Ecotoxicology and Environmental Safety 104 (2014) 18–22

Contents lists available at ScienceDirect

Ecotoxicology and Environmental Safety

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

Mercury in the fairy-ring of *Gymnopus erythropus* (Pers.) and *Marasmius dryophilus* (Bull.) P. Karst. mushrooms from the Gongga Mountain, Eastern Tibetan Plateau

Jerzy Falandysz [a,*], Anna Dryżałowska [a], Martyna Saba [a], Jipeng Wang [b], Dan Zhang [b]

[a] University of Gdańsk, 63 Wita Stwosza Str., 80-952 Gdańsk, Poland
[b] Institute of Mountain Hazards and Environment, Chengdu 610041, China

ARTICLE INFO

Article history:
Received 12 November 2013
Received in revised form
7 February 2014
Accepted 11 February 2014
Available online 12 March 2014

Keywords:
Bioconcentration
Forest
Fungi
Himalayan ecosystem
Litter
Soils

ABSTRACT

Gongga Mountain or Minya Konka, like the Himalayan Dimension Mountains, has its own microclimate and a 'circum-polar' climate and hence is sensitive to contamination by persistent pollutants that are trapped by cold temperature and wet precipitation. Elemental mercury (Hg) as vapour easy diffuses into the atmosphere and the rate of Hg deposition from global fallout is dependent on locally ambient temperature and precipitation. We investigated the accumulation and distribution of total Hg in two species of mushrooms, *Gymnopus erythropus* and *Marasmius dryophilus*, which grew on Gongga Mountain. The fruiting bodies were collected at a height of 2946 m above see level. Both species efficiently accumulated Hg. The median values for caps of *M. dryophilus* and *G. erythropus* were 1.168 and 3.078, and for stipes 0.573 and 1.636 mg/kg dry matter, respectively, and in the beneath litter and soil were 0.13 and 0.15 mg/kg dry matter. The Hg contents of the caps of *M. dryophilus* and the beneath litter and soils from pristine Himalayan forest of 1.168, 0.132 and 0.116 mg/kg dry matter (respectively) is high compared to values reported for similar species and soils from background areas in Poland −0.58–0.70 and 0.047–0.048 mg/kg dry matter. The absence of industrial activities, urbanization and Hg ore deposits at Gongga Mountain suggests that long-range atmospheric transport and subsequent deposition is the major source of elevated Hg observed in the mushrooms, litter and surface layer of soils in the outskirts of Gongga Mountain maritime glacier that has a peak of 7556 m above sea level.

1. Introduction

Elemental mercury (Hg), because of its unique physical and chemical features, is well known as a substance that is prone to long-range atmospheric transport while Hg vapors and most of the oxidized Hg compounds are highly toxic. In the past two centuries, the episodes of environmental pollution with Hg due to its exploitation for industrial, agricultural, military, medicinal and domestic purposes and releases due to combustion processes were the main factors responsible for the elevated Hg concentrations observed in the oceans (UNEP, 2013), and this is posing serious threat to biota in some regions of the world. Environmentally, monomethylmercury (MeHg) is the most relevant organic Hg compound that is persistent, neurodegenerative to the primates and some other biota, and is readily bioaccumulated and biomagnified in the food webs. In the terrestrial environment, the wild-grown mushrooms are organisms that often contain Hg at elevated concentrations and many examples are provided in recently published articles (Aloupi et al., 2011; Falandysz, 2002; Falandysz et al., 2001; 2002a,2002b,2002c, 2003a,2003b,2003c,2003d; Melgar et al., 2009; Nasr et al., 2012).

To estimate the potential of the fruiting bodies of macromycetes to sequester chemical element, it is common to calculate the bioconcentration factor (BCF) (Falandysz and Borovička, 2013). Mushrooms (Macromycetes), i.e. fungi developing fruiting bodies – both of saprophytic and mycorrhizal nature and parasites – are usually able to efficiently accumulate Hg from the soils substratum and sequester it in the mushroom flesh. The reported BCF values for Hg for many mushrooms showed their ability to either efficiently bioconcentrate Hg (BCF > 1; e.g. *Boletus edulis, Macrolepiota procera, Lycoperdon perlatum*) or bio-exclude Hg (BCF < 1; e.g. *Lactarius rufus, Russula emetica, Scleroderma citrina*) (Chojnacka et al., 2012; Falandysz and Bielawski, 2001, 2007; Falandysz and Brzostowski, 2007; Falandysz et al., 2002c, 2003d, 2004, 2013; Maćkiewicz and Falandysz, 2012; Melgar et al., 2009; Nasr and Arp 2011; Reider et al., 2011).

