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Differential Uptake of Heavy Metals by Gill, Muscles and Liver of Four Selected Fish Species from Red Sea

Khalid A. Al-Ghanim,[1] Magda Abdelatty,[2] Lyla Abdelfattah[3] and Shahid Mahboob[1]
[1]*Department of Zoology, College of Science, King Saud University, P.O. Box 2455, Riyadh-11451, Saudi Arabia*
[2]*Department of the Environmental Health, High Institute of Public Health, Alexandria University, Alexandria, Egypt*
[3]*Marine Chemistry Lab. National Institute of Oceanography and Fisheries, Alexandria, Egypt.*

Abstract.- Concentrations of 10 heavy metals (Cu, Zn, Cd, Pb, Fe, Mn, Cr, Se, As, and Hg) were determined in different organ tissues of four selected common red sea fish species *viz., Lethrinus nebulosus, Cetoscarus pulchellus, Plectorhynchus schotaf* and *Epinephelus* spp. There was a highly significant ($P< 0.01$) difference among the 4 fish species and between organs for the accumulation of all 10 metals. The concentration of Fe was highest closely followed by Zn, whereas Cd was detected in the lowest concentration. The liver accumulated the highest concentration of metals and muscles had the concentration of all studied metals**.** It has been observed that *Lethrinus nebulosus* species accumulated the highest concentration of total analyzed elements in this study, which indicate that this species have more potential to accumulate all of metals in each tissue.

Key words: Heavy metals, bioaccumulation.

INTRODUCTION

The Red Sea has a surface area of about 438,000 km². It is about 2250 km long and, 355 km at its widest point. There are six countries bordering the Red Sea; Saudi Arabia, Yemen, Egypt, Sudan, Eritrea and Djibouti (Red sea). Sewage is considered an important environmental threat throughout the region. Power and desalination plants, refineries, fertilizer manufacturers and chemical plants are located in the coastal areas. The effluents of these industries (oil, organic pollutants, heavy metals, heated brine and cooling water) are considered as major threat in these countries of the region (UNEP, 1997; Al-Balwai *et al*., 2013).

The Red Sea is a rich and diverse ecosystem. More than 1200 species of fish have been recorded in the Red Sea (FAO, 2011). Fish is a good source of animal protein for human beings. Omega-3 has unsaturated fatty acids which provides a low-cholesterol healthy source of protein and other nutrients. Therefore, fish consumption is recommended two or three times a week (Burger and Gochfeld, 2005).

* Corresponding author email: kghanim@ksu.ed.sa
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A wide range of pollutants is continuously discharged into marine environment, which ultimately affect the aquatic life including fish. The contaminants ultimately bio-accumulate in the muscle and other tissues of fish and hence pose a serious threat to human health (Sekhar *et al.,* 2003). Age, height, weight, gender, dietary habits, ecological needs, metal concentration in water and sediment, retention duration of fish in the aquatic environment, fishing period and the physical and physicochemical properties of water are among the factors that affect heavy metal accumulation in various organs of fish (Canli and Alti, 2003).

Fish species were recently suggested as environmental biomarkers (Tom *et al.,* 2002). It is also, considered as an early warning for the degradation of environmental quality, but also specific measures of toxic, carcinogenic and mutagenic compounds in biological materials (Verlecar *et al.,* 2006). Liver and gills as the main organs for metabolism and respiration are target organs for contaminant accumulation. The gills (Alazemi *et al.,* 1996), liver (Braunbeck, 1998) and kidney (Bernet *et al.,* 1999) are commonly the primary target organs for pollution. Measuring heavy metals in aquatic organisms may be a bio-indicator of their impact on the organism and ecosystem health (Krishnakumar *et al.,* 1994). Some metals are known to be toxic even at low concentrations, including arsenic, cadmium, mercury, zinc and lead. Others, such as copper and cobalt are known to be essential elements and play important role in biological metabolism at very low concentration (Le *et al.*, 2009) and either an excess or deficit can disturb biochemical functions in both humans and animals (Gulec *et al.*, 2011). The objectives of this study was to investigate the concentration of heavy metals in different organ of four selected common red sea fish species and to determine the fish tissue and species that accumulate the highest concentration of these metals.

MATERIALS AND METHODS

Four common red sea fish species viz., *Lethrinus nebulosus, Cetoscarus pulchellus, Plectorhynchus schotaf* and *Epinephelus* spp. were selected. Nine samples of each species were collected and stored in the deep freezer at -20°C until prepared for analysis (Ademoroti, 1996).

