخفضاً في العضلات (0.5-2.0) و مرتفعاً في الكبد (6.7-40.6) ، كما كان الحديد مرتفعاً في الكبد (30-1031) . أما تراكيز Mn فكانت منخفضة في العضلات (1.0-3.3) بينما بلغت في الخياشيم (3.8-19.0) ، و اشتملت كذلك الخياشيم تراكيز عالية من Ni (4.5-19.2) و Pb (35.0 – 8.7) بينما كانت التراكيز في الكبد (11.4 – 1.0 و 6.3-1.9) و العضلات (8.3-2.5 و 5.0 – 1.0) . كانت تراكيز Zn أعلى ما يمكن في المناسل (271.7 – 77.5) ، بينما كانت في العضلات (35.0 – 1.9) .

Keywords: Heavy metals; Gulf of Aqaba; Red Sea; Jordan;

1. Introduction

There are relatively few studies available on the content of many of the important toxic and essential trace elements in marine organisms of the Gulf of Aqaba. This is in spite of the rapid coastal development at the northern most tip of the Gulf at Aqaba town during the last three decades. During the past three decades, there has been a noticeable increase in the interest to measure these elements in marine sediments (Abu-Hilal, 1987; Abu–Hilal and Badran, 1990; Abu-Hilal, 1993), crustaceans (Abu-Hilal *et al.,* 1988), fish species (Wahbeh, 1985), mussels (Ababneh, 2004; Al-Batainh, 2004), seagrasses (Wahbeh, 1984; Abu–Kharma, 2006), algae (Wahbeh and *et al.,* 1985; Abu-Kharma, 2006), zooplankton (Bani Fawwaz, 2005) and corals (Al–Shloul, 2006; Al-Tarabeen, 2006). The work by Abu-Hilal (1987) described the high degree to which eight toxic heavy metals have contaminated the sediments of the Gulf in the submarine discharge zone of the previous Aqaba town municipal sewage outfall and the phosphate loading berth. Wahbeh and Mahasneh (1987) attributed the considerable variations in the elements

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among the tissues to diet although they did not consider the feeding habits of the species. Moreover, it is important to determine the spatial variability of these trace metals using fish from localities with various degrees of impact. This paper examines the degree to which common coastal fishes collected from polluted and unpolluted sites at the northern portion of the Gulf of Aqaba have accumulated the metals in their organs and edible tissues and compares these results to previously published data in order to evaluate the degree of anthropogenic trace metal contamination on the local fish population.

2. Materials and Methods

Fish were collected from three localities along the northern portion of the Gulf of Aqaba. The first locality was south of and adjacent to a phosphate polluted area near the port of Aqaba characterized by urban anthropogenic impact. The second site was a relatively unpolluted area in front of the Marine Science Station and the third was in front of the industrial complex zone adjacent to the Jordan-Saudi border representing industrial impact. In total, fish specimens of 11 different species were examined. These include the sergeant major fish *Abudefduf saxatilis*, the exquisite butterfly fish *Chaetodon austricus*, the striped butterfly fish C. fasciatus, the black tip grouper *Epinephelus fasciatus*, the cornet fish *Fistularia petimba*, the sea chub fish Kyphosus sp., the mullet fish Mugil sp., the goat fish *Mulloidichthys auriflama*, the goat fish *Parupenus cyclostomus*, the sparid fish *Polysteganus coeruleopunctatus*, and the wrass fish *Thalassorna sp*. Sampling, pretreatment, preparation of subsamples and analysis were made according to FAO Technical Paper No. 212 (1983). After capture the samples were weighed, measured, cleaned with deionized-distilled water, stored in pre-cleaned plastic bags, and kept frozen at -18 ^{0}C until further analysis. Frozen fish were partially thawed and dissected on cleaned plastic sheets using scalpels with steel blades and plastic forceps. Flesh, liver, gill, gonads and stomach were taken out and dried in a precleaned glass container at 103 ± 2 ^{0}C to a constant weight. A suitable volume of a mixture of hydrogen peroxide/nitric acid solution 1:1 v/v was used for the wet acid digestion of a preweighed tissue or organ. A Perkins Elmer 3030 atomic absorption spectrophotometer with digital read-out, deuterium lamp background corrector, and automatic zero to compensate the blank, was used for the determination of the metals. Settings were those recommended by the manufacturer. A standard curve was run with each analysis. A blank treated exactly as for the sample was also run with each batch of samples. Blanks were always of negligible values. The effect of interferences attributable to the matrix and the validity of the results were checked with the standard addition method. Recoveries were between 98 and 103% .The precision was confirmed by carrying out ten replicate analyses for three different samples. The coefficient of variation was less than 5% for all elements. Detection limits were considered as equal to 2 × standard deviation of the blank.

