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Accumulation of mercury, selenium and PCBs in domestic duck brain, liver and egg from a contaminated area with an investigation of their redox responses

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ABSTRACT

PCBs and methylmercury (MeHg) are two of the most ubiquitous contaminants in the Qingzhen (QZ) area of Guizhou province. The estimated tolerable daily intakes (TDIs) of total mercury (T-Hg), MeHg, PCBs and Se from contaminated rice, eggs and fish by Chinese people in QZ showed that both MeHg and PCBs exceeded the corresponding safety limits. Pearson's correlation analyses of mercury and Se in all duck tissues showed that there were high correlations with T-Hg or MeHg and Se in QZ samples. However, the molar ratio between T-Hg and Se in brain tissues was close to 1, suggesting that Se is antagonistic to mercury toxicity only in brain tissues. Biochemical analyses showed that both superoxide dismutase and glutathione peroxidase increased in the brain, whereas in the liver and egg these enzymes decreased. However, lipid peroxidation and H_2O_2 generation in liver and egg tissues showed contrary responses, where significant increases in these tissues were seen relative to controls. Mercury and PCBs co-accumulation in liver and egg tissues gave rise to large numbers of free radicals as well as aggravated alkyl free radicals, superoxide radical and nitric oxide, thereby resulting in oxidative stress in these tissues. It can be concluded that an adaptive response of the redox defense system is present in brain tissues, as opposed to a general break down of the redox defense system in liver and egg. The results obtained in this study will provide basic information on exposure and risk assessment in local residents.

1. Introduction

Extensive environmental pollution has arisen as a consequence of increased mining and industrial activities in the 20th century. This pollution is particularly intense in Guizhou province (N24°30′–29°13′, E103°1′–109°30′, 1100 m above sea level, subtropical humid climate) in southwestern China (Cheng et al., 2006; Tang et al., 2007). Exploration of Hg in Guizhou province has led to serious environmental pollution and severely deteriorated local ecosystems (Horvat et al., 2003; Cheng et al., 2005; Li et al., 2008). Although numerous studies have been carried out in Guizhou province, most of these, including our own previous studies, have focused only on inorganic pollutants, for example Hg, As and Se, and organic contaminants have been ignored (Cheng et al., 2005, 2006). In fact, pollution due to Polychlorinated biphenyls (PCBs) has become severe and has increased in Guizhou province as

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a result of rapid urbanization and industrialization. Due to their high lipophilicity and low biodegradability, PCBs from the environment have been found to accumulate in the adipose tissue of living organisms, including humans in Guizhou province (Nakata et al., 2005). The findings of our previous studies suggested that chemical industries were important sources of PCBs emission into the local environment (Cheng et al., 2007). In the present study, we selected subjects from the city of Qingzhen (QZ) in Guizhou province, which is representative of a region contaminated with methylmercury (MeHg) and PCBs. A chemical plant which is located in the vicinity of QZ and approximately 24 km from the capital city of Guiyang, discharges waste waters and exhaust gas into the environment and therefore contributes to the pollution problems in this area (Horvat et al., 2003; Cheng et al., 2006).

Many different species have been used in environmental biomonitoring studies in diverse habitats including forest, farmland, and urban and sub-urban areas. Typically, the bioavailability of environmental pollutants is assessed by measuring chemical residues in the tissues or fluids of animals living in appropriate habitats (Sobanska, 2005). However, few attempts have been made to study the potential effects of mercury and PCBs pollution on public health by examining animals living under natural conditions in the QZ area. Such studies are necessary because laboratory-based trials may not represent the full range of trace pollutants to which animals or humans are simultaneously exposed, nor do they consider the possible interactive effects of exposure to trace pollutants and natural environmental stressors normally encountered by animals and humans. For example, in the QZ area, Se is an important element which coexists with mercury (Horvat et al., 2003; Cheng et al., 2006). As Se is antagonistic to mercury and could provide protective effects by activating antioxidant enzymes or by binding mercury, the ecotoxicity of the QZ area is much more complex than that of a single toxic element in the laboratory. With this in mind, we selected ducks as biological indicators, since they share the same environment as humans, and are therefore exposed, at least in part, to the same pollutants (Ji et al., 2006a).

