Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 5, No. 1, p. 322-329, 2014
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Determination of lead and zinc in king mackerel *(Scomberomorus guttatus* Bloch & Schneider, 1801), *Spanish mackerel (Scomberomorus commerson* Lacepède, 1800) and Tiger-toothed Croaker *(Otolithes ruber* Bloch and Schneider, 1801) from Persian Gulf, Iran in 2001 and 2011

Abolfazl Askary Sary[1*], Mohammad Velayatzadeh[2]

[1] *Department of Fishery, College of Agriculture and Natural resource, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran*

[2] *Young Researchers Club, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran*

Article published on July 09, 2014

Key words: Heavy metal, fishes, Zinc, Lead, Persian Gulf.

Abstract

The present study was carried out to investigate contamination of heavy metals Pb and Zn in liver and muscle of *Scomberomorus guttatus*, *Scomberomorus commerson* and *Otolithes ruber* from Persian Gulf, Iran, in 2001 and 2011. Heavy metal levels in fish samples were analyzed by Perkin Elmer 4100 Zl atomic absorption. The results show that the highest concentrations of Pb and Zn in the liver of *Scomberomorus commerson* and *Scomberomorus guttatus* were 0.96±0.03 (2001) and 213±7.35 (2001) $mgkg^{-1}dw$ and the lowest concentrations of Pb and Zn in the liver of *Scomberomorus guttatus* and muscle of *Otolithes ruber* were 0.28±0.04 (2001) and 4.66±0.36 (2011) $mgkg^{-1}dw$. Concentrations of Zn and Pb in the liver and muscle of *Scomberomorus commerson*, *Otolithes ruber* and *Scomberomorus guttatus* have significant difference between 2001 and 2011 ($P<0.05$), except Pb in muscle of *Scomberomorus commerson* and in liver of *Otolithes ruber* ($P\geq0.05$).

***Corresponding Author:** Abolfazl Askary Sary ✉ askary_sary@yahoo.com

Introduction

The Persian Gulf is located in the south of Iran with average area and depth of 240,000 km2 and 35 m, respectively. The Persian Gulf is characterized by warm and saline water and is a shallow sea such as the Baltic and North Sea. The depth of the Persian Gulf decreases from east to west with maximum depth of 90 m in the strait of Hormoze (Kardovani, 1995; Agah *et al.,* 2009). Marine organisms, in general, accumulate contaminants from the environment and therefore have been broadly used in marine pollution monitoring studies. Heavy metals discharged into the marine environment can damage both marine species diversity and ecosystems, due to their toxicity and accumulative behaviour (Sivaperumal *et al.*, 2007).

Heavy metal pollution of aquatic environment has become a great concern in recent years. HMs can have toxic effects on organs (Macfarlane and Burchettt, 2000). Heavy metals have the tendency to accumulate in various organs of marine organisms, especially fish, which in turn may enter into the human metabolism through consumption causing serious health hazards. Iron, copper, zinc and manganese are essential metals while, mercury, lead and cadmium are toxic metals (Canli and Alti, 2003). Heavy metals still play an important role as pollutants affecting aquatic systems (Merian, 1991). Some of the metals found in the fish might be essential as they play important role in biological system of the fish as well as in human being, some of them may also be toxic as might cause a serious damage in human health even in trace amount at a certain limit. The common heavy metals that are found in fish include copper, iron, copper, zinc and manganese, mercury, lead and cadmium (Rashed, 2001; Canli and Alti, 2003; Fernandes *et al.*, 2008). Toxic elements can be very harmful even at low concentration when ingested over a long time period. The essential metals can also produce toxic effects when the metal intake is excessively elevated (Celik and Oehlenschlager, 2007).

Lead finds its way in waters through the discharge of industrial waste waters, such as from painting, dyeing, battery manufacturing units and oil refineries etc. Pb also enters the rivers both from terrestrial sources and atmosphere and the atmospheric input of Pb aerosols can be substantial (Mitra *et al.*, 2010). Lead enters into the body with gill cells and especially is accumulated in gills and the later aim organs are liver and muscle (Sadeghi-Rad, 1997). Although, Zinc usually is accumulated in bone, skin, liver, gill and kidney are accumulated the great amount of them (Celik and Oehlenshlager, 2004).

