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Rice consumption contributes to low level methylmercury exposure in southern China

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ABSTRACT

Fish consumption is considered as the primary pathway of human methylmercury (MeHg) exposure. However, recent studies highlighted that, rice, rather than fish, is the main route of human MeHg exposure in Guizhou, inland China. China is considered as the largest anthropogenic source of mercury (Hg) emission in the world, which has led to serious environmental Hg pollution. But there are no comprehensive studies regarding this environmental health problem to evaluate human Hg exposure and associated health effects. This study aimed to estimate daily MeHg intake and health risk in 7 provinces in southern China, and to assess the relative contribution from rice and fish consumption. The average levels of total mercury (THg) and MeHg in rice samples were generally low at 10.1 $ng \cdot g^{-1}$ and 2.47 $ng \cdot g^{-1}$, respectively. But a total of 36 rice samples (12.7%) had THg concentration exceeding the national limit (20 $ng \cdot g^{-1}$). Generally, rural population had significantly higher Probable Daily Intakes (PDIs) of MeHg than urban population from rice consumption and its relative contribution to MeHg exposure increased significantly from coastal to inland area. The averages of PDIs of MeHg were 0.020 $\mu g \cdot kg^{-1} \cdot d^{-1}$ and 0.028 $\mu g \cdot kg^{-1} \cdot d^{-1}$ for urban and rural population in southern China, respectively. Despite the serious environmental Hg pollutions in China, the general population in southern China had low risk of MeHg exposure. But rice is an important route of human MeHg exposure in southern China, especially for the rural population in inland area. The findings indicate that rice consumption should be considered when evaluating MeHg exposure in rice eating population in southern China.

1. Introduction

Methylmercury (MeHg) is a potent toxicant (ATSDR, 1999; NRC, 2000; USEPA, 1997). The nervous system is the primary target organ for MeHg poisoning and the brain of developing fetus is more sensitive than that of the adult (Clarkson et al., 2003). Using the benchmark dose lower limit (BMDL), the Joint Expert Committee on Food Additives (JECFA) of the Food and Agriculture Organization and the World Health Organization established a provisional tolerable weekly intake (PTWI) for MeHg to 1.6 $\mu g \cdot kg^{-1} \cdot week^{-1}$ (JECFA, 2003). In 1997, the United States Environmental Protection Agency (USEPA) set the limit of 0.1 $\mu g \cdot kg^{-1} \cdot d^{-1}$ as reference dose (RfD) for MeHg (USEPA, 1997). The major source of human exposure to MeHg is the consumption of fish and marine mammals (Mergler et al., 2007). In fish tissue, MeHg is attached to the thiol group of the cysteine residues in fish protein (Harris et al., 2003), which are not removed and destroyed by cooking or cleaning processes. MeHg contamination in fish poses a particular challenge to public health, because fish is a highly nutritious food, with known benefits for human health (Mergler et al., 2007).

Recent studies have highlighted that rice can accumulate relatively high levels of MeHg (174 $ng \cdot g^{-1}$) in mercury (Hg) mining areas in Guizhou Province, Southwestern China (Horvat et al., 2003; Qiu et al., 2008; Zhang et al., 2010a). Shi et al. (2005) also found the MeHg concentrations in rice samples produced in 15 provinces in China ranged from 1.9 to 10.5 $ng \cdot g^{-1}$. Furthermore, rice, rather than fish, is the main route of human MeHg exposure in Wanshan Hg mining area (Feng et al., 2008) and even in Guizhou Province in China (Zhang et al., 2010b). The bioavailability of Hg in rice is not known but adverse effects including neurobiological disruptions and increase of c-fos gene expression have been observed in rats feeding experiments with MeHg contaminated rice (Cheng et al., 2006; Ji et al., 2006). The probable daily intake (PDI) of MeHg from rice consumption indicated potential human health risk in Hg mining areas (Feng et al., 2008; Li et al., 2011; Zhang et al., 2010b). The MeHg translocation and accumulation in rice plant (Meng et al., 2010, 2011) and the effects of mitigation methods and cultivar variations (Peng et al., 2012; Rothenberg et al., 2011) were observed.