The fish samples were thawed at room temperature (about 27ºC) and dissected to remove gills, liver and muscles. These organs were oven dried at 110–115˚C for 24 h, ground in porcelain mortar and pestle (Godwin *et al*., 2011) for acid digestion according to Smith and Windom (1972). After digestion, the samples were stored in pre-cleaned polyethylene bottles until analyed. The acid digests of muscle, gills and liver of *Lethrinus nebulosus*, *C. spulchellus* and *Epinephelus* spp. were analyzed by atomic absorption spectrophotometer for Cu, Zn, Cd, Pb, Fe, Mn, Cr, Se, and As. These metals were also analyzed in muscles and gills of *P. schotaf*. Hg was assessed in the muscles of all the fish species. Acid blanks did not receive fish samples and were prepared exactly in the same way as the samples. The OD of acid blanks was substracted from the ODs of samples for purposes of calculation.

Statistical analysis

Descriptive statistics, pair-wise comparisons and Spearman correlation coefficient were done by using SPSS Statistics program.

RESULTS AND DISCUSSION

The mean of each measured metals in different fish tissues in the four fish species are presented in Table I. The biometric data revealed that the fish species, *P. schotaf* have the highest length and weight, while the *C. pulchellus* have the lowest weight. The correlation with the biometric data of the different studied species indicated the presence of a strong negative correlation between Hg accumulation with both length and weight of *C. pulchellus* and with length only in *P. schotaf*. However, the intermediate negative correlation appears between both Pb and Se accumulation with both length and weight of *P. schotaf*. In addition, Pb had an intermediate negative correlation with the weight of *L. nebulosus* and with length of *Epinephelus* spp. All these positive or negative correlations were not significant for all species. Generally there was a highly significant ($P<0.01$) difference between the four studied species and between organs in the accumulation of all measured metals.

In general, the Fe values were the highest closely followed by Zn but Cd was the lowest among the all detected metals. These results were in agreement with previous studies (Naim *et al*., 2008; Bashir *et al*., 2013; Arun and Hema, 2007; Abdelrahim *et al*., 2011). The highest concentration of Fe was found to be comparable with other investigations (Bhup *et al*., 2011) and indicated the presence of inorganic sources of iron, which more readily absorbed compared with organic sources. The highest accumulation of Se, Mn and Cd was recorded in *L. nebulosus*, and Se, Cr, and Fe were highest in *C. pulchellus*. On the other hand, Pb and Hg were highest accumulated in *P. schotaf*, but As was recorded in the highest concentration in *Epinephelus* spp. There was non-significant difference between *L. nebulosus* and *P. schotaf* for accumulation of As, Hg and Fe. Furthermore, there was a non-significant difference between *L. nebulosus* and *C. pulchellus* for the accumulation of only As. Nevertheless, between *L. nebulosus* and *Epinephelus* spp. a non-significant difference was observed for accumulation of Hg, Se, Cr, Cd and Cu. *L. nebulosus* and *Epinephelus* spp. showed similar pattern for accumulation of these metals.

Table I.- The concentration values (Mean±SD) of the different heavy metals in tissue organs of 4-studied species.

