Environmental Pollution 198 (2015) 126–132

Contents lists available at ScienceDirect

Environmental Pollution

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

Human exposure to mercury in a compact fluorescent lamp manufacturing area: By food (rice and fish) consumption and occupational exposure

Peng Liang [a, b], Xinbin Feng [b, **], Chan Zhang [c], Jin Zhang [a], Yucheng Cao [a], Qiongzhi You [a], Anna Oi Wah Leung [d], Ming-Hung Wong [a], Sheng-Chun Wu [a, *]

[a] School of Environmental and Resource Sciences, Zhejiang Agricultural and Forest University, Lin'an, Zhejiang Province 311300, PR China
[b] State Key Laboratory of Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang 550002, PR China
[c] College of Law and Political Science, Zhejiang Agricultural and Forestry University, Lin'an, Zhejiang Province 311300, PR China
[d] Department of Biology, Hong Kong Baptist University, Hong Kong, PR China

ARTICLE INFO

Article history:
Received 18 August 2014
Received in revised form
17 December 2014
Accepted 22 December 2014
Available online

Keywords:
Mercury
Compact fluorescent lamps
Methylmercury exposure
Rice

ABSTRACT

To investigate human Hg exposure by food consumption and occupation exposure in a compact fluorescent lamp (CFL) manufacturing area, human hair and rice samples were collected from Gaohong town, Zhejiang Province, China. The mean values of total mercury (THg) and methylmercury (MeHg) concentrations in local cultivated rice samples were significantly higher than in commercial rice samples which indicated that CFL manufacturing activities resulted in Hg accumulation in local rice samples. For all of the study participants, significantly higher THg concentrations in human hair were observed in CFL workers compared with other residents. In comparison, MeHg concentrations in human hair of residents whose diet consisted of local cultivated rice were significantly higher than those who consumed commercial rice. These results demonstrated that CFL manufacturing activities resulted in THg accumulation in the hair of CFL workers. However, MeHg in hair were mainly affected by the sources of rice of the residents.

1. Introduction

Human exposure to Hg compounds has been of great public concern around the world due to their high toxicity, and has been associated with several diseases such as neurologically related problems, myocardial infarction and autism (Li et al., 2008b).

The primary environmental source of human Hg exposure is through the digestion system, such as consumption of freshwater fish and seafood which have accumulated a considerable amount of Hg via biomagnification through the food chain/web (USEPA, 1997; WHO/IPCS, 1990). Recently, some studies showed that rice, rather than fish, may be one of the major Hg exposure pathways in inland China, where local residents consume few seafood products (Li et al., 2011b; Zhang et al., 2010). The probable daily intake (PDI) of methylmercury (MeHg) from rice consumption indicated potential human health risk in Hg mining areas (Feng et al., 2008; Li et al., 2011b; Zhang et al., 2010). Neurobiological disruptions and increase of *c-fos* gene expression have been observed in experiments involving rats fed with rice contaminated with MeHg (Cheng et al., 2006; Ji et al., 2006), although the bioavailability of Hg in humans is not well known. Current international safety guidelines established by the Joint Food and Agriculture Organization (FAO) and World Health Organization (WHO) Expert Committee on Food Additives (JECFA) recommend a maximum Provisional Tolerable Weekly Intake level (PTWI) for Hg of 1.6 μg/kg (body weight) for women of childbearing age and 3.3 μg/kg for the general population (JECFA, 2003). In 1997, the United States Environmental Protection Agency (USEPA) set the limit of 0.1 μg kg^{-1} d^{-1} as a reference dose (RfD) for MeHg (USEPA, 1997).

Besides the ingestion pathway, occupational exposures such as via inhalation of Hg vapor or dermal contact with elemental Hg or its compounds also pose a potential threat to human health, especially to people engaged in Hg mining, chloralkali plant operation and compact fluorescent lamp (CFL) industries. It has been

* Corresponding author.
** Corresponding author.
E-mail addresses: fengxinbin@vip.skleg.cn (X. Feng), shengchunwu@126.com (S.-C. Wu).

http://dx.doi.org/10.1016/j.envpol.2014.12.036
0269-7491/

well documented that occupational exposure may cause damage to the central nervous system (e.g., tremor and mental changes) and the kidneys (e.g., proteinuria) (WHO/IPCS, 1991).

CFL is a type of fluorescent lamp which relies on Hg as a source of ultraviolet radiation for the production of visible light. Good practice in the manufacturing of CFLs contained as low as 1.4–2.7 mg elemental Hg per lamp (Dunmire et al., 2003). There were 8.0 billion lamps produced in China in 2010 (Li et al., 2013). This implies that the annual elemental Hg consumption for CFL production in China reached up to 11.2–21.6 Mg.