This matter that, importance of the heavy metals measuring related to two important subjects which are aquatics ecosystem management and human helth, the present study was carried out to determine the level of Lead and zinc in liver and muscle of *Scomberomorus guttatus*, *Scomberomorus commerson* and *Otolithes ruber* from Hendijan Port areas, located in the north of Persian Gulf. Both cities have direct connection to Persian Gulf. The fish for people in those ports is generally catched from the Persian Gulf. It should be noted that fish species are considered of the diet in this region. No data exist for zinc and lead levels in this fish from mentioned areas.

The main objective of this study was to determinate the contents of zinc and lead in the muscle and liver of *Scomberomorus guttatus*, *Scomberomorus commerson* and *Otolithes ruber* from Persian Gulf from Iran, in 2001 and 2011, in order to assess fish quality and to assess the health risk for humans.

Material and methods

Sampling

The *Scomberomorus guttatus*, *Scomberomorus commerson* and *Otolithes ruber* in this study were collected 72 samples by local fisherman from the north Persian Gulf (Iran, Hendijan port 30°14'14''N , 49° 28' 37'' E) took place twice in 2001 and 2011. After capture, fishes were placed in plastic bags and transported to the laboratory in freezer bags with ice. sampling were cut into pieces and labeled, and then all sampling procedures were carried out according to internationally recognized guidelines (UNEP, 1991). Total fish weight and length were measured to the millomete and gram (Table 1).

Table 1. Mean length (cm) and weight (g) of the species examined in present study.

Species	Samples	Length±SD 2001	Length±SD 2011	Weight±SD 2001	Weight±SD 2011
Scomberomorus guttatus	24	60.00±6.2	53.33±4.5	833.57±104.25	645±47.69
Scomberomorus commerson	24	54.66±4.50	49.33±0.57	1116±215.37	1033±61.10
Otolithes ruber	24	41.00±5.29	35.33±2.08	816.67±125.83	615±15.04

Apparatus

A Perkin-Elmer, model 4100 ZL atomic absorption spectrophotometer, equipped with a GTA Graphite furnace, was used. Pyrolytic-coated graphite tubes with a platform were used and signals were measured as peak areas. The instrument setting and furnace programmes for analysis of Zinc and Lead metals are described in table 2.

Reagents

All reagents were of analytical reagent grade unless otherwise stated. Double distilled water was used for the preparation of solution. All the plastic and glass ware were soaked in nitric acid for 15 min and rinsed with deionized water before use. The stock solutions of metals (1000 mgl^{-1}) were obtained by dissolving appropriate salts of the corresponding metals (E. Merk) and further diluted prior to use. High purity Argon was used as inert gasted prior to use.

Chemical analyses (Wet-ashing)

The samples were solubilized using high-pressure decomposition vessels, commonly known as a digestion bomb. A sample (1gr) was placed in to Teflon container and 5 ml of concentrated HNO_3 was added. The system was heated to 130° C for 90 min and finally diluted to 25 ml with deionized water. The sample solution was clear. A blank digest was carried out in the same way. Zinc and lead metals were determined against aqueous standards.

Table 2. The instrument setting and furnace programmes for analysis of Zn and Pb by Perkin-Elmer, model 4100 ZL (AAS).

Working conditions	Pb	Zn
Wavelenght (nm)	283.3	307.5
Slit width	0.5	0.7
Lamp current (MA)	8	15
Ar Flow (ml/min)	250	250
Injection Volume (µl)	25	20
Heating programme temprture° C [ramp time (5), hold time (5)]		
Drying 1	125(1.20)	115(1.20)
Drying 2	150(5.30)	150(5.30)
Pyrolysis	900(15.10)	1250(15.10)
Atomization	2150(0.5)	1900(0.5)
Cleaning	2400(1.2)	2400(1.2)

Statistical analysis

Analysis of variance (ANOVA) was run for all the collected data for fish samples different using SPSS16. Mean values of each parameter were compared using Fisher's protected least tests with significance levels of 5% were conducted on each metal to test for significant differences between sites (Table 3 and 4). All statistical analyses were conducted by using Excel 2003 software.