Fish species	Tissues	Metals concentration µg.g^{-1}									
		Cu	**Pb**	**As**	**Se**	**Zn**	**Cr**	**Fe**	**Mn**	**Cd**	**Hg**
Lethrinus nebulosus	Muscle	16.67±2.99	0.20±0.02	0.11±0.02	0.91±0.02	2.48±0.32	19.11±0.33	109.19±3.29	3.42±0.23	0.53±0.05	0.12±0.03
	Liver	79.87±5.89	0.97±0.05	0.36±0.00	1.14±0.20	8.82±0.16	40.47±1.99	398.98±8.87	18.97±0.69	2.08±0.20	ND
	Gills	65.17±3.55	0.23±0.02	0.66±0.49	0.97±0.08	4.97±0.30	19.63±0.93	274.52±1.03	12.67±0.52	0.60±0.08	ND
	Total	53.90±28.74	0.47±0.38	0.38±0.03	1.00±0.15	5.42±2.77	26.40±10.61	260.90±125.98	11.69±6.79	1.07±0.77	0.12±0.03
Cetoscarus pulchellus	Muscle	12.88±1.63	0.39±0.04	0.21±0.01	0.59±0.05	2.47±0.45	36.47±1.48	181.85±2.97	2.65±0.56	0.57±0.16	0.02±0.00
	Liver	56.49±3.71	0.95±0.14	0.85±0.02	3.19±0.26	7.62±0.80	49.65±2.62	546.44±7.73	9.57±0.07	1.10±0.12	ND
	Gills	14.31±1.11	0.79±0.03	0.19±0.01	1.03±0.13	1.51±0.58	37.70±3.66	195.74±5.19	2.78±0.31	0.44±0.04	ND
	Total	27.89±21.56	0.69±0.28	0.45±0.03	1.60±1.21	3.87±2.89	41.72±6.92	308.01±178.99	4.99±3.44	0.71±0.32	0.02±0.00
Epinephelus spp.	Muscle	18.83±2.67	0.47±0.07	0.35±0.04	1.67±0.34	2.52±1.09	22.34±1.16	131.80±3.38	2.98±0.18	0.38±0.04	0.11±0.00
	Liver	82.43±2.75	0.67±0.11	0.77±0.04	7.06±0.27	9.57±0.34	32.66±2.13	504.79±5.54	13.68±1.03	1.99±0.23	ND
	Gills	34.12±2.71	0.31±0.00	1.29±0.08	1.18±0.29	3.51±0.35	23.64±0.70	269.54±7.06	11.34±1.04	0.54±0.07	ND
	Total	45.12±28.84	0.49±0.16	0.74±0.39	3.30±2.83	5.20±3.36	26.53±5.27	302.04±163.41	9.33±4.93	0.97±0.78	0.11±0.00
Lectorhynchus schotaf	Muscle	14.620.75	0.23±0.08	0.23±0.05	2.08±0.18	1.68±0.41	4.97±0.32	242.71±2.98	2.75±0.69	0.86±0.12	0.170.05
	Liver	ND	ND	ND	NM	ND	ND	ND	ND	ND	ND
	Gills	16.81±2.03	0.25±0.04	0.44±0.01	1.53±0.20	4.14±0.69	12.36±1.16	282.54±3.09	3.09±0.43	0.52±0.04	ND
	Total	15.72±1.82	0.24±0.06	0.63±0.12	1.81±0.5	2.91±1.44	8.66±4.15	262.62±2.92	2.92±0.55	0.69±0.20	0.17±0.05

ND: Not detected

The fish species *C. pulchellus* and *P. schotaf* exhibited a non- significant difference for the accumulation of Pb, Cd, and As. *Epinephelus* spp. and *P. schotaf* behaved similarly for bioaccumulation of Hg. This indicates that the presence of a wide difference between *Epinephelus* spp. and both *P. schotaf* and *C. pulchellus* for all the studied metal concentrations except Hg and Fe, respectively. The measured metals in different tissues of the four studied fish species revealed that the liver had the highest concentration of all the metals except As which recorded its highest value in gills of *Epinephelus* spp. These findings were not in line with other studies (Naim *et al*., 2008; Bashir *et al*., 2013; Abdelrahim *et al*., 2011; Metwally and Fouad, 2008) where it was reported that liver of fish had the highest accumulation of heavy metals.

The liver of *Epinephelus* spp. accumulates the highest values of each Cu, Pb and Zn (Table I), while in liver of *L. nebulosus* accumulates the highest concentration of Se, Mn, and Cd were detected as 1.14±0.20, 18.97±0.69 and 2.08±0.20 $\mu g.g^{-1}$dry weight, respectively. The highest concentration of Cd (2.08 $\mu g.g^{-1}$) in this study was higher than the study carried out on the same species (*L. nebulosus)* in each of Qatar, UAE and Oman, but Mn and Se were lower than the values recorded by the same study (Stephen, 2004). On the other hand, liver of *C. pulchellus* accumulates the highest values of Cr and Fe.

The muscles had the lowest concentration of all the tested metals except Cu was recorded in the lowest concentration in gills of *C. pulchellus*. These findings are in agreement with other studies who stated that muscles of fish in general has the lowest accumulation of heavy metals (Naim *et al*., 2008; Bashir *et al*., 2013, Arun and Hema, 2007; Abdelrahim *et al*., 2011; Metwally and Fouad, 2008). The muscles of *Epinephelus* spp. accumulate the highest concentration of Cu, As, Se and Zn. The *P. schotaf* muscles accumulate the highest concentration of Pb, Fe and Cd (Table I) but accumulate the lowest concentration of Cu and Cr.