Most of the previous studies reported potential human Hg exposure from broken CFL in the indoor environment (Li and Li, 2011; Sarigiannis et al., 2012). Measures to mitigate health risks to Hg exposure after the breakage of a CFL have been proposed, such as all windows and doors should be immediately opened and all occupants should vacate the room and wait 15–30 min after breakage before cleaning up. The room should also be ventilated for several hours (Sarigiannis et al., 2012). Our previous study revealed that CFL manufacturing activities resulted in Hg contamination to the local soil and sediment environment in a CFL production base in China due to the primitive technology used and the poorly-equipped facilities (Shao et al., 2012). Xu et al. (2007) reported that extremely high Hg concentrations in air were detected in a CFL manufacturing department and reached as high as 16,000 ng m^{-3}. However, data on human Hg exposure in CFL manufacturing areas are still insufficient and the sources of the Hg exposure have not been fully investigated. Some recent studies have confirmed that population in a Hg mining area who were expected to be mainly exposed to inorganic Hg (IHg), were also facing a serious threat of MeHg exposure via consumption of the local Hg-contaminated rice (Feng et al., 2008; Zhang et al., 2010). Hence, we hypothesize that the population in the CFL manufacturing area may beat the risk of co-exposure to both inorganic Hg (IHg) through inhalation and MeHg via food consumption. The objectives of this study were to: (1) investigate Hg contamination in rice samples from the CFL manufacturing area; and (2) to identify sources of possible human co-exposure through either inhalation of IHg or ingestion of MeHg via consumption of contaminated food using speciation analyses of human hair samples collected from the CFL production and control areas.

2. Materials and methods

2.1. Sampling area

Gaohong Town (30°19′N, 119°40′E) is located in northern Zhejiang Province, eastern China. It is commonly known as the “land of CFLs” since there are more than 180 CFL manufacturing factories in Gaohong producing 25% of the world production of CFLs in 2010 (SBZP, 2011).

Residents from four villages namely Shimen (SM), Nima (NM), Maling (ML) and Hongqiao (HQ) were chosen for this study (Fig. 1). Most of the CFL factories are located in NM and HQ villages, while a few is found in ML village. There are no factories located in SM villages, which was selected as the control site.

2.2. Sample collection

Hair samples were collected from 128 participants, in which 84 donors also provided samples of rice samples that their family consumed on a daily basis. In addition, 46 participants only provided rice samples, but refused to donate hair samples. A written consent form for the sample donation was obtained from each participant, together with a short questionnaire recording details concerning gender, age, occupation, source of the rice, weekly consumption amount of rice and fish. Among all of the hair samples, 63 were collected from CFL workers and 65 were from residents. Of the rice samples, 77 were locally cultivated and 53 were non-locally cultivated.

The sources of rice included the locally cultivated and commercial rice. Hair samples were cut with stainless steels scissors from the occipital region of the scalp, bundled together with scrip, placed and sealed in polyethylene bags. It is acknowledged that a complete sample set of rice and hair could not be obtained from all the participants since some of the participants were reluctant to supply either their hair or rice samples.

Five species of fish were collected from the local market in 2011 which included grass carp (*Ctenopharyngodon idellus*) (n = 6), northern snakehead (*Channa argus*) (n = 4), oriental weatherfish (*Misgurnus anguillicaudatus*) (n = 20), mud skipper (*Periophthalmus argentilineatus*) (n = 25) and yellow-headed catfish (*Pelteobagrus*

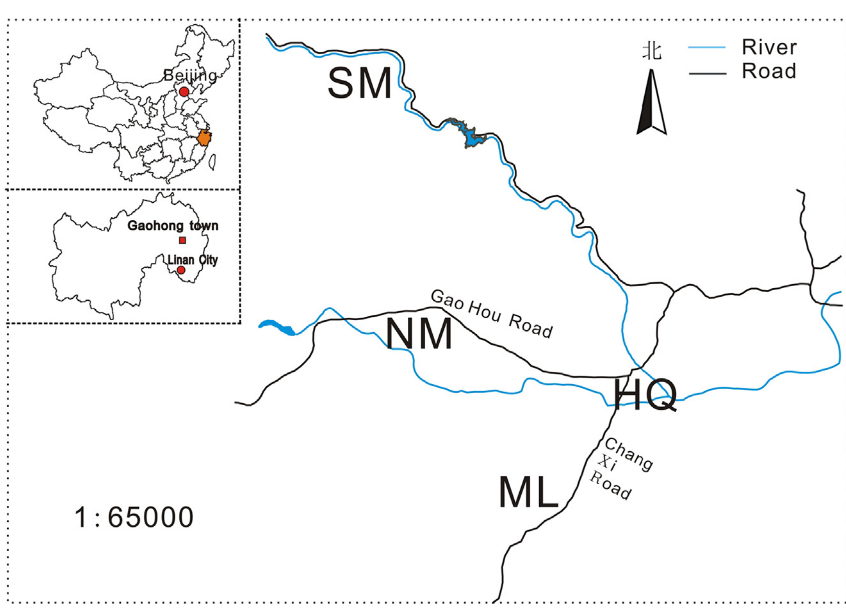

Fig. 1. Sampling site for this study. SM: Shimen NM: Nima; ML: Maling; HQ; Hongqiao.