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With rapid economic growth in the last 3 decades, China is considered as the largest anthropogenic source of Hg emission in the world (Pacyna et al., 2006). Its annual Hg emission reached 604.7 t in 2000, accounting for 28% of the global emissions (Pacyna et al., 2006). Coal combustion and non-ferrous metal smelting are the most important anthropogenic sources (Streets et al., 2005). The large Hg emissions have resulted in serious environmental Hg pollution in China (Feng, 2004; Jiang et al., 2006; Zhang and Wong, 2007). But there are no comprehensive studies regarding this environmental health problem to evaluate human Hg exposure and associated health effects.

Furthermore, Hg concentrations in soil are not evenly distributed over China; southern China has higher Hg concentrations than northern China (Zheng, 1994) as the Global Circum-Pacific Hg Belt crosses southern China (Feng, 2004). Northern and southern China are divided by the Huai River-Qinling Mountains in geography, with big differences in climate (cold and dry in northern China; warm and rainy in southern China), geography, culture, language, and cuisine. Rice is the second largest produced crop in the world and China is the largest rice producer with 30.7% of the global production (UNCTAD, 2011). Southern China is the main rice cultivation area accounting for 93% of national rice production in 2009 (NBS, 2010) and rice is the staple food for the population in this region. The relative high Hg background in the soil (Zheng, 1994) and frequent rice intake indicate that the general population in southern China may be at risk of elevated exposure to MeHg.

The objective of this study was to evaluate human health risk through rice and fish consumption in southern China and to calculate the relative contribution from rice and fish consumption. It will provide an overview of human MeHg exposure and risk assessment and new understanding of MeHg exposure pathways in southern China.

2. Materials and methods

2.1. Sample collection

A total of 284 polished rice samples (*Oryza sativa* L.) were collected in 2007 from markets in urban area or residents' house in rural area in 7 provinces in southern China, which include 4 coastal area: Guangdong ($n=47$), Shanghai ($n=34$), Jiangsu ($n=26$), Guangxi ($n=38$) and 3 inland areas: Hunan ($n=78$), Jiangxi ($n=30$), and Guizhou ($n=31$). Generally, the urban residents purchase rice from the market and the rural residents plant rice by themselves and can be self-sufficient. The spatial distribution is given in Fig. 1 and the basic information is listed in the Supporting information Table S1. Guangdong, Shanghai, and Jiangsu are the most economically developed provinces, while Guizhou is the poorest province in inland China. These 7 provinces cover 29.2% of population (388 million) and 46.4% of total rice production (90.4 million tons) in China. Except Shanghai City, the rice supply in other 6 provinces can be self-sufficient. The arsenic concentration and speciation in these rice samples have been reported (Zhu et al., 2008). The fish MeHg data in these 7 provinces were adopted from literatures.

2.2. Analytical method

In the laboratory, the rice samples were air dried, crushed, and sieved to 150 meshes. For total mercury (THg) analysis, rice samples were digested in a water bath (95 °C) with a fresh mixed acid of HNO_3:H_2SO_4 (4:1, v/v) (Horvat et al., 1991) and determined by $SnCl_2$ reduction, purge, gold trap, and cold vapor atomic fluorescence spectrometry (CVAFS) detection according to USEPA Method 1631 (USEPA, 1999). For MeHg measurement, rice samples were digested using the KOH-methanol/solvent extraction technique (Liang et al., 1994, 1996) and measured by aqueous ethylation, purge, trap, and gas chromatography (GC) coupled with CVAFS detection according to USEPA Method 1630 (USEPA, 2001). Detail information of quality control is available in the Supporting information.

