Journal of Cell and Animal Biology Vol. 6(1), pp. 1-9, 15 January, 2012
Available online at http://www.academicjournals.org/JCAB
DOI: 10.5897/JCAB11.078
ISSN 1996-0867

Full Length Research Paper

Determination of Cd, Pb, Hg, Cu, Fe, Mn, Al, As, Ni and Zn in important commercial fish species in northern of Persian Gulf

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Accepted 21 December, 2011

The concentration of 10 metals [Cadmium (Cd), lead (Pb), mercury (Hg), copper (Cu), iron (Fe), manganese (Mn), aluminum (Al), arsenic (As), nickel (Ni) and zinc (Zn)] were measured in muscle, gill and liver of 14 species from Hormoz Strait in North Costal of Persian Gulf in 12 months (April 2009 to March 2010). All samples were analyzed for Cd, Pb, Cu, Fe, Mn, Al, As, Ni and Zn concentrations by inductively coupled plasma-atomic emission spectrometry (ICP-AES) and for Hg by LECO AMA254 Advanced Mercury Analyzer. Results of our study showed, Iron had highest concentration (total mean concentration) in all species, and followed by Zn, Cu, Ni, Al, Pb, Mn, Cd and Hg and lowest concentration in three tissues was As. In addition the accumulation of metals was species-dependent, and was higher in *Scomberomorous commerson* and *Thannus tonggol* ($p<0.05$) and the lowest concentration was recorded in *Sardinella sindensis* ($p<0.05$).

Key words: Metal, Persian Gulf, fish.

INTRODUCTION

Marine pollution is a global environmental problem. Different human activities on land, water and air contribute to the contamination of seawater, sediments and organisms with potentially toxic substances. Contaminants can be natural substances or artificially produced compounds. After discharge into the sea, contaminants can stay in the water in dissolved form or they can be removed from the water column through sedimentation to the bottom sediments (Funes et al., 2006). Contamination with metals on local, regional and global scales, have been intensively studied in recent years, due to the fact that metals are persistent, toxic, tend to bioaccumulate, and they pose a risk to humans and ecosystems (Rainbow, 2002; Szefer, 2002). The main reason for this is the increasing metal input to the coastal zone from both rivers and non-point sources, especially in developing countries. Metal contamination can have adverse effects on marine organisms only after metal uptake and accumulation (Funes et al., 2006). Accumulation of metals in aquatic organisms is one of the most striking effects of pollution in aquatic ecosystem. Metals such as Pb, Cd, Cu, Fe occur naturally in water, soil and biota. Their concentration depend on local geology, local addition from mining and industrial activity waste water discharge and/or globally distributed pollution.

Fishes are often at the top of the aquatic food chain and may concentrate large amount of some metals from the water (Mansour and Sidky, 2002). Further, more fish is one of the most indicative factors in aquatic ecosystem, for the estimation of trace metals pollution and risk potential of human consumption (Papagiannis et al., 2004). Metals from geological and anthropogenic source are increasingly being released into natural waters (Nimmo et al., 1998). Contamination of aquatic ecosystems with

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metals has seriously increased worldwide attention, and a lot of studies have been published on the metals in the aquatic environment (Wagner and Boman, 2003). Under certain environmental conditions, metals may accumulate to toxic concentrations and cause ecological damage (Birungi et al., 2007). Metals are taken up through different organs of the fish, because of the affinity between them. In this process many of these metals are concentrating at different levels in different organs in the fish body (Rao and Padmaja, 2000). Hence, it is important to determine the concentrations of metals in commercial fishes in order to evaluate the possible risk of fish consumption (Cid et al., 2001). The present study has been conducted to determine Cd, Pb, Hg, Cu, Fe, Mn, Al, As, Ni and Zn concentrations in the gill, muscle and liver of 14 fish species in Hormoz Strait in north coastal areas of Persian Gulf.

METHODOLOGY

Site selection

Sampling sites was selected of an area that is polluted by different types of industrial and agricultural drainage, domestic waste water and oil pollution. The fish species were randomly collected from commercial catches landed at local fishing ports in North side of Hormoz Strait that is, a narrow between Oman Sea and Persian Gulf. Samples were collected from April 2009 to March 2010, twelve monthly. Body weight and length of fishes were measured prior to dissection.