The highest accumulation of Cr was recorded in *C. pulchellus* muscles and Mn in *L. nebulosus* (Fig. 2). However, the lowest accumulation of Pb, Zn and Mn were determined in muscles of *C. pulchellus*. As, Se, and Fe in *L. nebulosus*. The highest value of Mn in *L. nebulosus* muscles was recorded as 3.42±0.23 $\mu g.g^{-1}$ dry weights which was comparatively higher than reported by Stephen (2004) in the same species in Qatar, UAE and Oman. The lowest values of each Se and As (0.91±0.02 and 0.11±0.02 $\mu g.g^{-1}$, respectively) were lower than the values reported by the same study, but Fe value was higher than it. As and Cd concentration was recorded as 0.11 and 0.53 $\mu g.g^{-1}$, respectively in *L. nebulosus* muscles. These findings were in agreement with another study carried in the Arabian Gulf (Zyadah *et al*., 2012). The Cu and Pb were however slightly increased (2.48 and 0.90 $\mu g.g^{-1}$ respectively). In the present study the concentration of Pb, Cu, Cd and Zn in both liver and muscles of study species were higher than those in the previous studies (Metwally and Fouad, 2008) except for Zn which was less in muscles compared to this study.

The concentration of Cd in all the fish species was far below the US permissible limits (3-4ppm), FAO/WHO (FAO/ WHO, 2011) and Malaysian food (Malaysian food and regulations 1985) regulations (1ppm) except for *L. nebulosus*, which slightly exceeded (1.07±0.77 $\mu g.g^{-1}$), the value of FAO/WHO limits (FAO/WHO, 2011). Cd concentration in four fish species was higher than EU limits (0.05-1ppm) (Tom *et al*., 2002) and Saudi Arabian standards (SASO) which suggested maximum allowable limits for Cd in fish as 0.05 µg/g (MALs for any toxic heavy metals in fish species, 1977).

Pb in both *L. nebulosus* and *C. pulchellus* (0.97±0.05 and 0.95±0.14 $\mu g.g^{-1,}$ respectively were incompatible with US permissible limits (1.5-1.7ppm) (FAO Document Repository) and SASO (1977) limits (2.0 µg/ g) while *P. schotaf* reported the higher value (1.80 $\mu g.g^{-1}$) than US limits and below SASO (1977) limits. On the other hand, the *Epinephelus* spp. the Pb was recorded as 0.67±0.1 $\mu g.g^{-1}$ that was higher than acceptable limits as suggested by US (FAO Document Repository) and SASO (1977). The accumulated values of Pb in the present study were higher than EU limits (Tom *et al*., 2002) for Pb in fish (0.2-1.0 ppm) and FAO/ WHO (0.3 ppm) (FAO/WHO, 2011).

Cu and Zn concentrations were far below the MALs limits as recommended by FAO / WHO

(2011) (10 and 150 µg.g^{-1}, respectively). Malaysian Food and Regulations (1985) suggested upper limit as 30 and 100 µg.g^{-1}, respectively and SASO (1977) limits (20 and 50 µg.g^{-1}, respectively for the studied species except *L. nebulosus* which was not compatible with the limits suggested by SASO (1977) for Zn. The concentration of Mn in *L. nebulosus* and *Epinephelus* spp. (18.97±0.69 and 13.68±1.03 µg.g^{-1}) were higher than the permissible limits of 5.4µg.g^{-1} (FAO/WHO, 2011). The concentration of As and Hg in the four fish species were found to be within the permissible limits of SASO (1977) limits (1.0 µg.g^{-1}).

Overall ranking revealed from the results that among the four fish species the *L. nebulosus* accumulated the highest concentration of all the heavy metals, which indicates that this species have more potential to accumulate these metals in each muscle, liver and gills. It may be due to the feeding habits of the fish, lipid content in the tissue and excretion percentage of these toxic metals from their body (Fredrick *et al*., 2014).

CONCLUSION

Fish is widely accepted as a model organism for monitoring the environmental pollution in aquatic environment. We concluded that liver has more potential to deposit trace metals compared to muscles. *Lethrinus nebulosus* comparatively accumulated higher concentration of heavy metals compared to the *Cetoscarus pulchellus*, *Plectorhynchus schotaf* and *Epinephelus* spp**.**

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