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A comparative study of accumulated total mercury among white muscle, red muscle and liver tissues of common carp and silver carp from the Sanandaj Gheshlagh Reservoir in Iran

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HIGHLIGHTS

- T-Hg accumulated in fish red muscle tissue was lower than white muscle tissue.
- There are strong correlations between the level of accumulated T-Hg and fish weight and length.
- There is no correlation between the level of accumulated T-Hg and fish sex.
- Excessive consumption of fish weighted above 850 g from SGR would be dangerous.

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ABSTRACT

The Sanandaj Gheshlagh Reservoir (SGR) is a mercury polluted lake that is located in the West of Iran. Common carp (*Cyprinus carpio*) and silver carp (*Hypophthalmichthys molitrix*) are the most abundant fishes in the SGR. A total of 48 common and silver carps (24 each) were captured randomly, using 50 × 6 m gill net (mesh size: 5 × 5 cm) during July to December 2009. Each month, the levels of accumulated total mercury (T-Hg) in white muscle, red muscle and liver tissues of these fishes were measured using an Advanced Mercury Analyzer (Model; Leco 254 AMA, USA) on the dry weight basis. There were no statistically significant differences between T-Hg concentrations in white muscle, red muscle and liver in common carp in comparison with similar tissues in silver carp ($P > 0.05$). The content of T-Hg in liver tissue of both species was lower than of white and red muscle tissues. Higher levels of accumulated T-Hg were observed during summer. Results showed that T-Hg concentrations in common and silver carps target tissues were strongly dependent on age, length and weight ($P < 0.05$). The results indicated that the levels of accumulated T-Hg in tissues of all samples with weights of over 850 g were greater than those limits established by WHO and FAO (500 ng g^{-1}).

1. Introduction

Nowadays, mercury (Hg) pollution is considered as an environmental problem on a global scale (Boening, 2000). Exposure to heavy metals in environment is strongly associated with anthropogenic activities and physico-chemical interactions in earth crust (Kumar, 2006). The high concentration of heavy metals will restraint the natural growth of living creatures, disturb materials exchange as well as transformation in natural ecosystems, and cause disorders in body functions. Depending on their quality and quantity, heavy metals will suppress the natural operation of the respiratory and swimming systems (particularly in fish), weaken the neurological system, cause blood stream interruption, decrease the reproductive ability, and increase the probability of negative genetic mutation as well as the tissular disorders of aquatic organisms (Canli and Atli, 2003). The amount of heavy metal absorption differs amongst the different tissues and organs of aquatic creatures (e.g., muscle, liver, kidney, ovary and gill). It depends on the amount of bioaccumulation, physiology and feeding behavior of fishes (Heath, 1987; Williams et al., 1998; Canli and Atli, 2003).

Among heavy metals, mercury is a unique element which exists in different organic and inorganic forms in the nature (Zalups,

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2000). Mercury has a very high capability to be bioaccumulated in different parts of organism's body and being transformed to the higher trophic levels in natural food chains (Boening, 2000).

Inorganic mercury could be converted to methylmercury (M-Hg, the most toxic from of mercury) basically via anaerobic microorganisms existing in aquatic ecosystems substrates (UNEP, 2002; Eisler, 2006). The obvious characteristic of this compound is extraordinary toxicity, stability in the environment and accumulation in the tissues of living organisms with long biological half-life (UNEP, 2002). Its concentration could also significantly increase via biomagnifications processes within the natural food chains and could be transferred along long distances with fewer changes (Eisler, 2006).

M-Hg could strongly bind with sulfhydryl proteins groups (e.g., Cysteine and Methionine) and could also accumulate in the tissues and different organs of fishes and other creatures. It also could be magnified through the natural food chains (UNEP, 2002; Eisler, 2006). For those people who consume a significant amount of seafood, M-Hg is one of the most important sources for the mercury bioaccumulation (Gomez-Ariza et al., 2005). Hence, accumulated M-Hg in fishery products must be assumed as a hidden danger for human being health (Ebinghaus et al., 1994).

Fish is known as an appropriated bio-indicator to illustrate the severity of mercury pollution in marine and freshwater ecosystems (Gochefeld, 2003). Conventionally, fish muscle tissue is the most used part of fish body to evaluate the level of accumulated mercury in fish, because muscle tissue is the edible parts of fish and could have a great impact on human health (Pirrone and Mahaffey, 2005). M-Hg toxicity could be lowered via mineralization process in fish kidney (Palmisano et al., 1995). Increasing mercury concentration from a certain level in fish kidney is harmful for its health (Eisler, 2006).