Samples preparation

After the sampling, fish samples, were transferred to the laboratory in a thermos flask with ice in an isolated box on the same day (Eaton and Clescend, 1990). Approximately 5 g of samples muscle (edible parts), two gill arches from each sample and entire liver, were dissected, wash with de-ionized water, weighted and then packed in polyethylene bags and stored at -20°C prior to analysis. All of the samples were dried at 60°C for 48 h in laboratory oven (Pyle et al., 2005). All glassware's was cleaned prior using by soaking in 10% v/v HNO_3 for 12 h and then rinsed with ultra-pure water. Between 0.2 to 0.4 g of dried sample material were weighted and then digested in acid-cleaned Teflon beaker with 5 ml of ultra-pure nitric acid (65%v/v). Typical microwave digester was operated for 30 to 40 min at a target digestion temperature at 200°C and after then allowed for 1 h to cooling. Digested samples transferred to a graduated plastic test tube and brought up to volume (50 ml) with Mili-Q-water (MOOPAM, 1999). All samples were analyzed three times for Cd Pb, Cu, Fe, Mn Al, As Ni, Zn by inductively coupled plasma-atomic emission spectrometry (ICP-AES) and for Hg by LECO AMA254 Advanced Mercury Analyzer.

In order to assess the analytical capability of the proposed methodology, accuracy of metals analyzing was tested with reference matrices of dogfish liver tissue (DORM2), and muscle tissues (DOLT2). Results confirms that observed and reference values have not statistically differences (P<0.05). Analysis of the dog fish muscle and liver standard reference material DORM 2 and DOLT 2 are shown in Table 1. The statistical analyses were done using the SPSS software (Version 11.5). The data were tested to check the normality using Kolmogorov–Smirnov test, which showed that they have normal distributed. Pearson's correlation and paired samples *t*-test was used to compare heavy metals concentration between fishes and tissues. Some of detection limits factor were digestion by acid that have some human impact and time of digestion, that it took more time for preparation of samples.

RESULTS

The average concentration of metals in all fish samples in every month were shown in Table 2. Results showed the total concentration of Fe is very high than other metals (P<0.05), and As has the lowest concentration (P<0.05). Basis on this table there is no obvious seasonal pattern to metal contamination in the fish samples (P<0.05). The level of 7 of the 10 metals were analyzed (including Cd, Pb, Hg, Cu, Fe, Mn, As and Zn) were higher in the May than other months (P<0.05). Results of fish biometry and their Living environment were shown in Table 3. Basis on this table, *Scomberomorous commerson* had the largest total length in samples (68.9 ± 7.4 cm) and it had the highest weight too (10.39 ± 6.77 g) the shortest of samples was *Sardinella sindensis* (10.2 ± 1.2 cm) and lightest was this kind of fish too (0.06 ± 0.01 g) (Mean ± SD). Tables 4 and 5 shows concentration of metals in three tissues of locally fish caught and the total mean of metals concentration in three tissues of every species were shown in Table 6.

DISCUSSION

Results of this study showed variability of metals level in different species that conformed it is may depend on feeding habits (Roméo et al., 1999), ecological needs, metabolism (Canli and Atli, 2003) or age, size and length of the fish and their habitats (Canli and Atli, 2003). Concentration of metals detected in the muscle, gill and liver samples showed different capacities for accumulating. Among these three tissues based on their differences in physiological and histological properties, the highest metals concentrations were found in the liver and gill (P<0.05). In this study, Iron had the highest concentration (total mean concentration = 23.002 $mg.kg^{-1}$) in all species, and followed by Zn, Cu, Ni, Al, Pb, Mn, Cd, Hg and lowest concentration in three tissues of all species was As. The highest concentration was on dry months in this region (August and September) may be because of high evaporation rate in Persian Gulf. Two kinds of fish species (*S. commerson* and *Thannus tonggol*) showed high average concentration of metals (Table 6). Narrow barred Spanish mackerel, *S. commerson,* had higher concentration of Cd, Pb, Hg, Fe, Mn and As than other species (P<0.05); this phenomenon may be arising from diet, which feed primarily on small fish, like sardinella, clupeids, carangids and also squids and penaeoid shrimps. Another reason for this high concentration is positive correlation between length and weight that called "Bioaccumulation".

In the other species, Long tail tuna, *T. tonggol,* high

Table 1. Comparison of the obtained and reference metals concentrations (mg.g^{-1} dry weight).