3. Results and Discussion

Concentrations of the heavy metals Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn in the muscles and selected organs of the eleven fish species collected from the northern portion of the Gulf of Aqaba are presented in Tables 1 and 2. Levels of each metal are discussed below with reference to data available for fish species from the Red Sea and other areas of the world. Concentrations of metals are presented in μg g^{-1} dry weight unless otherwise mentioned.

Table 1: concentrations (μg g^{-1}g^{-1} dry weight) of heavy metals in the muscles of eleven species of common fish collected from the Gulf of Aqaba at the Phosphate Loading Berth (PLB), Marine Science Station (MSS), and Industrial Complex (IC).

Species	Site	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Abudefduf saxatilis	PLB	0.6	3.2	10.3	1.9	20.5	1.3	3.9	5.6	10.9
	MSS	0.5	3.0	5.0	2.0	5.5	1.5	3.5	6.5	35.0
Chaetodon austricus	IC	0.6	1.7	2.9	1.7	6.4	0.6	1.2	4.1	12.2
	MSS	0.5	2.5	1.0	1.0	4.5	2.0	1.5	1.5	10.0
	PLB	1.7	3.3	5.0	1.7	8.3	3.3	5.0	8.3	16.7
C. fasciatus	PLP	0.5	2.0	5.0	1.0	6.5	1.0	4.0	4.0	2.5
Epinephelus fasciatus	MSS	1.0	3.8	4.0	1.0	6.5	1.5	1.0	5.0	11.0
	MSS	0.9	7.1	4.6	0.9	8.3	1.9	4.6	5.6	7.4
	PLB	1.0	3.5	9.0	1.0	3.0	1.5	1.5	3.8	9.0
Fistularia petimba	PLB	2.0	2.5	2.0	1.0	13.0	1.5	2.5	3.5	7.5
Kyphosus sp.	PLB	0.5	1.5	2.3	0.8	6.0	0.5	1.0	4.0	28.3
Mugil sp.	PLB	0.5	2.5	1.5	1.0	14.0	1.5	2.0	3.0	9.5
Mulloidichthys auriflama	MSS	0.5	3.0	2.5	1.5	8.5	2.0	3.0	6.5	11.0
	PLB	0.8	5.0	3.5	1.0	2.5	1.0	2.5	2.5	17.0
Parupenus cyclostomus	MSS	0.5	2.5	1.5	1.0	6.8	1.5	2.0	2.5	18.0
Polysteganus coeruleopnctatus	MSS	0.5	2.0	1.5	0.5	6.0	1.0	1.5	4.0	8.0
Thalassoma sp	MSS	0.5	3.5	2.8	0.5	4.5	1.0	2.5	4.0	23.0
	PLB	ND*	ND	ND	ND	3.9	1.9	1.9	5.8	1.9

* ND: Not determined.

Table 2: Concentrations (μg g^{-1} dry weight) of heavy metals in selected organs in eleven species of fish from the Gulf of Aqaba collected at the Phosphate Loading Berth (PLB), Marine Science Station (MSS), and Industrial Complex (IC).