Results and discussion

Determination metals

Concentrations of metals Zn and Pb in muscle and liver of *Scomberomorus guttatus*, *Scomberomorus commerson* and *Otolithes ruber* were measured and presented in table 3 and 4. Concentrations of metals are presentedin mg Kg^{-1} dry weight mentioned.The highest and lowest concentrations of Pb in tissues were measured in liver of *Scomberomorus commerson* and *Scomberomorus guttatus* in 2001 (Table 3). The highest and lowest concentrations of Zn in tissues were measured in liver of

Scomberomorus guttatus in 2001 and muscle of *Otolithes ruber* in 2011(Table 4). The distribution patterns of Zn in tissues of *Scomberomorus guttatus*, *Scomberomorus commerson* and *Otolithes ruber* follows the order: liver> muscle. Heavy metal concentrations were higher in the gill and liver, in comparison with muscle. Livers were chosen as target organs for assessing metal accumulation (Hamilton and Mehrle, 1986). The concentration of Pb in muscle were higher than in liver (Table 3).

Table 3. The concentrations of Pb in muscle and liver of *Scomberomorus guttatus*, *Scomberomorus commerson* and *Otolithes ruber* from Persian Gulf ($mgkg^{-1}$).

Sample	Location	2001	2011
Scomberomorus guttatus	muscle	0.36±0.02[a]	0.40±0.01[a]
	liver	0.28±0.04[a]	0.43±0.01[b]
Scomberomorus commerson	muscle	0.53±0.05[a]	0.52±0.04[b]
	liver	0.96±0.03[a]	0.64±0.04[b]
Otolithes ruber	muscle	0.86±0.02[a]	0.47±0.03[b]
	liver	0.44±0.08[a]	0.55±0.02[b]

a, b p<0.05, significantly different in muscle and liver of species between 2001 and 2011

Table 4. The concentrations of Zn in muscle and liver of *Scomberomorus guttatus*, *Scomberomorus commerson* and *Otolithes ruber* from Persian Gulf ($mgkg^{-1}$).

Sample	Location	2001	2011
Scomberomorus guttatus	muscle	34.8±8.12[a]	6.52±0.28[b]
	liver	213±7.35[a]	7.17±0.26[b]
Scomberomorus commerson	muscle	23.2±6.72[a]	7.88±0.20[b]
	liver	66±9.87[a]	8.39±0.20[b]
Otolithes ruber	muscle	99.37±22[a]	4.66±0.36[b]
	liver	205±5[a]	5.25±0.25[b]

a, b p<0.05, significantly different in muscle and liver of species between 2001 and 2011

Comparison Zn and Pb

In this study concentrations of heavy metals Zn and Pb in the liver and muscle of *Scomberomorus commerson*, *Otolithes ruber* and *Scomberomorus guttatus* have significant difference between 2001 and 2011 (P<0.05), except for Pb in muscle of *Scomberomorus commerson* and liver of *Otolithes ruber* (P>0.05).

Estimation of the levels of various elements in different fish species as a measure of environmental pollution has been of great concern over decades. A variable range of different metal concentrations has been observed by various researchers worldwide (Ashraf *et al.*, 2006). The absorption of metals on to the gill surface, as the first target for pollutants in water, could also be an important influence in the total metal levels of the liver (Heath, 1987). Distribution patterns of metal concentrations in liver and muscle of *Scomberomorus guttatus*, *Scomberomorus commerson* and *Otolithes ruber* from Persian Gulf follows the sequence: Zn>Pb. There are various studies on the heavy metal levels in fish from different waters. Oymak *et al.*, (2009) studied the heavy metal levels in kidney, liver, gill and muscle of *Tor grypus* and Maaboodi *et al.*, (2011) studied the concentrations of Zn and Pb in liver of Carrassius, *Cyprinus carpio*, *C. aculeate* and *C. damasciana* which concentration of Zn were higher than Pb. Also, in other research, studied the heavy metal levels in muscle, liver, gonad, and gill of gilthead seabream (*Sparus aurata*), European seabass (*Dicentrarchus labrax*), and keeled mullet (*Liza carinata*) which concentration of Zn were higher than Pb (Turkmen *et al.*, 2010). The levels of Zn in all tissues were higher than the Pb levels, as Zn is present in many enzymes throughout the fish's body (Oymak *et al.*, 2009).