CRM		Pb	Cd	Hg	Cu	Fe	As	Ni	Zn
DORM-2	Certified	0.065±0.007	0.043±0.008	4.64±0.26	2.34±0.16	142±10	18±1.1	19.4±3.1	25.6±2.3
	Obtained	0.049±0.003	0.050±0.003	4.31±0.39	2.21±0.23	149±13	16±1.6	19.1±1.6	23.1±3.5
DOLT-2	Certified	0.16±0.04	24.3±0.8	2.58±0.22	31.2±1.1	1833±75	9.66±0.62	0.97±0.11	116±6
	Obtained	0.19±0.01	21.1±0.3	2.44±0.17	30.9±0.9	1813±69	9.30±0.42	0.91±0.06	111±3.1

Table 2. The average of metals concentration in all fish samples in different months (mg.kg^{-1}).

Month/metal	Cd	Pb	Hg	Cu	Fe	Mn	Al	As	Ni	Zn
April	0.256 ±0.12	1.022±0.15	0.199±0.09	1.120±0.21	12.036±0.98	0.354±0.07	1.587±0.21	0.042±0.01	0.987±0.13	3.258±0.29
May	0.415±0.11	1.103±0.25	0.139±0.08	1.002±0.31	24.509±2.58	0.741±0.25	0.658±0.18	0.112±0.07	1.888±0.81	4.621±1.02
June	0.125±0.05	0.589±0.18	0.215±0.04	1.014±0.65	18.660±2.98	1.069±0.58	0.421±0.03	0.055±0.01	2.254±0.73	3.955±0.96
July	0.101±0.06	0.601±0.31	0.121±0.04	0.899±0.01	8.231±1.93	0.736±0.33	0.369±0.12	0.101±0.09	1.745±0.45	4.889±0.1.33
August	0.145±0.08	1.232±0.65	0.112±0.02	2.129±088	19.447±2.33	0.778±0.22	2.958±0.22	0.111±0.05	2.971±0.87	3.514±0.25
September	0.438±0.14	1.815±0.88	0.320±0.07	1.133±0.40	55.211±7.52	1.687±0.52	1.253±0.54	0.124±0.06	0.965±0.74	5.743±0.88
October	0.155±0.06	1.159±0.87	0.103±0.24	1.010±0.64	32.230±5.04	0.899±0.11	0.988±0.19	0.041±0.01	0.77±0.23	4.002±0.58
November	0.124±0.09	1.089±0.45	0.225±0.41	2.008±0.23	13.258±3.69	0.987±0.15	2.504±0.66	0.063±0.03	1.242±0.41	3.632±1.22
December	0.519±0.14	0.940±0.18	0.119±0.02	1.122±0.71	16.055±5.01	0.729±0.04	1.213±0.69	0.040±0.01	1.358±0.24	3.321±0.84
January	0.206±0.08	1.411±0.14	0.125±0.03	1.116±0.65	18.241±3.58	0.637±0.14	0.887±0.08	0.089±0.01	1.023±0.08	5.036±0.32
February	0.111±0.57	0.728±0.33	0.098±0.01	0.781±0.2	38.144±9.84	0.805±0.12	1.452±0.58	0.091±0.01	1.003±0.33	4.105±0.87
March	0.102±0.01	0.977±0.33	0.104±0.08	0.864±0.21	20.005±3.33	0.816±0.29	2.314±0.5	0.051±0.01	1.065±0.1	3.147±0.22
Total (annual)	0.224±0.14	1.055±0.34	0.157±0.06	1.183±0.42	23.002±13.13	0.853±0.31	1.384±0.82	0.077±0.03	1.448±0.64	4.102±0.81

