Marine Pollution Bulletin 77 (2013) 437–444

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

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Methylmercury in fish from the South China Sea: Geographical distribution and biomagnification

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ARTICLE INFO

Keywords:
Methylmercury
Bioaccumulation
Biomagnification
Marine fish
South China Sea

ABSTRACT

We conducted a large-scale investigation of methylmercury (MeHg) in a total of 628 marine wild fish covering 46 different species collected from the South China Sea between 2008 and 2009. Biological and ecological characteristics such as size (length and wet weight), feeding habit, habitat, and stable isotope ($\delta^{15}N$) were examined to explain MeHg bioaccumulation in marine fish and their geographical distribution. MeHg levels in the muscle tissues of the 628 individuals ranged from 0.010 to 1.811 μg/g dry wt. Log_{10}MeHg concentration was significantly related to their length and wet weight. Feeding habit and habitat were the primary factors influencing MeHg bioaccumulation. Demersal fish were more likely to be contaminated with MeHg than the epipelagic and mesopelagic varieties. Linear relationships were obtained between Log_{10}(MeHg) and $\delta^{15}N$ only for one location, indicating that biomagnification was site-specific. Results from this study suggest that dietary preference and trophic structure were the main factors affecting MeHg bioaccumulation in marine fish from the South China Sea.

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Mercury (Hg) is recognized as an important pollutant since it can cycle globally and poses risks to humans and ecosystems. Emission inventories have indicated that Asian Hg sources account for more than 50% of the global anthropogenic total Hg (THg) (Jaffe et al., 2005; Zhang and Wong, 2007). Because of the rapid economic growth, Hg emissions in China grew quickly at a rate of 5.1% during the period of 1995–2005 (Streets et al., 2009), and the country is now responsible for 25% of worldwide Hg emission. The major sources of Hg in the environment in China are Hg production, coal combustion, and industrial sources (Tang et al., 2007).

A critical aspect of Hg cycling is its bioaccumulation and methylation (Amlund et al., 2007; Munthe et al., 2007). Once it enters aquatic ecosystems, a portion of the Hg can be methylated by bacteria (Swain et al., 2007). Methylmercury (MeHg) is considered as a neurotoxin, and its developmental neurotoxicity to the fetus constitutes the current basis for risk assessments and public health policies as indicated by the Madison Declaration on Mercury Pollution (Hurley et al., 2007). Humans and wildlife are most commonly exposed to MeHg through the consumption of fish from marine and freshwater sources (Swain et al., 2007; Zhang and Wong, 2007).

Unlike the concentrations of most other trace metals, the concentrations of Hg, especially MeHg, increase along the marine food chain through biomagnification. Consequently, $\delta^{15}N$ has been used to estimate the biomagnification of Hg in marine and aquatic food webs in the last decade (Mackintosh et al., 2004). Bioaccumulation and biomagnification of THg and MeHg concentrations in fish are generally influenced by fish size (Mason et al., 2006; Kehrig et al., 2008), trophic position (as indicated by $\delta^{15}N$) (Amlund et al., 2007; Mergler et al., 2007; Sharma et al., 2008), and life history (Swanson et al., 2011). Furthermore, Hg levels in fish also vary by geographic area (Kamman et al., 2005; Al-Reasi et al., 2007; Kinghorn et al., 2007). For these reasons the concentration and behaviour of Hg in aquatic systems have been of great interest and importance.

Compared to the situation for many freshwater fishes and ecosystems, there are relatively fewer monitoring data for Hg in marine fishes (Anonymous, 2007). Valid data on the MeHg concentration in fish of different species and information on the sources of MeHg to estuaries, coastal zones, and particularly the oceans are still limited, especially on a local level (Burger and Gochfeld, 2006; Munthe et al., 2007). In China, few studies have focused on MeHg bioaccumulation in fish, especially marine fish from tropical areas such as the South China Sea (Zhang and Wong, 2007). Marine fish consumption is currently a major route for human exposure to Hg in Chinese coastal cities (Liu et al., 2008), but few people are aware of it.

The objective of this study was to quantify MeHg in different marine wild fish species from different regions around the South

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0025-326X/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.marpolbul.2013.09.009

China Sea, and to determine the influence of biological and ecological factors (e.g. length, wet weight, feeding habit, habitat, and regional distribution) on the bioaccumulation of Hg in the muscle tissues of marine wild fish. Given the human and environmental health concerns of MeHg, it is critical to understand the spatial distribution of its production and fate in marine ecosystems. Data on Hg concentration in marine fish are necessary for estimating the national exposure, evaluating the potential risks of fish consumption, and issuing consumers advice.

Between October 2008 and June 2009, a total of 628 fish samples belonging to 46 species (mostly common edible fish) were collected from the South China Sea (Fig. 1). Samples from the Pearl River Estuary were captured with trawls while samples from the coral reef waters of Xisha Islands and Nansha Islands were caught with rod and line. Samples from other coastal areas, including Shantou, Beihai and Sanya coastal waters, were purchased from local fishermen as soon as the fish were caught. All samples were transported frozen or ice-cold to the laboratory where they were kept at −20 °C until further treatment.