Lead

They are accumulated in human tissues and may be the cause of some diseases (Yilmaz *et al.*, 2007). In this study the levels of minimum Pb were 0.28 $mgkg^{-1}$dw and maximum concentrations of this metals were 0.96 $mgkg^{-1}$dw. Pb concentrations in Grunt, Flathead, Greasy grouper, Tiger-tooth and Silver pomfret were 2-25, 0.2-17, 2-9, 1-9 and 3-33 ngg^{-1} from Persian Gulf (Agah *et al.*, 2009). In other study concentration of Pb in muscle Indo-Pacific king mackerel and Tigertooth croaker were 0.625 and 0.3 $mgkg^{-1}$ (Dobaradaran *et al.*, 2010). The concentrations of Pb in liver and muscle of samples in were 2001 higher than 2011. The Pb values in fish species were found to be in range of 0.068–0.874 mgg-1. These values were lower than those reported earlier in fish species of different lakes (Aucoin *et al*., 1999; Mendil *et al*., 2005). The concentrations of Pb in liver of *Scomberomorus commerson* in 2001 and 2011 were higher than muscle. Muscle tissue is the main edible fish part and can directly influence human health. Lead enters into the body with gill cells and especially is accumulated in gills and the later aim organs are liver and muscle (Sadeghi-Rad, 1997).

Zinc

In this study minimum and maximum concentrations of Zn were 4.66 and 213 $mgkg^{-1}$dw. Yilmaz *et al*., (2007) reported that Zn concentration was 6.350–28.550 $mgkg^{-1}$ in tissues of *Leucis cephalus* and 6.540–16.064 $mgkg^{-1}$ in tissues of *Lepomis gibbosus*. Levels of Zn in muscle and liver of *Sciaena umbra* were 11.6 and 28.3 $mgkg^{-1}$ (Turkmen *et al*., 2008). Also Abu Hilal and Ismail (2008) reported that concentrations of Zn were 1.9-35 $mgkg^{-1}$ in muscles, livers, gills, gonads, and stomachs of eleven common fish species collected from three sites in the northern Gulf of Aqaba. The concentrations of Zn in liver were higher than muscle of *Scomberomorus commerson*, *Otolithes ruber* and *Scomberomorus guttatus*. In other study such as *Sciaena umbra* (Turkmen *et al*., 2008), *Sparus auratus, Trigla cuculus, Sardina pilchardus*, *Mugil cephalus*, *Atherina hepsetus*, *Scomberesox saurus* (Canli and Alti, 2003) concentrations of Zn in liver were higher than muscle. The observed variability of heavy metal levels such as Zn and Pb in different species depends on feeding habits ecological needs, metabolism age, size and length of the fish (Linde *et al*., 1998) and their habitats (Canli and Atli, 2003; Tuzen and Soylak, 2007).

Comparison of International Standards

The mean estimated concentrations for Zn in the present study were higher than international standards for these metals as declare by the Ministry of Agriculture, Fisheries and Food (UK), Food and Agriculture Organization (FAO) and National Health & Medical Research Council (Australia). Concentrations of Pb in this study were lower than international standards World Health Organization (WHO), Ministry of Agriculture, Fisheries and Food (UK) and National Health & Medical Research Council (Australia), but the Pb concentrations were higher than Food and Agriculture Organization (FAO) and U.S. Food and Drug Administration (FDA).

Table 5. The tolerable values of some heavy metals in the fish ($mgkg^{-1}$).

Standards	Pb	Zn	References
WHO[1]	2	-	WHO, 1996
FDA[2]	0.5	-	Chen and Chen, 2001
UK(MAFF)[3]	2	50	MAFF, 1995
NHMRC[4]	1.5	150	Chen and Chen, 2001
FAO[5]	0.5	30	FAO, 1983
This study	0.28-0.96	4.66-213	

1- World Health Organization

2- U.S. Food and Drug Administration

3- Ministry of Agriculture, Fisheries & Food (UK)

4- National Health & Medical Research Council (Australia)