A silent epidemic of environmental pollution with Hg has been taking place in the past two centuries (UNEP, 2013). Sites at higher elevations, because of the presence of cloud formation and fog, the

* Corresponding author.
E-mail address: jerzy.falandysz@ug.edu.pl (J. Falandysz).

http://dx.doi.org/10.1016/j.ecoenv.2014.02.012
0147-6513

deposition of oxidized Hg (and reactive Hg°) on vegetation/air surfaces and high rate of rain/snow deposition, are subjected to elevated depositions of airborne Hg (Ritchie et al., 2006; Schemenauer et al., 1995; Stankwitz et al., 2012). The direct air-born Hg absorption has been found in mosses and lichens at high elevations (Evans and Hutchinson, 1996), while the accumulation of Hg in the soil increases overtime by seasonal litterfall and throughfall (Demers et al., 2007). In Polar Regions, the Hg depositions mostly occur during polar spring sunrise (Dastoor et al., 2008). In the Tibetan plateau, atmospheric deposition is the primary mechanism of contamination with Hg from major global emitters (Fu et al., 2008; Zhang et al., 2008). In 2005, the estimated global annual Hg demand was between 3000 and 3900 t. In the East and South-East Asia, the estimated use of 1500 t was the highest and the consumption in the South Asia was 200 t (UNEP, 2013). Estimated global emission of Hg to the air in 2010 from human activities (1960 t) was highest in the East and South-East Asia (39.7 percent) followed by South Asia (7.9 percent) (UNEP, 2013).

Mt. Gongga (Minya Konka) in the Daxue Shan mountain range is localized in the Garzê Tibetan Autonomous Prefecture of the Sichuan, which is the region rich in certain metal ore deposits (Li, Au, Ag), whiles the Sichuan province, is largely an agricultural area. Gongga Mountain like other of the Himalayan Dimension Mountains has its own microclimate and because of cold and precipitation is probably sensitive to pollution from some persistent compounds released into the atmosphere elsewhere in the World. The Gongga Mt. region is largely forested and inaccessible. It is without processing industries with limited agricultural activity (up to ~1800 m a.s.l.) and tourism. The dominant trees in the region of Gongga Mt. are the Faber's Fir (*Abies fabri*) that is conifer species and Poplar (*Populus purdomii*) that is broadleaf species (Cao et al., 2013) and both are endemic to Sichuan.

The prevailing winds coming to the eastern slope of Gongga Mt. are from east and south-east (East Asian Monsoon) and south (Indian Monsoon) directions (Fu et al., 2008; Wu et al., 2013). Both East Asian Monsoon (in May) and Indian Monsoon (in July) bring precipitation into the eastern slope of Gongga Mt. For the period from 1988 to 2010, the mean annual precipitation was 1947.4 mm and monthly precipitation varied between 24.2 mm (December) and 322.0 mm (July); while seasonal precipitation concentrates in May to October (1552.1 mm). In parallel to precipitation, the mean annual temperature is 4.2 °C, with minimum mean value in January (−4.6 °C) and maximum in July (12.5 °C) (Wu et al., 2013). Apart from monsoons, the proximity to Hailuogou maritime glacier may be a factor enhancing precipitation there.

We hypothesize that the Goonga Mt. ecosystem, because of the Himalayan dimension, climate, geographical localization and prevailing winds (from east, south-east and south of Asia), receive Hg, from a remote industrialized sites in the eastern, south-eastern and southern Asia, in amounts that exceed the geochemical background. It is expected that the deposition of airborne Hg in the subapline region of the Gongga Mt. should reflect on the fruit bodies of mushrooms from there. This study aimed at getting insight into the accumulation and distribution of total Hg in fruiting bodies of two species of mushrooms (*Gymnopus erythropus* and *Marasimus dryophilus*) that emerged in fairy ring from a remote place: the Himalayan type ecosystem of subalpine forest vegetation zone. Also sampled were the substratum beneath the mushrooms—decomposing leaves (layer ca. 4 cm thick) and top layer of soil. The sampling site was located at 2946 m a.s.l. on the eastern slope of Gongga Mt. of the Eastern Tibetan Plateau located in the western part of the Sichuan Province of China. Both species of mushrooms sampled develop mycelia in top layer of litter and can be considered as possible indicator of airborne Hg deposition in high mountain areas.