metal concentration (Cu, Ai, Ni and Zn) was recorded that it was more than other species (*p*<0.05); this fish feeds on variety of fish, Cephalopods and Crustaceans particularly stomatopods larvae. The lowest concentration was recorded in *Sind* sardinella, *S. sindensis,* which has the lowest weight (10.2±1.2) and the shortest length (0.06±0.01). the highest concentration of Cd were recorded in the liver of *S. commerson* (1.20 mg.kg^{-1}), the highest concentration of Pb was in liver of *S. commerson* (2.431 mg.kg^{-1}) and the highest concentration of Hg were recorded in liver in *S. commerson* (0.593 mg.kg^{-1}), this phenomenon may be because of liver chractristic and food habit of *S. commerson,* because *S. commerson,* is carnivorous and is on the top of the food chain. We observed highest concentration in liver of T. *tonggol* (4.311 mg.kg^{-1}) and also Fe concentration was higher in the gill in *S. commerson* (64.461 mg.kg^{-1}), than other species. Mn concentration in gill was higher in *S. commerson,* than other species (2.646 mg.kg^{-1}) and Al was highest in Muscle of *T. tonggol* (0.743±0.09). As was higher in liver of Euryglosa oreintalis (0.159 mg.kg^{-1}) than other concentration in other species. Ni was higher in liver of *S. commerson*, (2.723 mg.kg^{-1}) and Zn was highest in gill in *T. tonggol* (7.021 mg.kg^{-1}). Totally Cd, P, Hg, Ni was highest concentration in Liver of *S. commerson,* and Mn, Fe was highest in this species in gill.

This could be described by food habits and position of *S. commerson,* in food chain. The

Table 3. Results of fish samples biometry.

Scientific name	English name	Samples	Length (cm) Mean±Sd	Weight (Kg) Mean ± Sd	Habitat	Feeding
Scomberomorous commerson	Narrow barred Spanish mackerel	24	68.9±7.4	10.39±6.77	Pelagic - naritic	Carnivore on small fish
Rastrelliger kanagurta	Indian mackerel	24	18.2±3.4	0.20±0.05	Pelagic - naritic	Carnivore on fish larva and shrimp
Scomberomorus guttatus	king mackerel	24	43.1±6.9	0.65±0.11	Pelagic - naritic	Carnivore on small fish
Thannus tonggol	Longtail tuna	24	54.6±3.4	4.75±1.0	Pelagic - naritic	Carnivore on small fish and crasteasen
Pampus argenteus	Silver Pomfert	24	28.2±2.1	0.54±0.21	Benthopelagic	Filter feeders on phytoplankton and zooplankton
Acanthopagrus latus	Yellofin seabream	24	32.4±3.0	0.37±0.09	Demersal	Carnivores on zoobenthose
Argyrops spinifer	King soldier bream	24	33.1±1.9	0.43±0.14	Demersal	Carnivore on shrimps and mollusca
Mugile cephalus	Flathead grey mullet	24	17.3±2.2	0.48±0.3	Benthopelagic	Filter feeders on zooplankton, benthos
Euryglossa orientalis	Oreintal sole	24	18.7±2.3	0.32±0.12	Demersal	Carnivore on benthos
Psettodes erumei	Indian Sping turbot	24	37.4±3.1	1.23±0.33	Demersal	Carnivore on small fish
Epinephelus coioides	Orange-spotted grouper	24	40.2±3.7	1.43±0.44	Demersal	Carnivore on small fish and crustaceans
Pomadasys kaakan	Javelin gerunter	24	30.2±2.3	0.43±0.09	Reef-associated	Carnivore on Crustacean and polychita
Lutjunus johnii	John's snapper	24	30.1±2.9	0.64±0.29	Reef-associated	Carnivore on small fish and benthos
Sardinella sindensis	Sind sardinella	24	10.2±1.2	0.06±0.01	Pelagic – naritic	Filter feeders on phytoplankton, zooplankton

Table 4. Metals concentration in muscle, gill and liver of locally fish caught (mg.kg^{-1}).