Organ	Species	Site	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Liver	*Abudefduf saxatilis*	MSS	2.3	6.8	4.5	13.6	1027	6.8	11.4	ND	52.3
	Chaetodon austricus	IC	10.4	ND	6.3	14.6	256	4.2	2.1	4.2	122.9
	C. fasciatus	PLB	ND	1.8	8.9	7.1	411	5.4	ND	ND	101.8
	Epinephelus fasciatus	MSS	0.6	1.9	3.8	40.0	1031	3.1	1.9	6.3	64.4
		MSS	ND	ND	3.1	40.6	494	6.3	ND	ND	93.8
		PLB	2.0	3.0	11.5	19.0	30	3.0	4.0	3.5	54.0
	Fistularia petimba	PLB	0.5	2.0	4.0	6.0	470	3.0	2.5	4.0	58.0
	Kyphosus sp.	PLB	2.0	2.5	2.5	42.5	569	3.0	1.0	6.0	137.5
	Mulloidichthys aurirlama	PLB	0.8	4.2	4.6	23.5	386	3.8	1.5	3.8	74.2
	Parupenus cylostomus	MSS	0.5	2.0	ND	9.0	510	4.0	2.3	4.0	57.0
	Polysteganus coeruleopunctatus	MSS	1.9	2.0	1.9	6.7	208	4.8	2.9	1.9	63.5
	Thalassoma sp.	MSS	1.2	3.6	3.6	11.9	474	2.4	1.0	6.0	45.2
Gonad	*A. saxatilis*	MSS	0.5	3.0	3.0	4.0	16	2.5	3.5	5.0	205.0
	E. tasciatus	PLB	ND	5.0	10.0	6.7	105	3.3	5.0	6.7	271.7
	F. petimba	PLB	0.6	3.2	5.1	5.1	17	1.3	2.6	5.1	123.1
	M. auriflama	MSS	0.5	3.5	2.5	6.0	41	2.0	5.0	5.0	77.5
Gill	*A. saxatilis*	MSS	2.0	12.0	13.5	4.5	67	9.5	10.0	19.0	85.0
		PLB	2.9	13.5	44.2	7.7	ND	17.3	19.2	11.5	15.8
	C. austricus	IC	2.3	5.87	5.6	4.6	125	8.0	8.0	14.8	53.4
		MSS	2.2	4.3	4.3	3.3	62	8.7	6.5	16.3	45.7
	C. fasciatus	PLB	1.9	9.6	26.9	3.8	52	4.8	4.8	8.7	31.7
	E. fasciatus	MSS	2.0	13.5	15.0	5.0	68	5.0	7.5	15.0	71.5
		MSS	2.0	14.5	4.5	3.5	47	4.0	7.5	21.0	65.0
		PLB	2.5	15.0	34.0	4.0	40	6.0	8.5	19.0	52.0
	F. petimba	PLB	1.6	7.8	4.2	3.1	47	7.3	4.7	10.4	43.2
	Kyphosus sp.	PLB	1.5	7.5	9.0	3.5	91	5.0	4.5	12.5	43.5
	Mugil sp.	PLB	3.1	9.4	7.3	4.2	199	7.3	9.4	20.8	32.3
	M. auriflama	MSS	2.0	13.0	12.5	5.5	97	10.0	10.0	35.0	260.0
		PLB	2.3	12.1	9.1	4.6	67	3.8	9.0	18.9	74.2
	P. cyclostomus	MSS	2.5	17.0	ND	4.0	40	4.5	6.8	24.0	69.0
	P.coeruleo-punctatus	MSS	1.5	10.0	5.5	3.5	84	19.0	6.0	20.0	33.0
	Thalassoma sp.	MSS	2.2	11.8	11.0	3.7	121	5.9	6.6	14.7	80.2
Stomach	*A. saxatilis*	MSS	0.6	1.8	1.8	3.0	63	3.0	1.8	3.0	29.8
		PLB	3.1	7.8	12.5	10.9	27	10.9	12.5	10.9	31.3
	C. austricus	IC	2.8	ND	2.8	8.3	153	ND	2.8	ND	52.8
		MSS	4.2	8.3	8.3	8.3	279	12.5	16.7	4.2	66.7
	C. rasciatus	PLB	1.6	4.7	20.3	6.3	120	4.7	6.3	1.6	37.5
	E. fasciatus	MSS	0.5	3.0	3.0	8.5	38	2.5	2.5	4.0	97.5
		MSS	0.6	1.1	1.1	8.9	84	1.7	1.7	4.4	63.3
		PLB	1.3	3.8	8.3	8.3	57	2.6	2.6	3.9	53.5
	F. petimba	PLB	0.8	3.0	5.0	5.5	56	2.0	3.0	5.5	48.0
	Kyphosus sp.	PLB	1.0	4.5	22.0	9.5	63	4.5	2.8	15.0	36.5
	Mugil sp.	PLP	2.5	11.0	17.5	8.5	53	7.5	10.5	22.5	75.5
	M. auriflama	MSS	0.5	2.5	2.5	5.0	180	3.0	4.0	9.0	144.5
		PLB	1.1	7.1	6.5	7.1	391	14.7	5.0	6.5	71.2
	P. cyclostomus	MSS	0.2	9.5	ND	4.5	51	6.0	4.9	12.5	84.5
	P.coeruleo punctatus	MSS	1.0	1.5	1.5	10.0	73	7.5	1.5	5.0	56.5
	Thalassoma sp.	MSS	7.0	ND	20.5	8.5	64	9.0	23.0	10.0	41.5