2.3. Calculation of PDI and relative contribution

To estimate MeHg intake from rice and fish consumption, we calculated PDI values for the general adult in these 7 provinces according to the following formula (1):

$$PDI = \left(C \times IR \times 10^{-3}\right)/bw \quad (1)$$

where PDI is given in micrograms per kilogram of body weight per day ($\mu g \cdot kg^{-1} \cdot d^{-1}$); bw (body weight) = 60 kg; C is MeHg concentration in rice or fish ($ng \cdot g^{-1}$); IR is daily intake rate ($g \cdot d^{-1}$).

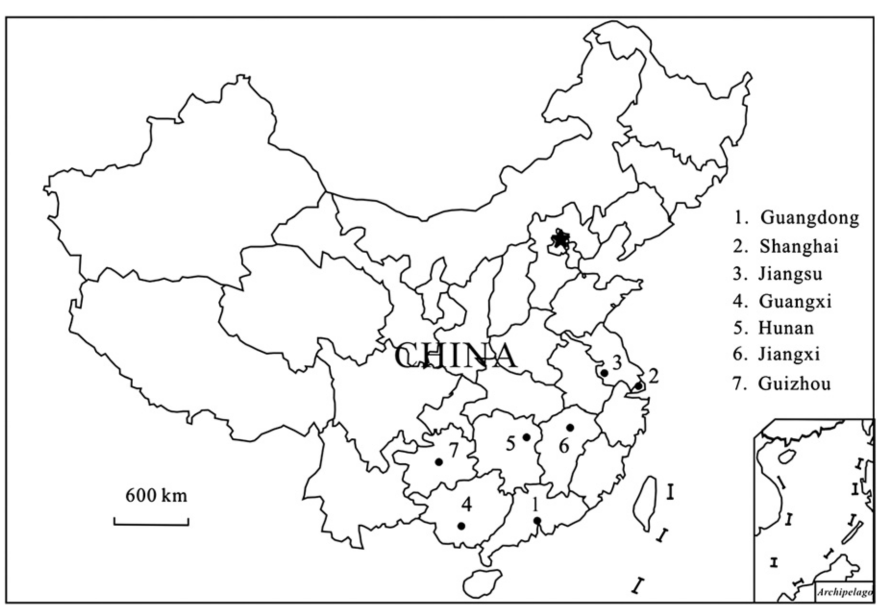

Fig. 1. The spatial location of different provinces for rice sampling in southern China.

The specific PDIs for each province were calculated using the mean of MeHg concentrations in the rice or fish collected in this specific area. The rice MeHg concentrations in these 7 provinces were obtained through this investigation, while the fish MeHg concentrations in these 7 provinces were based on the data from literature (Fu et al., 2010; He et al., 2010; Shang et al., 2010; Shao et al., 2011). The fish MeHg data of Guangdong province was based on Shang et al. (2010), which include 122 fish samples collected from 18 fish ponds from six cities in this province. The fish MeHg concentrations of Shanghai, Guangxi, Jiangxi and Jiangsu province were adopted from the fourth Chinese Total Dietary Study (TDS) carried out in 2007. The fish MeHg concentrations of Hunan province were based on 73 fish Hg data from Fu et al., 2010, which was on the assumption that 70% of Hg in fish is in the form of MeHg. The fish MeHg concentrations of Guizhou province were adopted from He et al. (2010), which consisted of 70 fish MeHg data from Hongfeng Reservoir. The fish MeHg data in these 7 provinces are representative to perform risk assessment.

The daily intake rates of rice and fish for urban and rural population were adopted from official data in the section of "People's Living Conditions" in China Statistical Yearbook (NBS, 2010). The urban and rural population is divided by the Chinese household registration system, which was developed in the 1950s to control the flow of people. There is a wide gap between the wealth of the countryside and the booming cities, with the income of rural residents less than a third of that of urban residents (Table S1). Stratified random sampling method was used in the national survey, and the sample size was 65,000 households in urban area, which cover big cities, small cities and counties. Rural Household Survey network distributed in 7100 villages in the country and it included more than 68,000 sampling households. The error was less than 3% in the national survey.