Species		Cd			Pb			Hg			Cu			Fe		
		Muscle	Gill	Liver	Muscle	Gill	Liver	Muscle	Gill	Liver	Muscle	Gill	Liver	Muscle	Gill	Liver
Scomberomorous	Mean	0.315	0.494	1.210	1.314	1.779	2.431	0.243	0.372	0.593	2.431	0.879	3.420	52.318	99.821	50.245
commerson	SD	0.074	0.087	0.012	0.142	0.239	0.371	0.054	0.031	0.087	0.531	0.009	0.054	7.987	11.342	7.336
Rastrelliger	Mean	0.112	0.197	0.262	0.392	0.943	1.341	0.089	0.109	0.123	2.321	1.231	2.938	5.791	10.721	18.721
kanagurta	SD	0.007	0.023	0.028	0.131	0.132	0.293	0.031	0.023	0.013	0.137	0.017	0.032	0.987	2.743	3.852
Scomberomorus	Mean	0.021	0.120	0.243	0.963	1.745	0.873	0.184	0.214	0.337	2.983	1.177	3.572	47.932	52.903	53.030
guttatus	SD	0.012	0.021	0.031	0.143	0.067	0.970	0.123	0.034	0.033	0.123	0.023	0.142	5.320	6.779	3.940
Thannus	Mean	0.212	0.314	0.579	1.215	1.532	1.842	0.102	0.182	0.209	1.874	2.593	4.311	15.392	2.294	7.212
tonggol	SD	0.054	0.114	0.119	0.210	0.149	0.298	0.012	0.078	0.092	0.054	0.034	0.231	1.543	1.372	2.593
Pampus	Mean	0.120	0.192	0.212	0.948	1.342	1.431	0.054	0.103	0.142	2.122	1.145	2.119	3.421	7.546	7.425
argenteus	SD	0.009	0.019	0.015	0.145	0.293	0.314	0.009	0.023	0.042	0.037	0.087	0.239	1.724	1.536	2.322
Acanthopagrus	Mean	0.062	0.072	0.102	0.792	1.219	1.672	0.042	0.131	0.112	1.931	1.211	1.541	20.941	19.980	20.941
latus	SD	0.007	0.012	0.019	0.172	0.194	0.142	0.008	0.009	0.081	0.029	0.112	0.054	2.329	3.654	3.499

Table 4. Contd.

Argyrops spinifer	Mean	0.054	0.081	0.122	0.543	0.894	1.021	0.037	0.044	0.032	2.784	1.983	3.747	31.172	5.421	50.198
	SD	0.012	0.013	0.015	0.082	0.102	0.120	0.008	0.003	0.009	0.019	0.019	0.039	5.439	9.332	5.173
Mugile cephalus	Mean	0.193	0.213	0.254	0.531	0.744	0.212	0.123	0.145	0.182	1.431	1.659	1.541	4.436	15.694	32.411
	SD	0.012	0.023	0.031	0.142	0.143	0.312	0.082	0.012	0.052	0.023	0.048	0.179	1.231	0.392	3.653
Euryglossa orientalis	Mean	0.214	0.294	0.197	0.973	1.431	0.873	0.154	0.087	0.192	2.931	1.231	0.953	16.941	31.590	39.742
	SD	0.052	0.067	0.032	0.079	0.171	0.127	0.071	0.009	0.023	0.131	0.143	0.039	5.432	5.333	6.943
Psettodes erumei	Mean	0.152	0.142	0.159	0.125	0.723	0.943	0.112	0.179	0.243	1.431	1.112	1.312	14.212	18.509	20.433
	SD	0.094	0.043	0.071	0.053	0.059	0.094	0.032	0.042	0.031	0.097	0.094	0.142	1.593	2.693	2.590
Epinephelus coioides	Mean	0.078	0.117	0.293	0.674	1.231	1.179	0.131	0.120	0.142	1.781	0.997	0.743	7.021	8.430	17.120
	SD	0.090	0.087	0.014	0.012	0.087	0.171	0.021	0.013	0.040	0.241	0.031	0.071	2.370	1.711	2.011
Pomadasys kaakan	Mean	0.091	0.179	0.215	0.743	0.994	1.121	0.159	0.171	0.210	1.232	1.235	1.240	18.123	17.129	18.932
	SD	0.012	0.071	0.087	0.079	0.970	0.078	0.022	0.052	0.041	0.071	0.071	0.092	2.959	5.431	3.3.431
Lutjunus johnii	Mean	0.123	0.145	0.117	1.231	1.543	1.342	0.141	0.159	0.194	1.671	1.314	1.745	23.001	30.140	35.140
	SD	0.028	0.031	0.051	0.171	0.147	0.123	0.031	0.040	0.031	0.054	0.054	0.254	3.147	3.366	5.171
Sardinella sindensis	Mean	0.032	0.112	0.182	0.184	0.392	0.872	0.089	0.071	0.129	1.431	0.743	0.847	1.236	5.431	6.971
	SD	0.011	0.015	0.015	0.093	0.082	0.162	0.023	0.019	0.021	0.154	0.031	0.023	0.543	3.510	1.421

results were confirmed the differences of accumulation of metals in the different tissues (Table 4). The highest concentrations of elements were found in the liver and gill, while the lowest concentrations of elements were found in the muscle. Many studies showed that metals accumulate mainly in metabolic organs such as Liver that stores metals to detoxificatante by producing metallothioneins (Carpene and Vasak, 1989; Karadede et al., 2004). The comparison between three major metals (Hg, Cd and Pb), which have high risk for human health in this study and the other studies at the different regions of the world is shown in Table 7. In this study, Cd concentration was generally more than other available data at other regions, it was about 9 times more than Adriatic Sea, about 13 times more than Masan bay, Korea, about 8 times more than Osaka, Japan and about 9 times more than Manila, Philippines and less than recorded concentration in Gulf of California and Iskenderun bay and Arabian Sea (Table 7). Pb Concentration was high than other place except in Iskenderun bay and Arabian Sea (Table 7).