3.1. Cadmium:

Cadmium is accumulated primarily in major organ tissues of fish rather than in muscles (Moore and Ramamurthy, 1984). This was the case in the present study as Cd in muscles ranged from 0.5 to 1.7 with a mean of 0.77 µg g^{-1}, whereas higher means were found in stomachs (1.8), livers (2.2), and gills (2.2). In the gonads of the eleven fish species sampled, Cd was similar to tissues and ranged from 0.5-0.6. These values are within the ranges reported for 21 species from the Red Sea (Hanna, 1989). However, higher means of Cd (1.3-8.6) in muscles of other fish species from the Gulf of Aqaba were reported (Wahbeh, 1985; Wahbeh and Mahasneh, 1987). These same authors reported high Cd levels in livers of these fishes (2.0-15.6). In contrast, Cd levels in muscles of fish from the Great Barrier Reef were consistently lower than 0.1 (Denton and Burdon Jones, 1986), while in livers of these fishes Cd concentrations varied from less than 0.1 to 209 µg g^{-1}. By comparison, most of the fish from the Mediterranean Sea examined contained Cd concentrations of less than 0.4 in their muscles, with the highest values reported from *Mullus barbatus* and *Sardinella aurita* (0.6-0.7) (Roth and Hornung, 1977). In general, it can be stated that the concentrations of Cd found in the present study are still considered as those of uncontaminated fish (< 1.5) reported by Moore and Ramamurthy (1984), and within the range of 0.2-3.5 µg g^{-1} reported for the Red Sea (Hanna, 1989) and the Mediterranean Sea, but are relatively high compared to those reported from Australia.

3.2. Cobalt:

There was a wide variation in mean concentration of Co in various organs of fish species examined. The highest mean was in gills (11.0) and stomach (5.0). Lower means were found in muscles (3.0), livers (3.3), and gonads (3.7). In addition, Co concentration varied among species. It ranged from 1.5 in muscles of *Kyphosus sp*. to 7.1 in E. *fasciatus*. In gills, Co concentration ranged from 4.3 in *C. austricus* to 17.0 in *P. cyclostomus*. In livers, it ranged from 1.9 in *E. fasciatus* to 6.8 in *A. saxatilis*. The concentration was low in stomach of *E. fasciatus* (1.1) and high in *Mugil sp*. (11.0), *P. cyclostoznus* (9.5), and *C. austricus* (8.3). In gonads, it ranged from 3.0 in *A. saxatilis* to 5.0 in *E. fasciatus*. Wahbeh and Mahasneh (1987) reported lower means of Co concentration in fish species from the Gulf of Aqaba, which ranged from 2.3 to 6.1 in gills, 0.3 to 6.1 in gonads, and 0.2 to 4.3 in muscles. Our results suggest that the comparisons could only be made within a species using similar organs because of the large intra species and intra organ variability. Regardless, the data is suggestive of increased Co contamination in the Gulf.

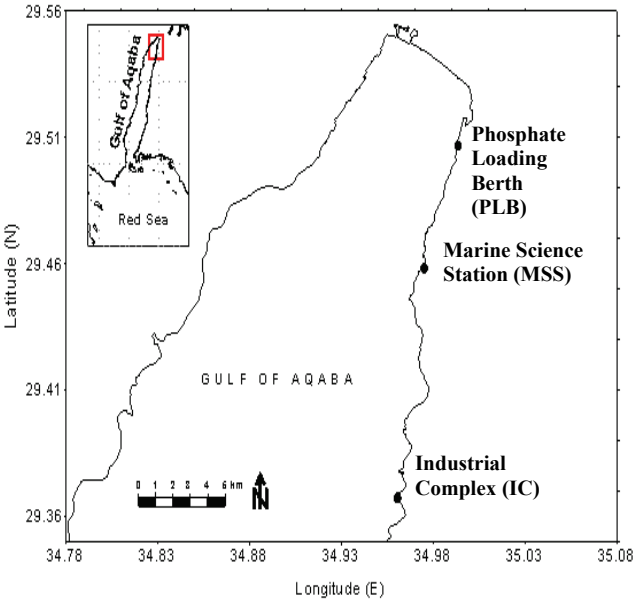

Figure 1: Locations of the sampling sites

3.3. Chromiurn:

Chromium does not normally accumulate in fish and hence low concentrations of Cr were reported even from the industrialized parts of the world (Moore and Ramamoorthy, 1984). The mean concentration of Cr found in the fish muscle samples from the Mediterranean coastal waters was 2.1. Even lower means were also reported from the Gulf of Aqaba for the muscle of *P. barberinus* (0.4) and *Scarus variegatus* (0.6) (Wahbeh and Mahasneh, 1987). However, in the present study higher concentrations were found in muscles of the examined fish (3.8), while it ranged from 4.9 in livers to 13.8 in gills. The values of Cr in muscles and livers are still in the range of values reported by Hanna (1989) for many Red Sea fishes. While this may suggest no large changes in Cr between 1989 and the present, it may indicate long term contamination of the Gulf waters with Cr as the values measured are high compared to other locations in the Red Sea region.

