Environmental Pollution 158 (2010) 2310–2316

Contents lists available at ScienceDirect

Environmental Pollution

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

Organochlorine pesticides and PCBs in fish from lakes of the Tibetan Plateau and the implications

Ruiqiang Yang [a], Yawei Wang [a], An Li [b], Qinghua Zhang [a], Chuanyong Jing [a], Thanh Wang [a], Pu Wang [a], Yingming Li [a], Guibin Jiang [a,*]

[a] State Key Laboratory of Environmental Chemistry and Ecotoxicology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, P.O. Box 2871, Beijing, 100085, China

[b] School of Public Health, University of Illinois at Chicago, Chicago, IL 60612, USA

Occurrence of POPs in higher-altitude lakes suggests that Tibetan Plateau acts as potential regional convergence zones for long-range atmospheric transported contaminants.

ARTICLE INFO

Article history:
Received 13 October 2009
Received in revised form
29 January 2010
Accepted 6 February 2010

Keywords:
POPs
OCPs
Long-range atmospheric transport
Alpine lakes
Indian monsoon

ABSTRACT

High mountains may play significant roles in the global transport of persistent organic pollutants (POPs). This work aims to investigate the levels, patterns and distribution of semi-volatile organoclorine pollutants and to improve the understanding of the long-range atmospheric transport and fate of contaminants on the Tibetan Plateau. A total of 60 fish samples were collected from eight lakes located between 2813 and 4718 m above sea level across the Plateau. Concentrations of polychlorinated biphenyls (PCBs), organochlorine pesticides (OCPs) including dichlorodiphenyltrichloroethane and its metabolites (DDTs), hexachlorocyclohexanes (HCHs) and hexachlorobenzene (HCB) were measured in fish muscle. The results showed that concentrations of DDT, HCH and HCB were comparable to or lower than those found in remote mountains of Europe, Canada and US, while PCB concentrations in fish were, on average, about 4–150 times lower on Tibet than at other mountain areas. The transport and fate of contaminants in the Plateau are significantly influenced by the unique climatological and meteorological conditions, particularly by the summer Indian monsoon and winter westerly jet stream.

1. Introduction

Persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs) are of high concern, not only because of their detrimental health effects but also because they are persistent and semi-volatile, thus able to travel long distances and distribute globally. Long-range atmospheric transport (LRAT) is a primary global transport pathway for POPs (Wania and Mackay, 1994). In warm regions, POPs tend to evaporate into the atmosphere, and the transport is often directed towards the colder polar regions where they are efficiently scavenged from the atmosphere. Similarly, low temperatures in alpine regions could allow high mountains to act as cold condensers and thus influence the global transport of POPs (Daly and Wania, 2005). In Europe and North America, recent research has shown evidence of cold trapping in alpine regions for various airborne pollutants (Daly and Wania, 2005; Blais et al., 1998).

The Tibetan Plateau (the Plateau) lies between the Himalayan range to the south and the Taklamakan Desert to the north. With an area of 2.5 million square kilometers and an average altitude over 4000 m above sea level (a.s.l.), the Plateau is the largest and highest plateau in the world. It is characterized by harsh climate featuring dramatic elevational temperature gradient and monsoon affected air movement and precipitation patterns. With sparse human population and minimal industrial activity, atmospheric transport is essentially the only source of POPs to most areas of the Plateau. Recent work showed an increase in some contaminants in conifer needles with increasing altitude along the northern slope of the central Himalayas and the southeast Tibetan mountains (Wang et al., 2006; Yang et al., 2008). These results are in accordance with the observation for the Canadian Rocky Mountains by Blais et al. (1998) and several other studies summarized by Daly and Wania (2005). Such an altitudinal trend can be confounded by other influencing factors such as proximity to sources, directions of diurnal and seasonal airflow, and the topographic feature of the sampling locations.