5- Food and Agriculture Organization

Conclusions

In this study the concentrations of Zn and Pb in the liver and muscle of *Scomberomorus commerson*, *Otolithes ruber* and *Scomberomorus guttatus* were significant difference between 2001 and 2011 ($P<0.05$), except for Pb in muscle of *Scomberomorus commerson* and liver of *Otolithes ruber* ($P>0.05$). The concentrations of Zn in liver were higher than muscle of *Scomberomorus commerson*, *Otolithes ruber* and *Scomberomorus guttatus*. The concentrations of Pb in liver and muscle of samples in 2001 were higher than 2011. Distribution patterns of metal concentrations in liver and muscle of *Scomberomorus guttatus*, *Scomberomorus commerson* and *Otolithes ruber* from Persian Gulf follows the sequence: Zn>Pb. The mean estimated concentrations for Zn in the present study were higher than international standards for these metals as declare by the Ministry of Agriculture, Fisheries and Food (UK) and National Health & Medical Research Council (Australia), but concentrations of Pb in this study were lower than international standards World Health Organization (WHO), Ministry of Agriculture, Fisheries and Food (UK) and National Health & Medical Research Council (Australia).

References

Abu Hilal AH, Ismail NS. 2008. Heavy Metals in Eleven Common Species of Fish from the Gulf of Aqaba, Red Sea. Jordan Journal of Biological Sciences **1**, 13-18.

Agah H, Leermakers M, Elskens M, Fatemi SMR, Baeyens W. 2009. Accumulation of trace metals in the muscle and liver tissues of five species from the Persian Gulf. Environment Monitoring and Assessment **157**, 499-514.
DOI: 10.1007/s10661-008-0551-8.

Ashraf W, Seddigi Z, Abulkibash A, Khalid M. 2006. Levels of selected metals in canned fish consumed in Kingdom of Saudi Arabia. Environmental Monitoring and Assessment **117**(1), 271-279.
DOI:10.1007/s10661-006-0989-5.

Aucoin J, Blanchard R, Billiot C, Partridge C, Schultz D, Mandhare K, Beck MJ, Beck JN. 1999. Trace metals in fish and sediments from Lake Boeuf, Southeastern Louisiana. Microchem Journal **62**, 299-307.
DOI: org/10.1006/mchj.1999.1735.

Canli M, Atli G. 2003. The relationships between heavy metal (Cd, Cr, Cu, Fe, Pb, Zn) levels and the size of six Mediterranean fish species. Environment Pollution **121** (1), 129-36.
DOI: org/10.1016/S0269-7491(02)00194-X.

Castro-Gonzalez MI, Mendez-Armenta M. 2008. Heavy metals: Implications associated to fish consumption. Environmental Toxicology and Pharmacology **26**, 263-271.
DOI: 10.1016/j.etap.2008.06.001.

Celik U, Oehlenschlager J. 2004. Determination of zinc and copper in fish samples collected from Northeast Atlantic By DPSAV. Food Chemistry **87**, 343-347.
DOI: org/10.1016/j.foodchem.2003.11.018.

Celik U, Oehlenschlager J. 2007. High contents of cadmium, lead, zinc and copper in popular fishery products sold in Turkish supermarkets. Food Control **18**, 258-261.
DOI: org/10.1016/j. foodcont. 2005.10.004.

Chen YC, Chen MH. 2001. Heavy metal concentrations in nine species of fishes caught in coastal waters off Ann-Ping, S.W. Taiwan. Journal of Food and Drug Analysis **9**, 107-114.

Dobaradaran S, Naddafi K, Nazmara SH, Ghaedi H. 2010. Heavy metals (Cd, Cu, Ni and Pb) content in two fish species of Persian Gulf in Bushehr Port, Iran. African Journal of Biotechnology **9**(37), 6191-6193.

Food and Agriculture Organization (FAO). 1983. Compilation of legal limits for hazardous substances in fish and fishery products," *FAO Fishery Circular*, No. 464, 5–10.

Fernandes C, Fontaínhas-Fernandes A, Cabral D, Salgado MA. 2008. Heavy metals in water, sediment and tissues of *Liza saliens* from Esmoriz–Paramos lagoon, Portugal. Environment Monitoring and Assessment **136**, 267–275.
DOI: 10.1007/s10661-007-9682-6.

Heath AG. 1987. Water Pollution and Fish Physiology. CRC Press, Florida, USA, 245 pp.

Kardovani, P. 1995. Iranian marine ecosystem (the Persian Gulf and the Caspian Sea) (Vols. 1 & 2). Tehran, Iran: Ghomes.

