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Organochlorine pesticides and polychlorinated biphenyls in grass, yak muscle, liver, and milk in Ruoergai high altitude prairie, the eastern edge of Qinghai-Tibet Plateau

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HIGHLIGHTS

- OCPs and PCBs in yak in Ruoergai highland at 3,500 m (a.s.l.) were measured.
- HCHs, DDTs, and PCBs were detected in yak muscle, liver, and milk.
- HCB and β-HCH were the main POPs in yak milk.
- The consumptions of yak muscle and milk would not pose risk to local people.

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ABSTRACT

In highland pastures, where no agricultural and industrial activities exist, organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) are believed to be mainly coming from water–soil–grass system which is subject to air–water and air–soil exchanges and atmospheric precipitation. Samples of grass and yak muscle, liver, and milk were measured for OCPs and PCBs in the summer and winter of 2011. The total concentrations of HCHs, DDTs, endosulfans, HCB, and PCBs in grass samples were in the range of 0.53–2.45, 1.6–6.0, 1.10–4.38, 0.30–1.24, 0.65–2.04 ng g^{-1} dw (dry weight), with the means 1.38, 2.86, 2.06, 0.73, and 1.19 ng g^{-1} dw, respectively. The mean concentrations of HCHs and DDTs in yak muscle were 1.65 and 0.55 ng g^{-1} fw (fresh weight), respectively; no significant seasonal differences. The average total concentrations of HCHs, DDTs, HCB, endosulfans, and PCBs in yak milk were 4.46, 0.59, 1.00, 0.27, and 0.097 ng g^{-1} fat, respectively. Among the POPs investigated, β-HCH and HCB were dominant in yak muscle and liver, whereas β-HCH dominated the yak milk. Consistent with the results of other studies, PCB 153, 138, and 180 were detected in yak milk that is in accordance with the case reported for farmed cow milk in China and other countries. A human health risk was conducted based on the intake of OCPs via consumptions of the yak muscle and milk. Since the daily intake of HCHs and DDTs was lower than WHO or USEPA's acceptable daily intake or minimal risk level, showing that the consumptions of the yak muscle and milk would not pose any immediate risk to local people.

1. Introduction

Organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) are persistent organic pollutants (POPs); they have slow degradation rates and have extensive historical uses in agricultural and industrial applications. Some volatile POPs, such as some lower chlorinated PCBs can undergo long range atmospheric transport (LRAT), and therefore they have been globally detected in animals and humans, even in remote areas like the Arctic, where these compounds have never been used (Hansen, 2000; Muir and de Wit, 2010). The United Nation Environment Protection (UNEP) has established a global treaty, known as the Stockholm Convention in 2001; the aims of the convention are to eliminate of production of POPs and control unintentionally produced POPs (UNEP, 2001, 2009a); among the POPs, PCBs, polychlorinated dibenzo-p-dioxin and polychlorinated dibenzofuran (PCDD/Fs), and OCPs such as hexachlorocyclohexanes (HCHs), dichlorodiphenyltrichloroethane (DDT) are of most concerned. Endosulfan is an insecticide that persists in the environment, which was also added to another international treaty, the Rotterdam Convention, which requires government-to-government notification when dangerous pesticides and other chemicals cross international borders (USEPA, 2002).

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Due to the lipophilic properties, POPs are accumulated in fatty tissues in animals and humans. These compounds bioaccumulate and biomagnify along the food chains and have health impacts on wildlife and human (Tanabe, 2002). Health effects such as endocrine disruption, mutation, and carcinogenicity have been suggested to link with the bioaccumulation of POPs (Hansen, 2000). As mentioned above, these compounds can also be transferred to remote clean areas via LRAT at regional or even global scale (Wania and Mackay, 1993). High mountains and cold regions have been suggested to be the sink and important reservoirs of POPs (Blais et al., 1998). Compared to the low-altitude areas, high-altitude regions have low air temperature and relatively high snow precipitation. Detection of POPs have been observed in air, water, and soils in the high altitude regions of the western China, such as the Himalayas and Tibetan Plateau (Wang et al., 2006, 2007a; Yang et al., 2008; Kang et al., 2009; Pan et al., 2013; Sheng et al., 2013).

Previous studies have shown that food is a major route of human exposure to OCPs and PCBs via the consumption of contaminated fish, meat, and dairy products (Duarte-Davidson and Jones, 1994; Darnerud et al., 2006). Several mass balance studies have demonstrated that POPs such as PCBs, PCDD/Fs, and polybrominated diphenyl ethers (PBDEs) of different physico-chemical properties played an important role in their transfer and accumulation from feed to cow tissues and milk (McLachlan, 1993; Thomas et al., 1998, 1999a; Kierkegaard et al., 2007; Tato et al., 2011). In contrast, limited study is available in highland (Tato et al., 2011). In China, only PCBs in butter samples in Lhasa, Tibet have been reported (Wang et al., 2010). In highland pastures, where no agricultural and industrial activities exist, PCBs and OCPs are believed to be coming from atmospheric precipitation into surface water, soils, and grass; PCBs and OCPs are expected to transfer from grass to cow. Yak meat and milk are the main foodstuffs for highland residents in central Asia and high plateau regions of the western China. Consumption of these foodstuffs may be an important exposure route for the local residents to intake PCBs and OCPs. Therefore, it is important to understand how these POPs such as PCBs, HCHs, DDTs, endosulfans, and HCB transfer from grass to cows' tissue and milk in order to evaluate human exposure to these chemicals via dietary exposure in free-range livestock farming in highland plateaus.