The average body weight of 60 kg for adult population was according to the second National Physique Monitoring Bulletin (GASC, 2005). It is assumed that there are no losses of MeHg during cooking processes both for rice (Li et al., 2010a, 2010b) and fish (Harris et al., 2003).

We hypothesize that rice and fish consumption are two sources of human MeHg exposure in southern China. According to the PDIs of MeHg from rice and fish consumption, the relative contributions were calculated to assess the main pathway in urban and rural population in these 7 provinces.

2.4. Data analysis

All data were analyzed using SPSS 11.5 for windows. The characteristics of Hg concentrations were described in mean ± standard deviation (SD) and examined using descriptive statistics. Mean values of rice Hg concentrations were compared between different provinces using t test. The correlation coefficients between rice THg and MeHg concentrations were studied by the Pearson correlation analysis. The results of statistical tests were considered statistically significant if $p<0.05$.

3. Results

3.1. Hg in rice and fish

The THg concentrations in all rice samples ranged from 0.86 to 47.2 $ng\cdot g^{-1}$ with a mean of 10.1 $ng\cdot g^{-1}$. The MeHg concentrations in all rice samples varied from 0.13 to 18.2 $ng\cdot g^{-1}$ with a mean of 2.47 $ng\cdot g^{-1}$. The MeHg constituted a large proportion of THg in the rice grain, with an average of 35.8% (1.70–96.7%). There was a significant correlation between THg and MeHg concentrations in rice samples ($r=0.36$, $p<0.01$). In addition, the percentage of Hg as MeHg in rice was negatively correlated to the THg concentrations ($r=-0.55$, $p<0.001$).

The average concentrations among rice collected from different provinces varied from 3.60 to 20.1 $ng\cdot g^{-1}$ for THg (Fig. 2) and from 1.76 to 3.33 $ng\cdot g^{-1}$ for MeHg (Table 1, Fig. 3). The comparisons between Hg concentrations in the rice samples collected from these 7 provinces in southern China are shown in Fig. 2 for THg and Fig. 3 for MeHg. The THg concentrations in rice samples collected from Guangdong, Hunan, Guizhou, Jiangsu, Guangxi, and Jiangxi were significantly higher than that from Shanghai City. The MeHg concentrations in rice samples collected from Hunan and Guangxi were significantly higher than that from Shanghai City.

A total of 36 rice samples (12.7%) had THg concentration exceeding the national tolerance limit of Hg in human foods (20 $ng\cdot g^{-1}$) recommended by the Standardization Administration of China (SAC, 2005), which indicated the impact from environmental Hg pollution in southern China. Among the provinces, rice samples collected from Jiangxi (14/30, 46.7%), Jiangsu (6/26, 23.1%) and Guizhou (6/31, 19.4%) had high ratio exceeding the national limit (Supporting information Table S2).

The fish MeHg concentrations in these 7 provinces were based on the data from literature and listed in Table 2. The MeHg concentrations in fish tissue ranged from 12.0 to 38.5 $ng\cdot g^{-1}$ in these 7 provinces.

3.2. PDIs of MeHg via rice and fish consumption

The PDIs of MeHg through rice consumption in these 7 provinces are presented in Table 1. Generally, rural population had significant higher PDIs of MeHg than urban population in the same province, which is due to large daily rice intake (Table 1). The average PDI of MeHg from rice consumption for urban adult population in different provinces ranged from 0.004 to 0.008 $\mu g\cdot kg^{-1}\cdot d^{-1}$. In comparison, the average PDI of MeHg from rice consumption for rural population in these 7 provinces was 0.019 $\mu g\cdot kg^{-1}\cdot d^{-1}$, which amounted to 8.3% of PTWI recommended by JECFA.

