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Comparative Study of Mercury Accumulation in Two Fish Species, (*Cyprinus carpio* and *Sander lucioperca*) from Anzali and Gomishan Wetlands in the Southern Coast of the Caspian Sea

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Abstract Anzali and Gomishan wetlands are considered as two of the most important wetlands in southern coast of Caspian Sea. To investigate mercury accumulation in these ecosystems, total mercury concentrations were measured in the muscle tissue of two fish species. Higher mercury concentrations were detected in *C. carpio*, an omnivorous benthic/pelagic species (Anzali wetland: 0.2 μg g^{-1} wet weight; Gomishan wetland: 0.2 μg g^{-1} wet weight), than in *S. lucioperca*, a carnivorous pelagic species (Anzali: 0.06 μg g^{-1} wet weight; Gomishan: 0.15 μg g^{-1} wet weight).

Keywords Mercury · Anzali and Gomishan wetlands · European pike perch · Common carp

The Iranian coast of the Caspian Sea stretches for nearly 700 km from Azerbaijan in the west to Turkmenistan in the east. This coastline receives effluents discharges from heavily industrialized and populated areas. These pollutants originate from anthropogenic activities such as agriculture, mining, oil refining, petrochemical and chemical industry, wood and paper manufacturing, energy production and shipping The Caspian has been described as a land lock body of water, a lacking tidal activity where the bulk of the discharged contaminants remain trapped within its basin. Moreover, sea currents transport and circulate the entrapped pollutants along the Iranian coast of the Caspian Sea (Tabari et al. 2010). Contamination by heavy metals such as mercury (Hg) is a critical form of pollution in the Caspian Sea because of its toxicity, non biodegradability and persistence for several decades in the aquatic environment (Kaewsarn and Yu 2001).

There are two important wetlands in the southern basin of Caspian Sea, Anzali and Gomishan wetlands (Fig. 1). Anzali wetlands, represents an internationally important wildlife reserve and sanctuary which is listed under Ramsar Convention. Gomishan wetlands are in southeast corner of the Caspian Sea, which has been described as a coastal permanent brackish lagoon (Ramsar Convention Bureau 1997). Ghomishan was registered in 2001 in the list of International Wetlands Convention (Ramsar). The water level of Anzali and Gomishan wetlands are depended on to water level of the Caspian Sea. As result, contaminants can enter from the Caspian into these wetlands. Therefore, pollution levels in these wetlands not only depend on inflow from industrial, municipal, and agricultural wastes that are discharged into these wetlands, but also on the pollutions that arrives from the Caspian Sea.

In our study, Hg levels were measured in muscle of two fish species, (*Cyprinus carpio* and *Sander lucioperca*) from Anzali and Gomishan wetlands, in an effort to assess the extent of mercury pollution in these wetlands. The areas where the fish specimens were sampled are shown in Fig. 1. Anzali wetland is situated in the province of Gilan, in North of Iran. It is located at the southwest of the Caspian Sea (37°28/N, 49°25/E), adjacent to the city of Bandar-e-Anzali. Its open surface area is estimated at 200 km^2.

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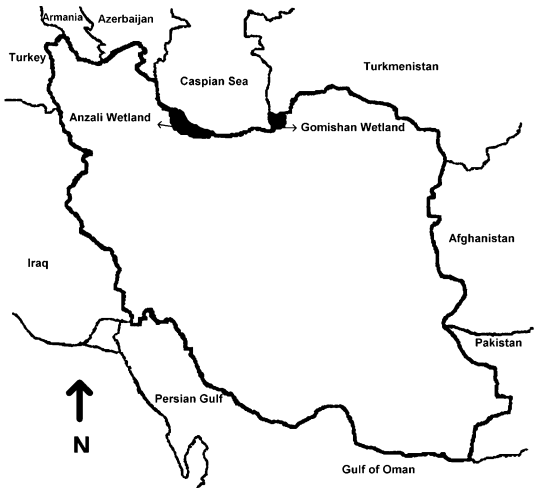

Fig. 1 The arrows indicate the location of the sampling area

The Gomishan wetland is situated at the southeast of the Caspian Sea (37°11/N, 53°57/E). It is a type of large shallow marsh lagoon with a surface area of 20,000 ha, average depth of 100 cm, and maximum depth of 250 cm.

Some of Fish species are at the top position in the aquatic food chain and may directly affect the health of humans, which makes them much of significance for the bio monitoring using fish. We hypothesized that since there are more factories, and agricultural activities around the Anzali wetland than Gomishan wetland, we expected to see the higher Hg concentrations in fish species of Anzali wetland compared to fish species of Gomishan wetland.