3.4. Copper:

Relatively high mean concentrations of Cu were found in livers (19.1) and stomachs (7.6) of the fish examined, compared to those found in muscles (1.1), gills (4.3), and gonads (5.5). There was also a wide variation in Cu content in livers among species as it ranged from 6.0 for *F. petimba* to 42.5 for *Kyphosus sp*. In muscles, there was a narrower range of concentration (0.5- 2.0). The same trend of difference between muscles and livers was reported by Powell et al. (1981) who found low Cu level in muscles of eight species of marine fish from Bougainville Island, Papua New Guinea (< 1.0 µg g^{-1} wet weight), while higher means were found in the livers (7.2- 15.2) of these fishes. Similar mean values were found in muscles of fish from coastal waters around England (0.67-1.80 µg g^{-1} wet

weight) (Portmann, 1972). In muscle tissue of 50 species of fish from the Great Barrier Reef Cu ranged from 0.47 to 2.4 (Denton and Burdon-Jones, 1986). This range is similar to that obtained in the present study. However, the livers of these fishes contained almost 5 times Cu (up to 226) higher than those obtained in the present study and than those found in the livers of 21 species from the Red Sea (3.49-61.00 µg g^{-1}) (Hanna, 1989). The data indicate that the fish in the Gulf compare to other fish world wide and are not more contaminated with Cu than that at other marine environments.

3.5. Iron:

There was a wide variation in mean concentrations of Fe among organs, particularly between livers (30-1031; mean 530) and muscles (2.5-20.5; mean 7.5). Similar variations were also found in stomachs (26.6-391.3; mean 109.3), gills (40.0-199.0; mean 80.5), and gonads (16.0-105.0; mean 44.8). Comparatively high levels of Fe were also reported for livers (413.3-1333.3), gills (80.0-320.4), gonads (88.9-160.0), and muscles (35.6-71.2) of fish species from the Gulf of Aqaba previously analyzed (Wahbeh and Mahasneh, 1987). On the other hand, Cross et al. (1973) reported lower mean levels of Fe in the muscles of the blue fish, *Pomatomus saltatrix* (4.5-5.0 µg g^{-1} wet weight). While we can not report increased Fe contamination in recent years in the Gulf like for Cr, values are high and suggest long term contamination.

3.6. Manganese:

Although this element is of low toxicity, it has a considerable biological significance and seems to accumulate in certain fish species (Eustace, 1974; Uthe and Bligh, 1971). The lowest mean concentration of Mn was 1.5 (range 0.5-3.3) in the muscles of the fish examined, while it was 2.3 (1.3-3.3) in gonads, 4.4 (2.4-6.8) in livers, 6.1 (2.0-14.7) in stomachs, and 7.9 (3.3-17.3) in gills. Cross et al. (1973) reported lower Mn concentration (0.20-0.28 µg g^{-1} wet weight) in the muscle of the blue fish *P. saltatrix*. Eustace (1974) found that 39 species of marine fish from Derwent Estuary, Tasmania, contained up to 0.6- 4.4 µg g^{-1} wet weight Mn when homogenized whole. By comparison, Wahbeh and Mahasneh (1987) reported higher mean concentrations (5.6-26.8) in various organs of fish they examined from the same study area within the Gulf of Aqaba. Our data are generally within the range of fish from other water bodies and do not indicate any particular contamination issue.

3.7. Nickel:

Similar to manganese the lowest mean concentration of Ni was 2.5 (range 1.0-4.6) in the muscles of fish examined, while it ranged from 8.1 (4.5-19.2) in gills to 6.4 (1.5-16.7) in stomachs, 4.0 (2.6-5.0) in gonads, and 3.9 (1.0—11.4) in livers. Other studies have shown that Ni concentrations in fish muscles are generally lower than those in other tissues (Moore and Ramamoorthy, 1984). Wright (1976) reported more or less the same range of concentrations in muscles (0.5-7.2), livers (1.7-10.8), and gills (3.3-4.5) of several fish species off the NE coast of England. In contrast, Hanna (1989) reported higher values of Ni in the muscles (0.2-7.2), livers (1.58-42.90), and gonads (3.2-1.3.9) of 21 fish species from the Red Sea. Our data show more pristine conditions than those in the Red Sea and similar to values in the Atlantic, thus not necessarily indicative of a Ni pollution problem.