In the laboratory, we determined the fish length and body weight, and then the skinless white dorsal muscle tissues were removed with clean scalpels and weighed (wet weight). Following weighing, muscle tissues stored in sealed plastic bags were freeze-dried. The dry weight of each muscle tissue was determined in order to calculate the wet/dry weight (W/D) ratio of each sample. Then they were homogenized and kept dry until analysis.

MeHg in fish was extracted by digesting approximately 20 mg of dry tissues with 25% KOH in methanol at 85 °C for 4 h. The extracted fish tissues were buffered with sodium acetate at pH 4.9, and ethylated by sodium tetraethylborate in a 40 mL Teflon line borate glass bottle. The quantification of MeHg was carried out by the automated methylmercury analytical system (MERX, Brooks Rand). The quality of MeHg determination was ensured by conducting replicate assays for 20% of the samples (SD < 10%) and analysis of the standard reference material NIST SRM 1566b, oyster tissue (13.2 ± 0.7 ng/g) and IAEA 142 (No. 55) muscle tissue (47 ng/g), with recovery rates of 90–98%. MeHg concentrations were expressed on a dry-weight basis and appropriately converted using the wet weight/dry weight ratio when comparing with other data reported on a wet-weight basis.

The $^{15}N/^{14}N$ of a powdered sample was analyzed using an elemental analyzer coupled to a Delta XL Plus mass spectrometer (Finnigan). Samples were added into tin capsules and combusted in a flow of helium to reduce all forms of nitrogen to pure N_2. The pure gas was then separated on a gas chromatographic column before being injected into the mass spectrometer. Isotopic ratio was reported in part per thousand (‰) relative to the standard (atmospheric nitrogen) and was defined in delta notation as:

$$\delta^{15}N = (R_{sample}/R_{standard} - 1) \times 10^3$$

where $R = {}^{15}N/{}^{14}N$. Most biota was ^{15}N-enriched versus atmospheric dinitrogen.

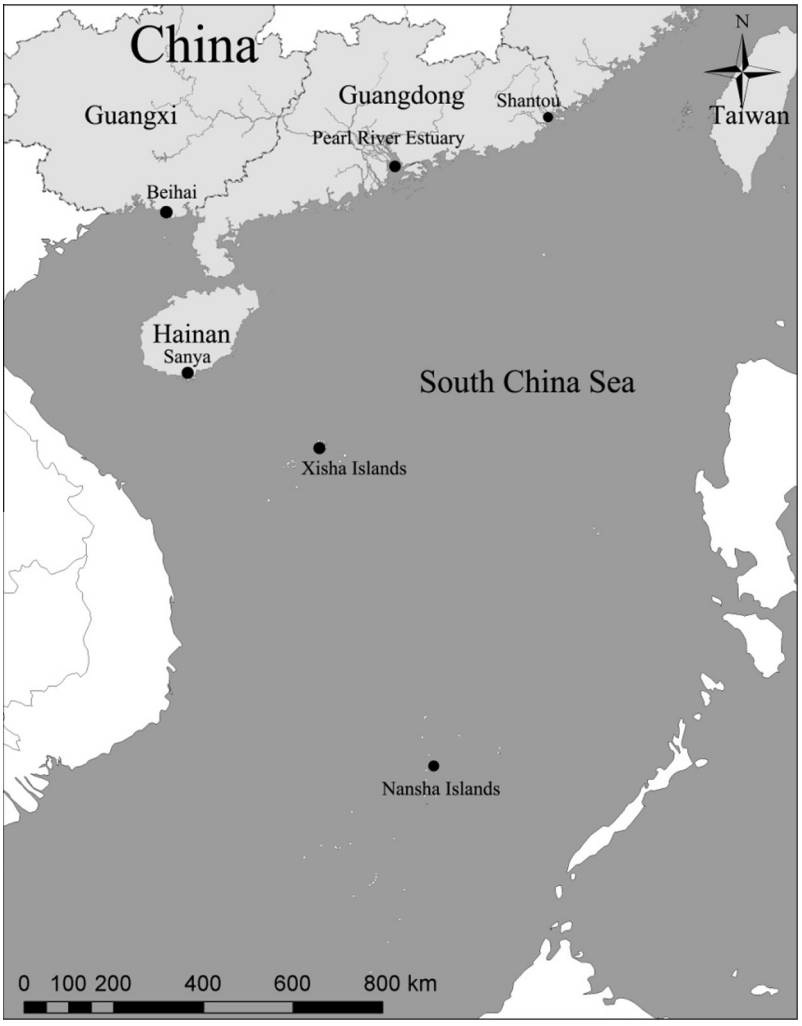

Fig. 1. Locations of sampling sites in the coastal coral reef waters of the South China Sea.

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