Linde AR, Sanchez-Galan S, Izquierdo JI, Arribas P, Maranon E, Garcya-Vazquez E. 1998. Brown Trout as biomonitor of heavy metal pollution: effect of age on the reliability of the assessment. Ecotoxicological and Environmental Safety **40**, 120-125.
DOI: org/10.1006/eesa.1998.1652.

Macfarlane GB, Burchett MD. 2000. Cellular distribution of Cu, Pb and Zn in the Grey Mangrove *Avicennia marina* (Forsk). Aquatic Botany **68**, 45-49. DOI: http://dx.doi.org/10.1016/S0304-3770(00)00105-4.

Maaboodi H, Jamili S, Maddani H. 2011. Accumulation of heavy metals (Lead and Zinc) in the Liver of some edible fishes in Zayandeh-rood. Research Journal of Environmental Sciences **5** (3), 295-301.
DOI: 10.3923/rjes.2011.295.301.

MAFF. 1995. Monitoring and surveillance of non-radioactive contaminants in the aquatic environment and activities regulating the disposal of wastes at sea, 1993. Aquatic Environment Monitoring Report No. 44. Direcorate of Fisheries Research, Lowestoft.

Mendil D, Uluozlu OD, Hasdemir E, Tuzen M, Sari H, Suicmez M. 2005. Determination of trace metal levels in seven fish species in lakes in Tokat, Turkey. Food Chemistry **90**, 175-179.
DOI: org/10.1016/j.foodchem.2004.03.039.

Merian E. 1991. Metals and their Compounds in Environment and Life. Occurrence, Analysis and Biological Relevance. New York, Verlag Chemie Weinheim.

Mitra A, Mondal K, Banerjee K. 2010. Concentration of Heavy Metals in Fish Juveniles of Gangetic Delta of West Bengal, India. Journal of Fisheries and Hydrobiology **5**(1), 21-26.

Oymak SA, Karadede-Akin H, Dogan N. 2009. Heavy metal in tissues of *Tor grypus* from Ataturk Dam Lake, Euphrates River-Turkey. Biologia **64**(1), 151-155.

Rashed MN. 2001. Monitoring of environmental heavy metals in fish from Nasser lake. Environmental International **27**, 27-33.

Sadeghi-Rad M. 1997. Studying and determination of heavy metals (Mercury, Cadmium, Lead, Zinc, Cobalt) in some species of Anzali swamp edible fish (Carp, Duck fish, Carassius, Phytophag). Science Magazine Iran Fish **4**, 1-16.

Sivaperumal P, Sankar, TV, Viswanathan Nair, PG. 2007. Heavy metal concentrations in fish, shellfish and fish products from internal markets of India vis-a-vis international standards. Food chemistry **102**, 612-620.

Turkmen M, Turkmen A, Tepe Y, Ates A, Gokku K. 2008. Determination of metal contaminations in sea foods from Marmara, Aegean and Mediterranean seas: Twelve fish species. Food Chemistry **108**, 794-800.
DOI: org/10.1016/j.foodchem.2007.11.025.

Turkmen A, Turkmen M, Tepe Y, Cekic M. 2010. Metals in tissues of fish from Yelkoma Lagoon, northeastern Mediterranean. Environmental Monitoring and Assessment **168**, 223-230.
DOI:10.1007/s10661-009-1106-3.

Tuzen M, Soylak M. 2007. Determination of trace metals in canned fish marketed in Turkey. Food Chemistry **101**(4), 1378-1382.
DOI: org/10.1016/j.foodchem.2006.03.044.

Tuzen M. 2009. Toxic and essential trace elemental contents in fish species from the Black Sea, Turkey.

Journal of Food and chemical Toxicology **47**(9), 2302-2307.
DOI: org/10.1016/j.fct.2009.04.029.

UNEP. 1991. Sampling of selected marine organisms and sample preparation for the analysis of chlorinated hydrocarbons Reference Methods for Marine Pollution Studies No. 12. Rev. 2. UNEP. Nairobi. 17.

WHO. 1996. Health criteria other supporting information. In: Guidelines for Drinking Water Quality, vol. 2, 2nd ed., pp. 31-388, Geneva.

Yilmaz F, Ozdemir N, Demirak A, Tuna AL. 2007. Heavy metal levels in two fish species *Leuciscus cephalus* and *Lepomis gibbosus*. Food Chemistry **100,** 830-835.
DOI: org/10.1016/j.foodchem.2005.09.020.