Different from rice consumption, urban population had significant higher PDIs of MeHg than rural population from fish consumption (Table 2). The average PDI of MeHg for urban adult population in these 7 provinces ranged from 0.002 to 0.039 $\mu g\cdot kg^{-1}\cdot d^{-1}$. In comparison, the average PDI of MeHg from rice consumption for rural population in these 7 provinces was 0.009 $\mu g\cdot kg^{-1}\cdot d^{-1}$, which amounted to 3.9% of PTWI recommended by JECFA.

3.3. Relative contribution to MeHg exposure

The PDIs of MeHg from fish and rice consumption in these 7 provinces are presented in Fig. 4 for urban population and in Fig. 5 for rural population. The percentages of PDI of MeHg from rice consumption varied greatly; the lowest was found in the urban population in Guangdong Province (10.8%) and the highest was found in the rural population in

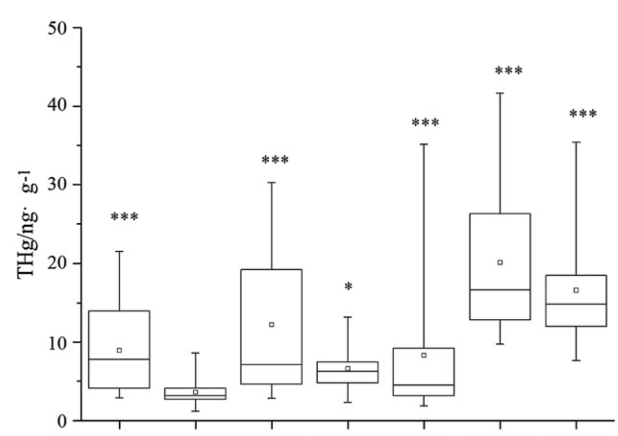

Fig. 2. Comparison between THg concentrations in the rice samples collected from 7 provinces in southern China. ***, $p<0.001$; *, $p<0.05$; compared with Shanghai; each box represents interquartile range (25th and 75th percentiles), the band near the middle of the box is the 50th percentile (the median), and the whisker represents 5th and 95th percentiles.

Table 1
The PDIs of MeHg from rice consumption in these 7 provinces in Southern China.

Province	Rice MeHg/ $ng \cdot g^{-1}$	Urban residents			Rural residents		
		Daily intake/ $g \cdot d^{-1}$	Mean PDI/ $\mu g \cdot kg^{-1} \cdot d^{-1}$	95% PDI/ $\mu g \cdot kg^{-1} \cdot d^{-1}$	Daily intake/ $g \cdot d^{-1}$	Mean PDI/ $\mu g \cdot kg^{-1} \cdot d^{-1}$	95% PDI/ $\mu g \cdot kg^{-1} \cdot d^{-1}$
Guangdong	1.86	154.8	0.005	0.010	514.5	0.016	0.035
Shanghai	2.11	114.1	0.004	0.009	365.9	0.013	0.030
Jiangsu	1.78	129.3	0.004	0.012	397.3	0.012	0.038
Guangxi	3.14	137.0	0.007	0.016	493.2	0.026	0.058
Hunan	3.33	137.0	0.008	0.026	575.3	0.032	0.107
Jiangxi	2.04	137.0	0.005	0.010	576.8	0.020	0.040
Guizhou	1.76	150.7	0.004	0.011	391.8	0.011	0.030
Average	2.29	137.1	0.005	0.014	473.5	0.019	0.048

Guizhou Province (98.0%). Generally, from coastal to inland area, the relative contribution of PDI of MeHg from rice consumption increased significantly for both urban and rural population. In the same province, rural population had significantly higher percentages of MeHg exposure from rice consumption than urban population.