Materials and Methods

Common carp ($n = 7$) and European pike perch ($n = 7$) were collected by net in each study area early in February 2011. Samples were kept in pre-cleaned boxes with ice and were transported to the laboratory and stored at −20°C until further analysis. In the laboratory fish were weighed and measured then dorsal muscles were removed. For this purpose, skin was carefully separated from the muscle and muscle was kept to measure mercury. The samples were freeze-dried, homogenized, and ground with mortar and pestle. The mercury was measured by the LECO AMA 254 Advanced Mercury Analyzer (USA) according to ASTM, standard No. D-6722. The LECO AMA 254 is a unique Atomic Absorption Spectrometer (AAS) that is specifically designed to determine total mercury content in various solids and certain liquids without sample pre-treatment or sample pre-concentration (Al-Majid and Preston 2000). The detection limit of the method used was 0.001 μg g^{-1} in dry weight. In order to avoid possible contamination, all the glassware and equipment used were acid washed (Nitric acid %4). The data were reported as μg g^{-1} dry weight (dw) and wet weight (dw).

All statistical analyses were performed using SPSS version 16. All data were diagnosed for normality of distribution and homogeneity of variance before subjecting to parametric statistical tests. Mercury concentrations in muscle were tested for mean differences between species using independent sample *T* Test. Correlations between the biological variables size and weight in relation to concentration of total mercury in species were evaluated by Pearson correlation.

Results and Discussion

Table 1 shows mean values of total Hg in muscle tissue of the two fish species in each study area. The statistical analysis provided convincing evidence of significant differences in total mercury between the two species. The common carp from Anzali and Ghomishan had same levels of Hg (0.2 μg g^{-1} ww; $p > 0.05$). The Pike-perch (*S. lucioperca*) of Anzali had 0.06 μg g^{-1} ww whereas Gomishan's Pike perch had 0.15 μg g^{-1} ww).

A comparative study of mercury levels between species is essential because it will allow us to identify the better species for monitoring purposes. In this study, a significant difference in mercury levels was found between the two fish species from each study area. The wide variability of mercury levels among the different species is in accordance with the process of uptake of this metal in fish and the interaction of numerous parameters, either abiotic (water and sediments) or biotic (size, sex, longevity, growth rate, feeding habits, trophic position, habitat) (Storelli et al. 2005). One of the possibilities for higher mercury levels in the Common carp when compared to the European pike perch is differences in their feeding habits (Jeffree et al. 2006). European pike perch is a carnivorous fish and feeds mainly on gregarious, pelagic fishes While Common carp is a omnivorous fish, can eat a vegetarian diet of water plants, but prefer to scavenge the bottom for insects, crustaceans (including zooplankton), and benthic worms. Also, Common carp can feed in deep water in close contact

Table 1 Total mercury concentrations in two fish species (mean ± standard error)

Fish specie-sampling site	Hg concentration (μg g^{-1} dw)	Hg concentration (μg g^{-1} ww)
C. carpio- Anzali	0.99 ± 0.06	0.20 ± 0.02
C. carpio- Gomishan	1.00 ± 0.11	0.20 ± 0.03
S. lucioperca- Anzali	0.30 ± 0.06	0.06 ± 0.01
S. lucioperca- Gomishan	0.69 ± 0.14	0.15 ± 0.03

Table 2 Correlation between total mercury concentration and length and weight of two fish species

	C. carpio Anzali	*C. carpio* Gomishan	*S. lucioperca* Anzali	*S. lucioperca* Gomishan
Mean size (cm)	33.14 ± 1	34.5 ± 0.5	32.21 ± 0.5	36.57 ± 1.27
Mean weight (kg)	0.47 ± 0.03	0.52 ± 0.02	0.3 ± 0.02	0.42 ± 0.06
r (correlation fish size-Hg concentration)	0.62	0.60	0.21	0.19
p-value	0.04	0.05	0.64	0.69
r (correlation fish weight-Hg concentration)	0.64	0.23	0.78	0.83
p-value	0.02	0.62	0.04	0.02

with the upper layer of sediment, the site of mercury methylation and it has been clearly documented that benthic fish show higher total mercury concentrations in their muscles than pelagic organisms, confirming the significant process of sedimentation and persistence of this metal in depths (Storelli et al. 2005).