Alpine lakes are unique depositories of long-range transported contaminants. The lakes on the Plateau are generally characterized

* Corresponding author. Tel.: +86 10 62849334; fax: +86 10 62849179.
E-mail address: gbjiang@rcees.ac.cn (G. Jiang).

0269-7491/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.envpol.2010.02.004

by low temperature, low dissolved organic carbon (DOC) and low nutrient level (Xiang and Zheng, 1989). In these lakes, the food chain is generally short and simple compared with the lowland aquatic ecosystems. The fish inhabiting the lakes often have higher lipid storage, longer lives and slower growth rate than those in lowland lakes (Wu and Wu, 1992). Such fish might be sensitive to long-term accumulation of persistent pollutants and can be used as an important environmental compartment for transport studies in remote areas (Demers et al., 2007).

In this study, fish samples were collected from eight alpine lakes across the entire Plateau. Concentrations of PCBs and OCPs including dichlorodiphenyltrichloroethane and its metabolites (DDTs), hexachlorocyclohexanes (HCHs) and hexachlorobenzene (HCB) were quantified in the muscle of 60 fish samples. The contaminant levels, congener profiles and dominant factors influencing on the spatial distribution of POPs in the fish were examined.

2. Experimental section

2.1. Sample collection

The sampling locations are shown in Fig. 1, and the related geographic information is summarized in Table 1. The eight alpine lakes are located on the Plateau between latitudes 28.9°N and 37.3°N, and longitudes 79.9°E and 100.3°E, with elevations ranging from 2813 to 4718 m above sea level (a.s.l.). All studied lakes were of natural origin and situated far from known pollution sources. Fish samples were collected using fishing nets in August 2007 (except Co Na Lake and Keluke Lake, which were sampled in August 2006). Each fish was individually wrapped in solvent-rinsed and baked foil and placed into a self-sealed polyethylene bag. Clean nitrile gloves were used when handling samples. Most fish species collected belonged to the same family Cyprinidae and subfamily Schizothoracinae, which are unique in the Plateau (Wu and Wu, 1992). All the fish taken from a single lake were of the same species. Samples were stored in an ice-cooled box during transportation.

2.2. Fish characterization

Each fish was treated as an individual sample except for fish from Co Na Lake and Keluke Lake. These two lakes were sampled during the early stage of this work, and three fish from each of these two lakes were pooled to form a composite sample for the lake. For each sample, muscle tissue was homogenized and freeze-dried, and the subsamples were kept at −20 °C until chemical analysis. The actual age of each fish was determined by counting the growth ring of the vertebra of the fish. The lipid content was determined gravimetrically. The conditioning factor, which is the ratio of weight (cg: g×100) to cubic length (cm^3), was measured to compare the relative health status of individual fish from each lake.

2.3. Chemical analysis

The analytical procedure for OCPs was similar to our previously established method with some modifications (Yang et al., 2007). One gram of freeze-dried sample was mixed with sodium sulfate and extracted on a Dionex 300 accelerated solvent extractor (ASE) in 1:1 (v/v) dichloromethane:hexane. Suitable amounts of two surrogate standards, 2,4,5,6-tetrachloro-m-xylene (TMX, 1 ng) and PCB209 (5 ng) were added. Lipid content was determined gravimetrically using 20% of the extract. The other extract was subsequently concentrated on a rotary evaporator and subjected to clean up on a glass column (12 mm i.d.) packed with 8 g of activated florisil. The elution was conducted by 70 mL 4:1 (v/v) hexane: dichloromethane and finally concentrated to about 0.5 mL by a gentle stream of nitrogen gas. Thirteen kinds of OCPs, including α-, β-, γ-, δ-HCH, HCB, *p,p′*-DDE, *o,p′*-DDE, *p,p′*-DDD, *o,p′*-DDD, *o,p′*-DDT and *p,p′*-DDT were analyzed by an Agilent 6890N gas chromatography (GC) equipped with a ^{63}Ni electron capture detector (micro-ECD) (USA). A DB-5 fused silica capillary column (30 m length × 0.25 mm i.d.) coated with 5% dimethylsiloxane (film thickness 0.25 μm) was used for separation. The oven temperature was held at 80 °C for 1 min, ramped at 10 °C/min to 180 °C, held for 5 min, then at 2 °C/min to 215 °C, held for 4 min, and finally at 25 °C/min to 280 °C and held for 15 min. The temperatures of injector and detector were 230 °C and