4. Discussion

4.1. Rice and fish Hg levels

The significant negative relationship between THg concentrations and the percentage of Hg as MeHg in the rice samples indicated different uptake mechanisms of inorganic Hg and MeHg in the rice grain (Qiu et al., 2008) or possible inorganic Hg contamination in the rice samples. The rice samples collected from Jiangxi, Jiangsu and Guizhou had high ratio of THg concentrations exceeding the national limit. This may be due to the specific characteristics of these 3 provinces. Rich in mineral resources, Jiangxi is one of the major bases of nonferrous and rare earth elements in China (Zaw et al., 2007). Jiangsu is one of the most industrialized and economically developed regions in China. Guizhou is one of the world's most important Hg production centers and has high THg background in the soil (Feng and Qiu, 2008). There are important Hg emissions and contamination sources in these 3 provinces such as nonferrous metal smelting, chemical industry, coal combustion, Hg mining, etc. (Li et al., 2009).

Previous data for Hg in rice were collected mostly from the Hg mining areas in Guizhou Province, inland China. Highly elevated THg concentrations (up to 1120 $ng \cdot g^{-1}$) were reported (Feng et al., 2008; Horvat et al., 2003; Meng et al., 2010, 2011; Qiu et al., 2008; Zhang et al., 2010a,b). More importantly, the highly toxic MeHg concentrations can reach as high as 174 $ng \cdot g^{-1}$ (Qiu et al., 2008).

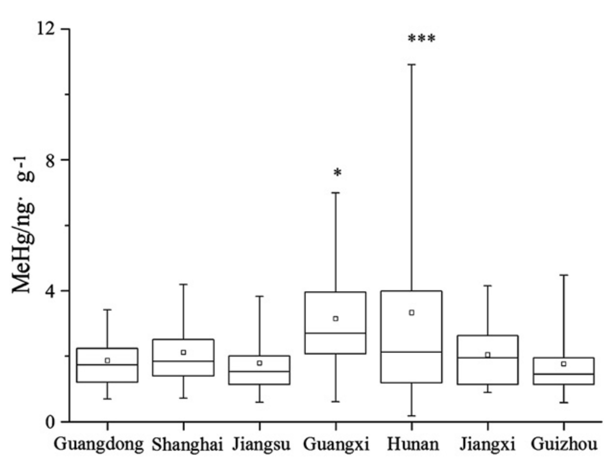

Fig. 3. Comparison between MeHg concentrations in the rice samples collected from 7 provinces in southern China. ***, p<0.001; *, p<0.05; compared with Shanghai.

Table 2
The PDIs of MeHg from fish consumption in these 7 provinces in Southern China.

Province	Fish MeHg /$ng \cdot g^{-1}$	Urban residents		Rural residents	
		Daily intake/ $g \cdot d^{-1}$	Mean PDI/ $\mu g \cdot kg^{-1} \cdot d^{-1}$	Daily intake/ $g \cdot d^{-1}$	Mean PDI/ $\mu g \cdot kg^{-1} \cdot d^{-1}$
Guangdong	38.5[a]	61.5	0.039	38.5	0.025
Shanghai	14.0[b]	55.3	0.013	50.6	0.012
Jiangsu	14.0[c]	46.1	0.011	29.6	0.007
Guangxi	29.8[b]	32.2	0.016	9.8	0.005
Hunan	24.5[d]	30.1	0.012	17.0	0.007
Jiangxi	15.9[b]	33.4	0.009	15.2	0.004
Guizhou	12.0[e]	10.5	0.002	1.1	0.0002
Average	21.3	38.4	0.015	23.1	0.009

a, Shao et al. (2011); b, Shang et al. (2010); c, is adopted from Shanghai data; d, Fu et al. (2010), on the assumption of 70% of Hg in fish is in the form of MeHg; e, He et al. (2010).