In addition, the importance of size to body mercury is widely recognized in aquatic organisms. Usually, older organisms show higher mercury levels as a consequence of a longer exposure time (Storelli and Marcotrigiano 2000). The relationships between mercury concentration in fish species with length and weight of them presented in Table 2. In *C. carpio*, mercury concentrations increased with the increase in length (Anzali: $r = 0.62$; $p < 0.05$, Gomishan: $r = 0.60$, $p < 0.05$) in both sampling sites and mercury concentrations increased with the increase in weight, only in Anzali ($r = 0.64$, $p < 0.05$). Also, in *S. lucioperca*, mercury concentrations increased with the increase in weight (Anzali: $r = 0.78$, $p < 0.05$; Gomishan: $r = 0.83$, $p < 0.05$) in both sampling sites.

A comparison of total mercury contents was carried out between fish of the same species from different localities. The results of this investigation indicated, higher values for species from Gomishan than those from Anzali (Fig. 2). Mercury concentrations varied significantly ($p < 0.05$) in the *S. lucioperca* in two wetlands. While, there was no statistical difference ($p > 0.05$) between Hg concentrations in the *C. carpio* in two wetlands. We had predicted that fish species from Anzali wetland would show higher levels of mercury in their muscles, because Anzali is closer to sources of pollution than Gomishan. One possible reason to clarify this point is related to the circulation of water in Caspian Sea. Circulation of water in the southern part is counterclockwise and is from west to east of coastal area (Korotenko et al. 2000). This status may cause higher contamination in the east compared to the west of Caspian Sea. Another reason for higher concentration of mercury in fish samples from Gomishan compared to Anzali wetland may be due to the fact that samples from the Gomishan had higher length and weight compared to samples from Anzali (Table 2).

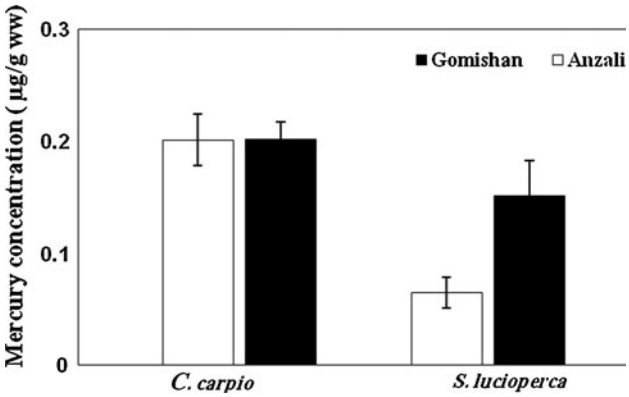

Fig. 2 Comparison of mercury levels in two fish species from different sampling sites

Common carps from this study had higher levels of Hg in muscles than Common carps from Ya-Er Lake, china (Jin et al. 2006), Zahlinice Reservoir, Czech Republic (Houserova et al. 2007), Vestonice Reservoir, Czech Republic (Kenšová et al. 2010), and lake of Beysehir (Altındag and Yigit 2005). By comparison with Common carp, European pike perch has received little attention. European pike perchs from Vestonice Reservoir, Czech Republic had higher levels of Hg in muscles (Kenšová et al. 2010), than those we collected from Gomishan and Anzali (Table 3; Fig. 3).

The demand for fish as a source of protein is increasing, and these species consumption per capita in Iran has increased from 2 to 7 kg in the last two decades, especially in some inland areas that are far away from the sea (Ebrahimi and Taherianfard 2010). It has already been mentioned that governmental agencies have set limits for mercury concentrations above which the fish is considered unsuitable for human consumption.

The maximum allowed concentration of Hg in fish meat according to the standards stipulated by the Environmental

Table 3 Comparison of mercury levels in this study with different standards

	Hg concentration ($\mu g\ g^{-1}$ ww)
WHO	0.5
EPA	0.2
Canada	0.5
Brazil	0.5
Europa	0.5
This study	$\leq$0.2

Fig. 3 Schematic of water circulation in Caspian Sea

Protection Agency (EPA) of the United States are 0.2 $\mu g\ g^{-1}$ (Sun et al. 2006); the highest concentrations of Hg in fish tissues of *C. carpio* and *S. lucioperca* were within this range. Furthermore Canadian authority allows a maximum of 0.5 $\mu g\ g^{-1}$ total mercury (wet weight) in fish for commercial sale (Health and Welfare Canada 1979). The total mercury concentrations found in fish from Anzali and Gomishan wetland are within acceptable levels for human consumption according to the World Health Organization (WHO 1990). European Commission Decision (Official Journal of the European Communities 1994) sets the maximum limit for mercury in seafood at 0.5 $\mu g\ g^{-1}$ ww. In the present study, total mercury concentrations in fish samples did not exceed from 0.5 $\mu g\ g^{-1}$ ww.

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