Mean concentration of Pb in study area was 2 times more than Gulf of California, 23 times more than Adriatic Sea, 13 times more than Mason bay, Korea, 21 times more than Osaka Japan and 7 times more than Manila bay, Philippines (Table 6). About Hg concentration, our results were lower than other results except about one region including Atlantic Sea (our results 2 times more than this) (Table 6). Concentration of three major metals including (Hg, Cd and Pb) compared with standards, Table 8 showed Hg and Cd concentration is below than standards and Pb concentration is exceed than standard, and there is high risk for women and children for consuming fish. Trace element levels are known to vary in fishes depending on various factors such as its habitat, feeding behavior and migration even in the same area (Anders et al., 2000; Canli and Atli,

Table 5. Concentration of metals in muscle, gill and liver of locally fish caught (mg.kg^{-1}).

Species		Mn			Al			As			Ni			Zn		
		Muscle	Gill	Liver	Muscle	Gill	Liver	Muscle	Gill	Liver	Muscle	Gill	Liver	Muscle	Gill	Liver
Scomberomorous	Mean	2.431	2.646	1.541	0.587	1.923	1.722	0.062	0.098	0.111	0.721	2.441	2.723	2.734	3.477	3.311
commerson	SD	0.172	0.131	0.123	0.170	0.141	0.299	0.009	0.022	0.019	0.144	0.303	0.390	0.341	1.231	0.777
Rastrelliger	Mean	0.194	0.342	0.451	1.293	1.346	1.843	0.011	0.042	0.088	0.339	1.556	1.940	3.599	5.789	4.512
kanagurta	SD	0.032	0.023	0.021	0.118	0.077	0.240	0.005	0.017	0.022	0.107	0.245	0.093	1.901	2.491	1.132
Scomberomorus	Mean	0.063	0.193	0.272	0.792	1.733	2.320	0.073	0.080	0.112	0.877	1.345	1.667	1.431	3.021	4.211
guttatus	SD	0.012	0.033	0.019	0.056	0.250	0.336	0.070	0.013	0.012	0.093	0.110	0.127	0.773	0.691	1.509
Thannus	Mean	0.743	0.649	0.887	3.541	3.421	3.311	0.112	0.093	0.140	2.943	3.091	2.970	5.707	7.021	6.015
tonggol	SD	0.091	0.041	0.023	0.232	0.333	0.507	0.011	0.007	0.032	0.233	0.247	0.193	1.673	2.915	2.500
Pampus	Mean	1.127	2.431	3.550	0.344	0.543	0.640	0.096	0.119	0.092	1.124	1.776	1.500	3.300	5.355	5.315
argenteus	SD	0.056	0.017	0.192	0.179	0.091	0.133	0.070	0.017	0.021	0.087	0.094	0.250	0.553	2.066	1.605
Acanthopagrus	Mean	0.649	0.943	0.756	1.512	1.741	1.922	0.018	0.049	0.055	1.394	2.441	2.009	5.600	5.519	5.944
latus	SD	0.043	0.022	0.117	0.115	0.520	0.311	0.003	0.022	0.014	0.199	0.338	0.243	0.149	0.098	0.385
Argyrops	Mean	0.937	0.889	0.931	0.823	1.370	1.665	0.054	0.033	0.050	1.741	1.940	1.850	2.843	3.771	3.601
spinifer	SD	0.125	0.018	0.115	0.122	0.311	0.295	0.006	0.014	0.009	0.113	0.239	0.093	1.323	0.131	1.193
Mugile	Mean	0.327	0.241	0.559	0.642	1.750	0.742	0.023	0.038	0.054	0.677	0.877	0.579	3.551	5.693	5.515
cephalus	SD	0.093	0.059	0.031	0.076	0.099	0.125	0.009	0.014	0.016	0.085	0.157	0.117	1.602	1.022	2.101
Euryglossa	Mean	0.743	0.470	0.679	2.823	3.012	3.115	0.094	0.123	0.159	2.320	1.821	1.709	4.301	6.533	6.401
orientalis	SD	0.076	0.073	0.127	0.311	0.230	0.235	0.011	0.010	0.029	0.305	0.113	0.332	1.590	1.788	2.314
Psettodes	Mean	0.821	0.962	0.890	0.432	0.676	0.787	0.049	0.071	0.088	0.843	1.490	1.853	2.320	3.451	3.721
erumei	SD	0.043	0.183	0.093	0.031	0.053	0.800	0.011	0.023	0.017	0.033	0.122	0.117	0.109	0.308	0.034
Epinephelus	Mean	0.399	0.531	0.643	0.693	0.570	0.542	0.091	0.087	0.121	1.231	1.543	1.644	3.539	3.655	2.991
coioides	SD	0.079	0.179	0.049	0.049	0.230	0.188	0.009	0.029	0.036	0.097	0.201	0.310	0.231	0.329	0.087
Epinephelus	Mean	0.399	0.531	0.643	0.693	0.570	0.542	0.091	0.087	0.121	1.231	1.543	1.644	3.539	3.655	2.991
coioides	SD	0.079	0.179	0.049	0.049	0.230	0.188	0.009	0.029	0.036	0.097	0.201	0.310	0.231	0.329	0.087