The THg and MeHg concentrations in the rice samples reported in this study were significantly lower than that from the Hg mining areas in Guizhou Province (Feng et al., 2008; Horvat et al., 2003; Meng et al., 2010, 2011; Qiu et al., 2008; Zhang et al., 2010a,b). The THg concentrations were comparable with that from 20 provinces in China (with a mean of 5.8 $ng \cdot g^{-1}$, Qian et al., 2010) and that reported in the third national Total Diet Study conducted in China in 2000 (with a mean of 9.0 $ng \cdot g^{-1}$), which was considered to be an average concentration for THg in rice collected in China (Li et al., 2006). The MeHg concentrations were comparable with those reported from Changshun (2.5 $ng \cdot g^{-1}$, Feng et al., 2008), Huaxi (2.9 $ng \cdot g^{-1}$, Meng et al., 2010) and Leigong (2.1 $ng \cdot g^{-1}$, Zhang et al., 2010b) in Guizhou Province. These concentrations were considered to be typical for MeHg found in rice collected from control sites for Hg mining areas.

The fish MeHg concentrations were relatively low compared with that reported in Europe and North America, even serious environmental Hg pollutions were found in China (Feng, 2004; Jiang et al., 2006; Zhang and Wong, 2007). The low level of fish MeHg in China may be due to: (1) the aquatic food chains are generally short, which does not favor the bioaccumulation of MeHg in fish; (2) most of the fish (mainly herbivorous or omnivorous fish) were produced by aquaculture, where the fish are very young and the growth rate is very fast (Yan et al., 2010).

4.2. Sources of MeHg exposure

The major source of human exposure to MeHg is usually from consumption of fish and marine mammals (Mergler et al., 2007). Previous studies confirmed that rice consumption was the main route of MeHg exposure for local residents in inland Guizhou Province (Feng et al., 2008; Zhang et al., 2010b). And fish consumption contributed only 1–2% of the total MeHg intake, because of its low daily fish

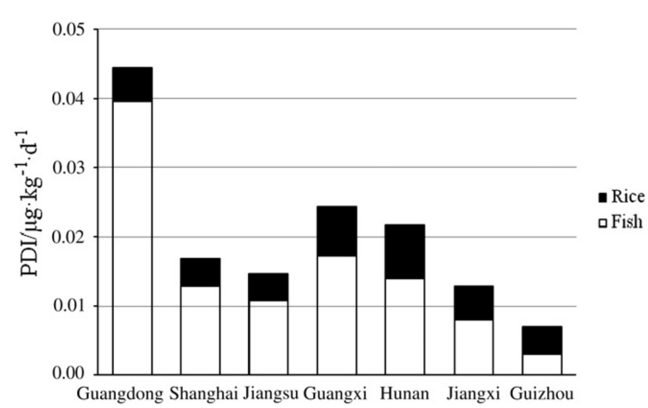

Fig. 4. The comparison of PDIs of MeHg from rice and fish consumption for urban population in southern China.

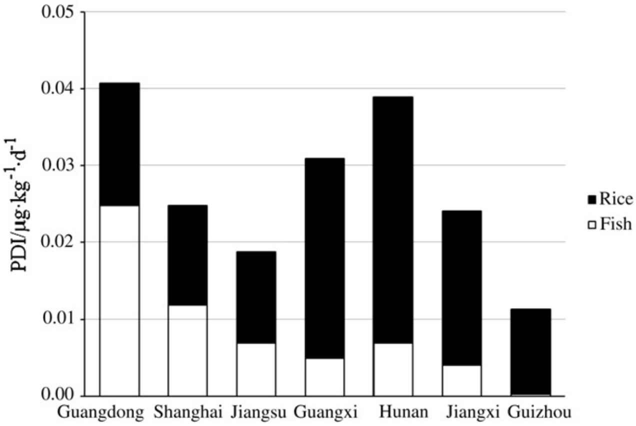

Fig. 5. The comparison of PDIs of MeHg from rice and fish consumption for rural population in southern China.

consumption (1.1 $g \cdot d^{-1}$). We re-confirmed in this study that the percentage of PDI of MeHg from rice consumption was 98.0% in the rural population in Guizhou Province. The relatively high contribution of rice to MeHg intake was observed in the rural populations averaging at 71.8%. These results indicate that even though the MeHg concentrations in rice grains are generally lower than that in fish, rice was the main route of MeHg exposure for rural population in southern China.