2. Materials and methods

Matured specimens of *Gymnopus erythropus* (Pers.) Antonin, Halling & Noordel and *Marasmius dryophilus* (Bull.) P. Karst. mushrooms (Supporting materials, Figs. S1–S3) (Index Fungorum, 2013; Xiaolan, 2009) and beneath litter (broadleaf plant litter) and surface (0–10 cm) layer of soil were collected from two fairy rings at forested sites of the Gongga Mt. The sampled sites were located within the Subalpine Ecosystem Meteorological Station—Hailuogou Station (101°59′54″E, 29°34′34″N; 2947.8 m a.s.l.) of the Chinese Academy of Sciences at the Gongga Mt. (peak at 7556 m a.s.l.) in the east edge of Tibetan Plateau (101°53′E, N 29°36′N). The materials were collected in July 10 [*G. erythropus*—formerly known as *Marasmius erythropus* (Pers.) Fr. (Xiaolan, 2009)] from one fairy ring and on September 10, 2012 (*M. dryophilus*) from another ring (Fig. 1). The distance between the places at which fruit bodies emerged in a fairy-ring was ~30 m. For *G. erythropus*, 31 caps and 31 stipes; litter (2 samples) and one pooled sample of top layer (0–10 cm) of soil beneath the fruit bodies were examined. For *M. dryophilus* 37 caps and 37 stipes; 8 litter samples and 7 soil samples were sampled (Table 1). Broadleaf trees and shrubs of several plant species dominated the sampled sites and therefore litter sampled were composed entirely of fallen leaves of the broadleaf species (Fig. S2).

Immediately after collection the fruiting bodies were cleaned-up of visible plant vegetation and soil substrate debris with a plastic knife and later air-dried for 3 days. Thereafter, each sample of the fruit body was separated into two parts—cap and stipe, and dried in electrically heated laboratory oven at 65 °C for 72 h. The litter and soil samples were air dried at room temperature under clean (dust free) condition for 18 weeks, and thereafter sieved through a pore size of 2 mm. Next, the sub-samples of mushrooms, litter and soil were weighed into ceramic boats of Hg analyzer.

Total Hg content of the materials was determined by cold-vapour atomic absorption spectroscopy after direct sample matrix combustion (Mercury analyzer type MA-2000, Nippon Instruments Corporation, Takatsuki, Japan) and the analyses were subjected to analytical control and quality assurance (AC/QA) checks as described earlier (Jarzyńska and Falandysz, 2011; Nnorom et al., 2013). Two new fungal materials were included in the AC/QA checks, i.e. dried fruiting bodies of *Agaricus campestris* (CRM: CS-M-2) and *Boletus edulis* (CRM: R-9). Because

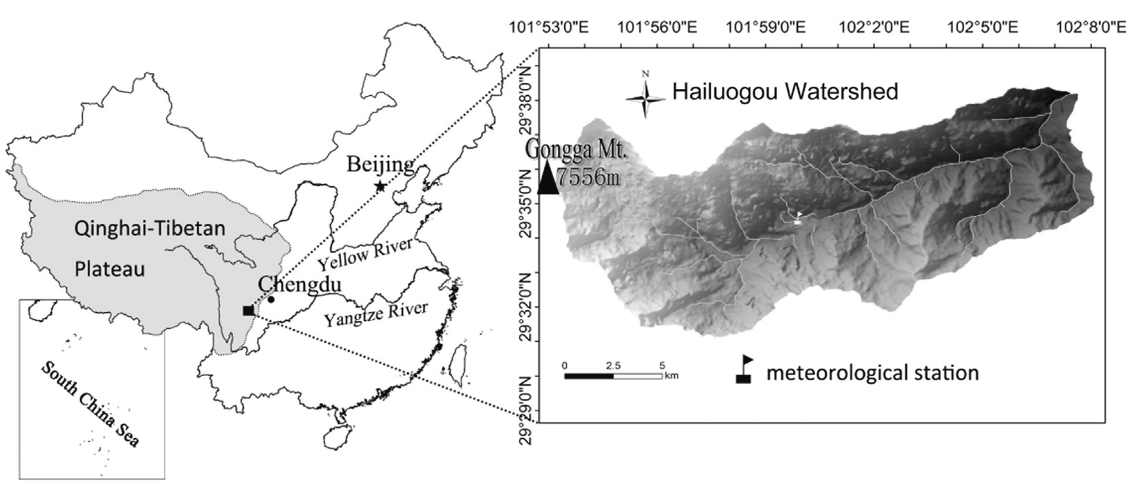

Fig. 1. Location of sampling site ( ) at Mt. Gongga—meteorological station (an original picture after Zhou et al. (2013) and with kind permission from the authors).