Several studies have been carried out in order to measure the levels of accumulated mercury in miscellaneous tissues of different species of fish and other aquatic organisms in different parts of the world (e.g., Cronin et al., 1998; Al-Majed and Preston, 2000; IKingura and Akagi, 2003; Agusa et al., 2004; Weis, 2004; Adams and Onorato, 2005; Storelli et al., 2005; Regine et al., 2006; Burger and Gochfeld, 2007; Houserova et al., 2007; Jewett and Duffy, 2007), but none measured the accumulated total mercury in fish red muscle.

According to the available literature, fish muscles could be categorized into the two different groups including red muscle and white muscle. The red muscle has too many capillary vessels. Its red color is due to the high concentrations of red pigments jointed to the oxygen in blood (hemoglobin) and the myoglobin proteins (Freadman, 2006). Myoglobin proteins are able to store oxygen for the occasions which fish needs more oxygen and will facilitate diffusion of oxygen for the oxygen-demanding tissues (Nelson and Cox, 2009). All types of metabolic processes in red muscle tissues of fish are aerobic which could provide the necessary energy for the fish continuous swimming (Freadman, 2006). By virtue of presence of intensive capillaries web, the presence of myoglobin proteins and sulfhydryl protein groups in fish red muscle tissue, it is assumed that this tissue is more exposed to mercury and the probability of mercury bioaccumulation occurrence in this tissue could be higher than other edible tissues of fish, such as the white muscle.

Common carp and silver carp play important roles in the regional resident's food basket and are among the most frequently consumed and relatively cheap food sources. In addition, the Sanandaj Gheshlsgh Reservoir (SGR) is one of the most important water sources in the area and studies have indicated unacceptable levels of mercury in its water (Amani, 2008). It has been proven that mercury polluted water has harmful effect on human health (Eisler, 2006). Therefore, monitoring and comparing the level of T-Hg in different tissues of commercially important fish species of the SGR could be vital to the health of those who live in the region. The present research project was designed to determine the content of accumulated T-Hg in liver, white muscle and red muscle tissues of two most abundant fish species in the SGR and to monitor the temporal changes of T-Hg in the above mentioned fish tissues, from July to December, 2009. Common carp and silver carp were selected as the experimental animals in this study because of their different diets.

2. Materials and methods

2.1. Study area

The Sanandaj Gheshlagh Reservoir (SGR) (35°25′–35°30′N and 46°57′–47°30′E) is located in the Northeast of Sanandaj city in the west of Iran. The SGR covers an area of approximately

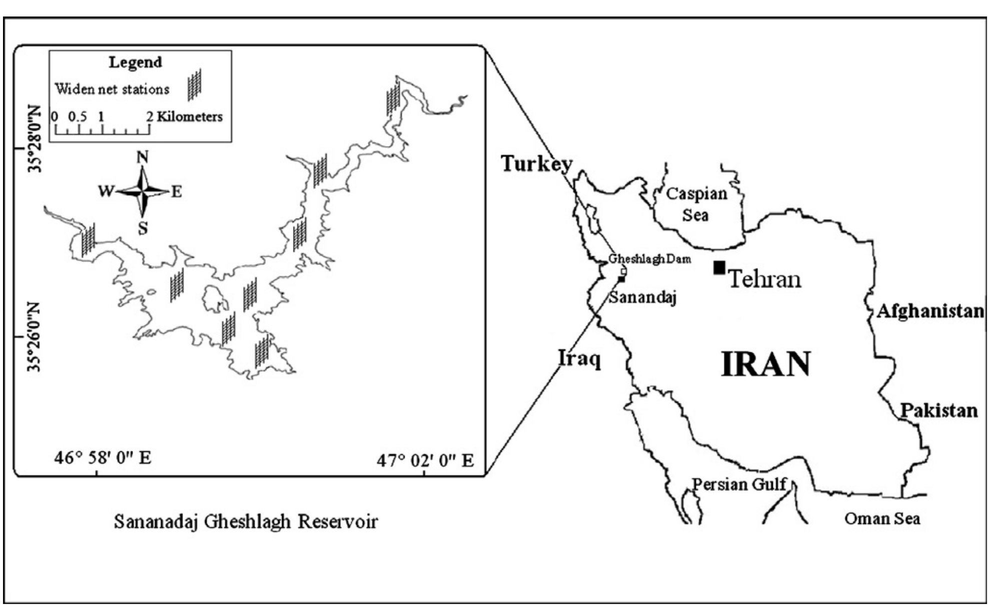

Fig. 1. Location of Sananadaj Gheshlagh Reservoir (SGR).