Food is generally recognized as the main source of MeHg and PCBs intake in humans. More than 90% of the total daily intake of these contaminants is derived from food. Rice is eaten with almost every meal and provides more calories than any single food in the QZ area. Fish and eggs are the main source of nourishment for pregnant women and children in the QZ area. Therefore, these three food types, together with the ducks, were monitored for PCBs, MeHg and Se in the present study, and the redox responses in the brain, liver and egg tissues of ducks were analyzed. As oxidative stress is one of the most important pathogenic factors related to the toxicity of contaminants (Ferreira et al., 2010), and could trigger a cascade of events leading to cell injury and tissue dysfunction in many diseases, we focused our attention on the oxidative status of domestic ducks. Since oxidative stress results from an imbalance in the intracellular production of free radicals and the antioxidant defense system (Ji et al., 2006b), we chose to determine free radicals and some major antioxidants in the present study. The results obtained in this study will provide basic information on exposure and risk assessment in human populations.

2. Materials and methods

2.1. Sample collection

Rice samples were taken from 13 different cultivated locations around the QZ chemical plant. The rice was irrigated using wastewater from the chemical plant, and was eaten by the local peasants. Ten crucian carps (the major fish consumed by local residents) were obtained from the pool near the chemical plant, each about 0.2 kg. The edible parts of the samples were dissected on site to collect small muscle samples (10–20 g) from the dorsolateral area of the body. The samples were then cut and homogenized and stored at −20 °C until analysis. In consideration of individual difference, ten female domestic ducks from a local peasant were as an exposure group. If the ducks were from different resources, different biochemical indicators could be due to the different ages or the feeding ways of the ducks instead of mercury pollution. These ducks were 18 months old, had a body weight of 3.5 ± 0.5 kg, were herded under natural conditions, and lived on rice and sometimes, food from a brook. Control samples of rice, Crucian carp and ducks were obtained from a peasant in the rural area of Shanghai (SH) – an area with relatively low contamination. Ducks were sacrificed by cervical dislocation, and brain, liver, and egg tissues were collected. These tissues were subdivided into portions for both chemical and biochemical analyses. These biota samples were then stored at −20 °C, and rice samples were kept at 4 °C until analysis.

2.2. Chemical analysis

Total mercury (T-Hg) and MeHg content were analyzed using cold vapor atomic adsorption spectrometry and gas chromatography with electron capture detection methods, respectively, as described by Akagi et al. (2000). Total selenium (T-Se) content was determined by hydride generation-atomic fluorescence spectrometry. PCB content was measured according to the US Environmental Protection Agency method 8000 series. Analytical standards were a mixture of Aroclor 1254, Aroclor 1242 (Supelco Inc., Bellefonte, PA) and the surrogate PCB209 (AccuStandard Inc., New Haven, CT). Details of the analytical methods for Se and PCBs can be found in our previous studies (Ji et al., 2006b; Cheng et al., 2007).

2.3. Biochemical assays

The activity of superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px) were estimated by the method of Marklund and Marklund (1974) and the 5,5′-dithio-bis-(2-nitrobenzoic acid) photometric method (Rotruck et al., 1973), respectively. Nitric oxide (NO) content was measured by the enzymatic reduction assay (Kim et al., 2002). Lipid peroxidation (LPO) and H_2O_2 generation were assayed using the method of Devasagayam and Tarachand (1987) and Holland and Storey (1981), respectively. Electron spin resonance (ESR) measurements were conducted using a Bruker EMX-spectrometer and a flat cell assembly. Details of the analytical methods for biochemical analysis can be found in our