Table 5. Contd.

Lutjunus	Mean	0.493	0.590	0.589	1.732	1.645	1.892	0.071	0.051	0.081	0.729	0.846	0.701	2.759	2.844	2.650
johnii	SD	0.132	0.184	0.124	0.536	0.195	0.318	0.016	0.013	0.031	0.019	0.111	0.026	0.176	0.221	0.394
Sardinella	Mean	0.096	0.192	0.171	0.293	0.334	0.282	0.022	0.020	0.041	0.448	0.691	0.540	2.011	2.991	3.201
sindensis	SD	0.090	0.062	0.970	0.095	0.029	0.073	0.008	0.010	0.021	0.107	0.200	0.170	0.962	0.940	0.999

Table 6. Total mean of metals concentration in three tissues of every species ($mg.kg^{-1}$).

Species	Cd	Pb	Hg	Cu	Fe	Mn	Al	As	NI	Zn
Scomberomorous commerson	0.673 ±0.13	1.841±0.08	0.403±0.07	2.243±0.26	64.461±10.45	2.206±0.65	1.411±0.07	0.900±0.14	1.962±0.21	3.174±0.95
Rastrelliger kanagurta	0.1900.01	0.892±0.21	0.107±0.09	2.163±0.44	11.744±1.08	0.329±0.04	1.494±0.12	0.047±0.01	1.278±0.21	4.633±1.02
Scomberomorus guttatus	0.128±0.08	1.194±0.47	0.245±0.11	2.577±0.53	51.288±12.33	0.176±0.01	1.615±0.22	0.088±0.01	1.296±0.29	2.888±0.39
Thannus tonggol	0.368±0.11	1.530±0.65	0.164±0.44	2.926±0.75	8.299±1.02	0.760±0.14	3.424±0.29	0.115±0.08	3.001±0.45	6.248±1.25
Pampus argenteus	0.175±0.09	1.240±0.47	0.100±0.07	1.795±0.71	6.131±1.12	2.369±0.52	0.509±0.11	0.102±0.02	1.467±0.62	4.657±1.05
Acanthopagrus latus	0.079±0.01	1.228±0.84	0.095±0.01	1.561±0.51	20.621±11.31	0.783±0.09	1.725±0.7	0.041±0.01	1.948±0.65	5.688±1.08
Argyrops spinifer	0.086±0.02	0.819±0.25	0.038±0.01	2.838±0.84	28.930±9.45	0.919±0.31	1.286±0.22	0.046±0.01	1.844±0.42	3.405±1.02
Mugile cephalus	0.220±0.14	0.496±0.19	0.150±0.08	1.544±0.21	17.514±5.29	0.376±0.11	1.045±0.96	0.380±0.21	0.711±0.09	4.920±1.2
Euryglossa orientalis	0.235±0.11	1.092±0.43	0.144±0.13	1.705±0.63	29.424±11.23	0.631±0.02	2.983±1.03	0.125±0.02	1.950±0.71	5.745±1.23
Psettodes erumei	0.151±0.09	0.597±0.21	0.178±0.04	1.285±0.22	17.718±5.62	0.891±0.31	0.632±0.26	0.690±0.18	1.395±0.43	3.164±1.08
Epinephelus coioides	0.163±0.41	1.028±0.41	0.131±0.04	1.174±0.41	10.857±3.21	0.524±0.11	0.602±0.27	0.100±0.08	1.473±0.41	3.395±1.27
Pomadasys kaakan	0.162±0.07	0.953±0.27	0.180±0.07	1.236±0.21	18.061±4.35	1.269±0.11	0.593±0.31	0.114±0.07	0.624±0.08	4.024±1.08
Lutiunus johnii	0.128±0.02	1.372±0.7	0.165±0.02	1.577±0.56	29.427±10.12	0.557±0.43	1.756±0.98	0.068±0.02	0.759±0.65	2.751±0.91
Sardinella sindensis	0.109±0.07	0.483±0.13	0.096±0.01	1.007±0.54	4.546±2.33	0.153±0.06	0.303±0.18	0.028±0.01	0.560±0.28	2.734±1.07
Total mean	0.205±0.16	1.055±0.38	0.157±0.08	1.831±0.62	23.002±17.75	0.853±0.68	1.384±0.91	0.077±0.26	1.448±0.67	4.102±1.20