3.8. Lead:

The mean concentration of Pb was lowest in the muscles (4.5) and livers (4.4) of the fish examined, while the highest was in the gills (17.6) of these fishes. These results are consistent with what has been reported by Moore and Ramamoorthy (1984) that there is often little accumulation of Pb in the muscles of marine and freshwater fish species. Low concentrations of Pb in the muscles of marine fish were reported from coastal areas of England and Wales (< 1.0 µg g^{-1} wet weight) (Portmann, 1972), West Malaysia (< 0.5 mg kg' wet weight) (Baji et al., 1979), Gulf of Mexico (0.05-0.73 µg g^{-1} wet weight) (Taylor and Bright, 1973), and Gulf of Aqaba (0.8-2.6 µg g^{-1}) (Wahbeh and Mahasneh, 1987). In fishes of the Red Sea Pb ranged between 0.01-0.66 µg g^{-1} in the muscles, 0.1-2.4 in the livers, and <0.05-0.14 in the gonads (Hanna, 1989). Our data indicate that the fish in the Gulf contain higher levels of Pb compared to other fish at other marine environments world wide.

3.9. Zinc:

There was great variation in Zn concentrations among species. The mean concentration in muscles was 13.3 and ranged from 1.9 in *Thalassorna sp*. to 35.0 in *A. saxatils*. The highest concentration was in the livers of these fishes (45.2-137.0; mean 75.2). Powell et al. (1981) recorded lower mean concentration of 3.0-4.5 µg g^{-1} wet weight) in muscles of fish from Bougainville Island. However, they reported higher means from the livers of these fishes (30.0-44.9). Similar range of concentration (4.3-41.8) was found in the muscles of fish species from the Great Barrier Reef (Denton and Burdon-Jones, 1986). However, they reported relatively high concentrations in the livers of these fishes. By comparison, Hanna (1989) found much higher and wider concentrations of Zn in the muscles (8.4-195.0 µg g^{-1}), livers (43-620), and gonads (72-259) of fishes from the Red Sea. Our data show that Zn levels in the fish of the study area are within the levels reported from the Red Sea and other regions world wide.

4. Conclusions

- Cadmium is accumulated primarily in major organ tissues of fish rather than in muscles. In the present study Cd in muscles ranged from 0.5 to 1.7 with a mean of 0.77 µg g^{-1}, compared to higher means in stomachs (1.8), livers (2.2), and gills (2.2).
- However, the concentrations of Cd found in the present study are still considered as those of uncontaminated fish (< 1.5 µg g^{-1}) reported by Moore and Ramamurthy (1984), and within the range of 0.2-3.5 µg g^{-1} reported for the Red Sea (Hanna, 1989) and the Mediterranean

Sea, but are relatively high compared to those reported from Australia.

- The data is suggestive of increased Co contamination in the Gulf. Cobalt concentration varied among species. Highest means were in gills (11.0) and stomachs (5.0) while lower means were found in muscles (3.0 μg g^{-1}).
- High concentrations of Cr were found in gills (13.8 μg g^{-1}) of the examined fish while the values in muscles (3.8), and livers (4.9) are still in the range of values reported by Hanna (1989) for many Red Sea fishes. However, while the results may suggest no large changes in Cr between 1989 and the present, it may indicate long term contamination of the Gulf waters with Cr as the values measured are high compared to other locations in the Red Sea region.
- Relatively low mean concentrations of Cu were found in muscles (1.1 μg g^{-1}) of the fish examined, compared to those found in gills (4.3) gonads (5.5) livers (19.1) and stomachs (7.6).
- The data indicate that the fish in the Gulf are compared to other fish world wide and are not more contaminated with Cu than those at other marine environments. The range of Cu in muscle tissue in the present study is similar to that obtained in muscle tissues (0.47 to 2.4 μg g^{-1}) of 50 species of fish from the Great Barrier Reef (Denton and Burdon-Jones, 1986).
- There was a wide variation in mean concentrations of Fe among organs, with higher concentrations in liver (30-1031; mean 530 μg g^{-1}) and lower concentrations in muscles (2.5-20.5; mean 7.5 μg g^{-1}).

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