Ruoergai (Zoige) highland prairie with an average altitude of 3500 m above sea level (a.s.l.) in Qinghai-Tibetan Plateau was selected as the research area to study the levels of typical POP compounds (OCPs and PCBs) in grass, yak meat and milk in high altitude areas. The present investigation reports the results from a detailed field study conducted to quantify the OCP and PCB levels in grass, yak, meat and milk. Ten OCPs and six indicator PCB congeners were analyzed by a high resolution gas chromatograph–high resolution mass spectrometry (HRGC–HRMS). The aims of this study are to provide information on the composition patterns of the POP compounds in grass and yak samples and to conduct a health risk assessment of local residents on POP exposure via uptake of yak meat and milk.

2. Materials and methods

2.1. Research areas and geographic setting

Ruoergai highland prairie is located at the eastern edge of the Qinghai-Tibetan Plateau, north of Sichuan Province, at altitudes of 3200–3600 m a.s.l. It is in the convergence zone of East Asia monsoon and the Qinghai-Tibetan Plateau climate system. The eco-environment is pasture and alpine wetlands; it is one of the largest three grasslands in China having an 808,000 hectare natural grassland in Ruoergai pasture. The economics is mainly free-range livestock farming (yak, sheep, and horse), and most of the population is Tibetan.

The climate of Ruoergai highland grassland is characterized by cold weather, with an annual average temperature of 2 °C, and an annual average precipitation of 600 mm, which mostly occurs between June and August. Summer is short (June and July) and the average temperature is 10.8 °C, whereas the average temperature in winter is −5 °C. The prevailing wind is mainly westerly and northwesterly. The climate of this region has changed dramatically since the 1990s; decreasing precipitation and increasing evaporation trends were observed, and these trends have lead to shrinking of the wetland area; consequently, water resources drastically reduced, grassland degradation, and accelerated soil desertification.

2.2. Sample collection

Grass, yak muscle, liver, and milk samples were collected in June and November 2011. The sampling locations are given in Fig. 1. Grass samples ($n = 27$), mainly *Kobresia* sp. and *Polygonum* sp., were collected using a small stainless shovel in five different farms (Heihe Farm,

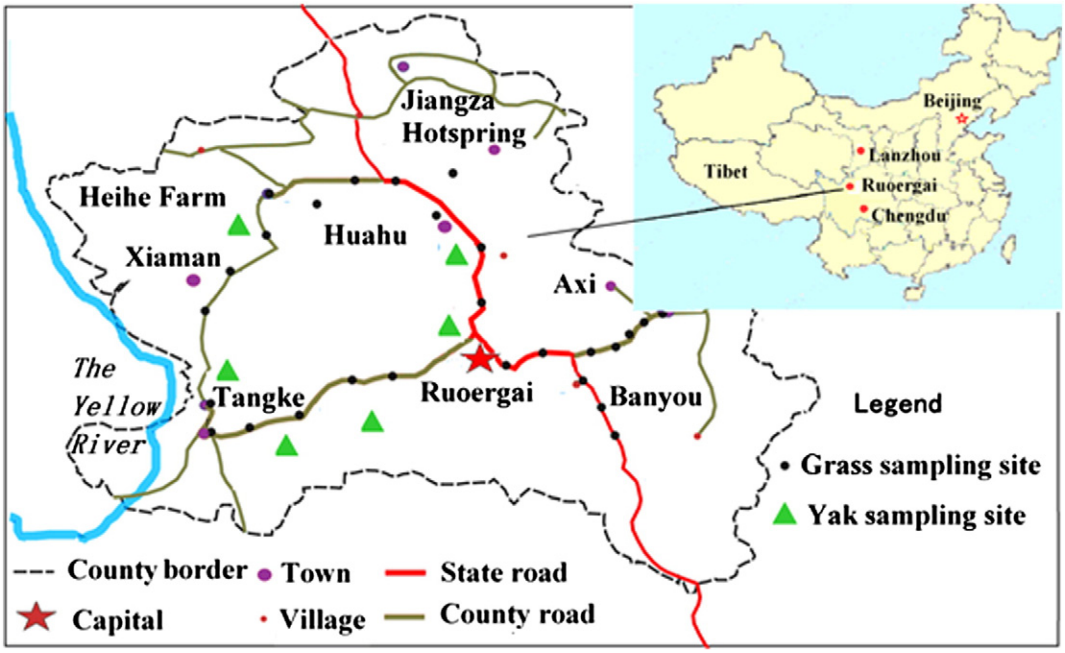

Fig. 1. Map of sampling locations in the Ruoergai highland prairie.