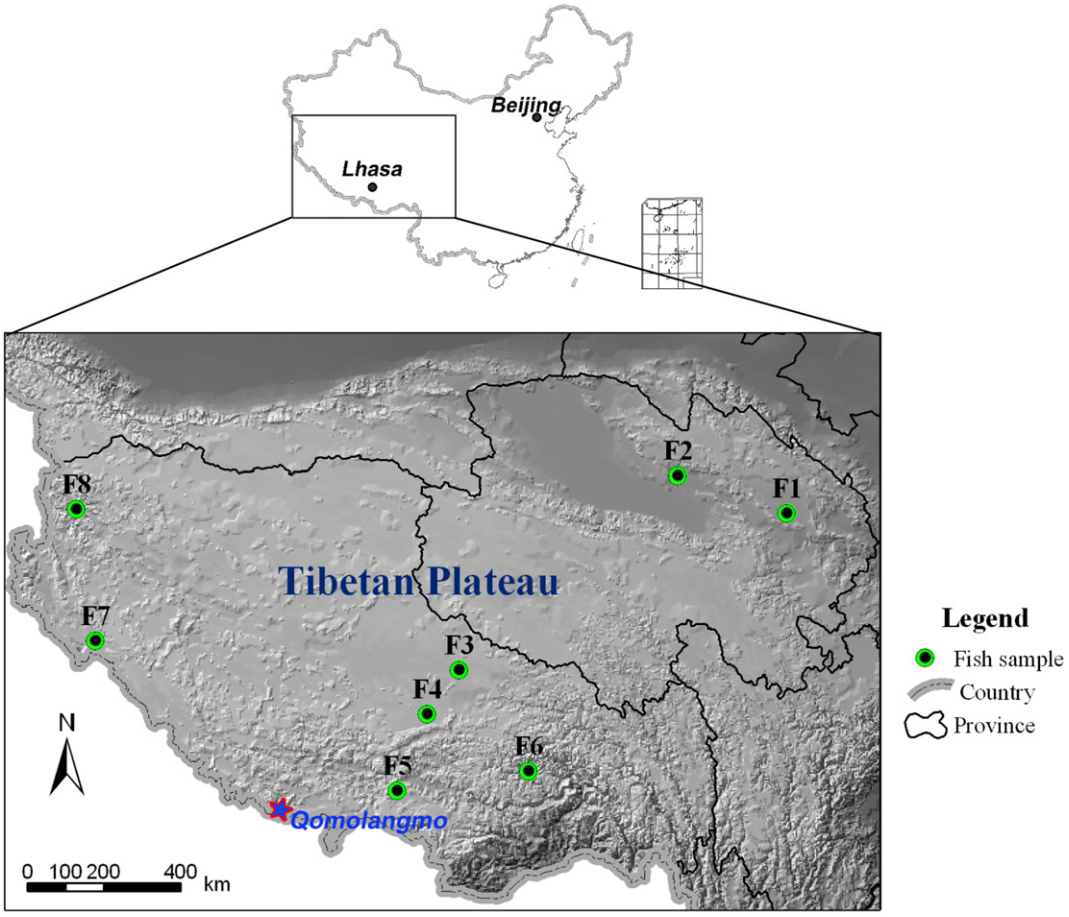

Fig. 1. The study area and sampling sites (F1: Qinghai; F2: Keluke; F3: Co Na; F4: Nam Co; F5: Yamdro; F6: Basum; F7: Manasarovar; F8: Palgon).