From coastal to inland area, the relative contribution from rice consumption increased significantly for both urban and rural population. Diet structure has a significant effect on the pathways of MeHg exposure, since the population in coastal area eats more fish than inland area. In the same province, rural population got more MeHg exposure from rice consumption than urban population. There are clear differences in the pattern of rice and fish consumption between urban and rural population as a result of income difference (Supporting information Table S3). As incomes rise, diets improve: the city dweller consumes significantly less grain and more meat, fish, fruits and vegetables than the rural counterpart (NBS, 2010).

4.3. Potential health risk

Overall, the average PDI of MeHg from rice and fish consumption was below the guidelines for public health concerns. However, the 95th percentile PDI of MeHg from rice consumption for rural population in Hunan exceeded the RfD of 0.1 $\mu g \cdot kg^{-1} \cdot d^{-1}$ for children and pregnant women established by the USEPA (1997), which indicated some sub-populations may be at potential risk of MeHg exposure.

Other high risk groups include residents in regions affected by point sources of Hg pollution. For example, Zhang et al. (2010b) predicted that approximately 22,400 and 107,200 residents in Guizhou Hg mining areas were exposed to MeHg exceeding the JEFCA and USEPA guideline, respectively. Besides Hg mining areas, the population in the vicinity of hotspots of Hg pollution, such as amalgamation gold mining, chemical plant, metal smelting and coal combustion power plant, may be also at potential risk of MeHg exposure (Feng, 2004; Li et al., 2009).

The results of PDIs of MeHg from rice and fish consumption (0.020 $\mu g \cdot kg^{-1} \cdot d^{-1}$ for urban population and 0.028 $\mu g \cdot kg^{-1} \cdot d^{-1}$ for rural population) were comparable with the previous report on MeHg exposure from fish consumption in 12 provinces in China (0.006 $\mu g \cdot kg^{-1} \cdot d^{-1}$, Shang et al., 2010), US adult women (0.02 $\mu g \cdot kg^{-1} \cdot d^{-1}$, Mahaffey et al., 2004), Korean population (0.03 $\mu g \cdot kg^{-1} \cdot d^{-1}$, Lee et al., 2006), and Southeast Asia populations (0.027–0.097 $\mu g \cdot kg^{-1} \cdot d^{-1}$, Agusa et al., 2007), but were lower than that reported in Japanese populations with high fish consumption (0.14 $\mu g \cdot kg^{-1} \cdot d^{-1}$, Zhang et al., 2009). The results of this study confirmed the low risk of human MeHg exposure through rice and fish consumption in southern China, even serious environmental Hg pollution were found in China (Feng, 2004; Jiang et al., 2006; Zhang and Wong, 2007). The low averages of hair THg concentrations (generally <1 μg/g) reported in five coastal sites (Shanghai, Ningbo, Dalian, Xiamen, and Zhoushan) in eastern China (Liu et al., 2008) also confirmed our results in this study.

Because rice does not contain a lot of beneficial micronutrients associated with fish (e.g., n − 3 long-chain polyunsaturated fatty acid, selenium, the essential amino acids, Li et al., 2010a, 2010b), the current Reference Doses of MeHg exposures from fish consumption may underestimate the health effects of MeHg exposure from rice consumption. It is urgent and critical to setup the dose–response relationship of MeHg exposure from rice consumption and to reduce the health risk in southern China.

5. Conclusions

The average levels of THg and MeHg in the rice samples collected from southern China were generally low. But 12.7% of the rice samples had THg concentration exceeding the national limit. The general populations in southern China had low risk of MeHg exposure through rice and fish consumption. However, rice consumption is still the main route of MeHg exposure for rural population in southern China.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.envint.2012.08.006.

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