2003). Based on ecological characteristics and feeding habits of fish species in present study, fishes could be grouped as 2 different groups (Table 3): filter feeders (including *Papmus argenteus*, *Mugil cephalus*) and carnivores on small fish, benthos and shrimps (including other species such as *S. commerson, T. tongol*), these species-specific characteristic results in variation of trace element accumulation between species.

Conclusion

This study was carried out to provide information on metals concentration in 14 fish species from Persian Gulf. The metal content is species-dependent, with some species showed high concentration of metals, and some showed low concentration. The metal concentrations in the fish tissues were also time-dependent, with residues much higher during the rainy season. We conclude that the regular consumption of some of these fish species even during the dry season, could pose health risks, but totally have risk for human health especially for children and pregnant women.

This high level of metals in water and sediment and fish body rising from anthropogenic activity such as industrial wastewater, urban waste water,

Table 7. Comparing between results of this study with same in other regions (mg.kg^{-1}).

Location	Cd	Pb	Hg	Reference
Gulf of California	0.46	0.355	1.6	(Soto-Jimenze et al., 2009)
Adriatic sea	0.022	0.045	0.515	(Storelli, 2008)
Atlantic coast	-	-	0.073	(Voegborlo and Akagi, 2007)
Iskenderun bay	0.950	2.320	-	(Türkmen et al., 2005)
Mediterranean sea	0.37 – 0.79	2.98 – 6.120	-	(Roditi-Elasar et al., 2003)
Masan Bay and Korea	0.015	0.076	-	(Kwon and Lee, 2001)
Osaka and Japan	0.027	0.048	-	(Masahiro et al., 1999)
Manila bay and Philippines	0.024	0.135	0.289	(Maricar et al., 1997)
Arabian sea and Pakistan	0.320	4.120	0.133	(Tariq et al., 1994)
North side of Hormoz striate, Persian Gulf and Iran	0.205	1.055	0.157	Current study

Table 8. Comparison results with standard.

Standard/result	Cd	Pb	Hg
EPA standard	1	1	0.5
Italy standard	-	5	0.7
Japan standard	-	-	1
Our results	0.205	1.055	0.157

ship industrial, oil and gas exploration and petrochemical industries. Generally, according to the results and according to regional conditions such as high evaporation, semi-closed, waste water discharge, etc and compared to other regions, Persian Gulf in the critical condition that requires more attention and control of its pollutants.

ACKNOWLEDGMENT

We express our special thanks to Hossein Pasha, who had kindly assisted us in data analysis. We are also grateful to Dr. Ali Javadi and Dr. Ali Reza Moemeni for their valuable help in fish sampling and laboratory analysis. This work was funded by the Tarbiat Moallem University and Islamic Azad University–Science and Research Branch of Ahwaz by corporation of Hormozgan Department of Environment and Persian Gulf and Oman Sea Ecological Research Institute and Iranian Fishery Organization.

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