Environmental Pollution 191 (2014) 166–174

Contents lists available at ScienceDirect

Environmental Pollution

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

Environmental fate and behavior of persistent organic pollutants in Shergyla Mountain, southeast of the Tibetan Plateau of China

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ARTICLE INFO

Article history:
Received 16 December 2013
Received in revised form
22 April 2014
Accepted 23 April 2014
Available online 20 May 2014

Keywords:
POPs
Environmental behaviors
Air
Mountain
Tibetan Plateau

ABSTRACT

Pristine mountains are ideal settings to study transport and behavior of persistent organic pollutants (POPs) along gradients of climate and land cover. The present work investigated the concentrations and patterns of 28 organochlorine pesticides (OCPs), 25 polychlorinated biphenyl (PCBs), 13 polybrominated diphenyl ethers (PBDEs), and 3 hexabromocyclododecane (HBCDs) isomers in the air of the Shergyla Mountain, southeastern Tibetan Plateau. Endosulfan I, hexachlorobenzene, pentachlorobenzene, hexachlorocyclohexanes and dichlorodibenzotrichloroethane and its degradation products (DDTs) were the predominant compounds while PBDEs and HBCDs showed the lowest background concentrations. Most of the target POPs had significantly higher concentrations in summer than those in winter. Increasing trends of the concentrations of DDTs and endosulfan were found with increasing altitude on the western slope in the Shergyla Mountain. Potential forest filter effect was observed based on the lower air concentrations of the target POPs in the forest than the ones out of the forest.

1. Introduction

Persistent organic pollutants (POPs) are chemical substances that persist in the environment, bioaccumulate through the food web, and pose a risk of causing adverse effects to humans and the ecosystem. With the evidence (Cabrerizo et al., 2012; Estellano et al., 2008; Wang et al., 2009) of long-range atmospheric transport (LRAT), these compounds can reach pristine areas where they are never used or produced, such as high latitude or altitude regions. Organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs) and hexabromocyclododecanes (HBCDs) are four categories of POPs under the Stockholm Convention. Most of OCPs were introduced to the large-scale commercial production and use since 1950s and they have been totally prohibited in the year of 1983 in China. PCBs and PBDEs are both industrial chemicals and share many similar physicochemical properties. They have been ubiquitously found in the environment in the worldwide. As one of the most used brominated flame retardants, HBCDs have just been listed into Stockholm Convention as a new POPs in 2013.

Passive air samplers (PAS) are widely used for investigating the concentrations, distribution patterns and transport mechanisms of POPs in atmospheric environments. Compared to active air samplers, PAS are relatively simple, low-cost, and free of a power supply. The common used sampling media equipped with PAS includes semi-permeable membranes, polyurethane foam and XAD resins. Thereinto, XAD-based PAS shows higher uptake capacity and can be deployed for longer sampling periods (Wania et al., 2003) for gas phase concentrations of OCPs (Schrlau et al., 2011), PCBs (Shen et al., 2006; Wang et al., 2010), PBDEs (Shen et al., 2006; Wang et al., 2010) in various areas, especially in high altitude regions and remote areas. In the mountain areas, specific mountain conditions (e.g., elevation and topographical gradients) and climate conditions (e.g., variation of temperature and precipitation) strongly affect the environmental behavior of POPs (Daly and Wania, 2005), and make the contaminant fate different from that in neighboring lowlands.

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http://dx.doi.org/10.1016/j.envpol.2014.04.031
0269-7491/

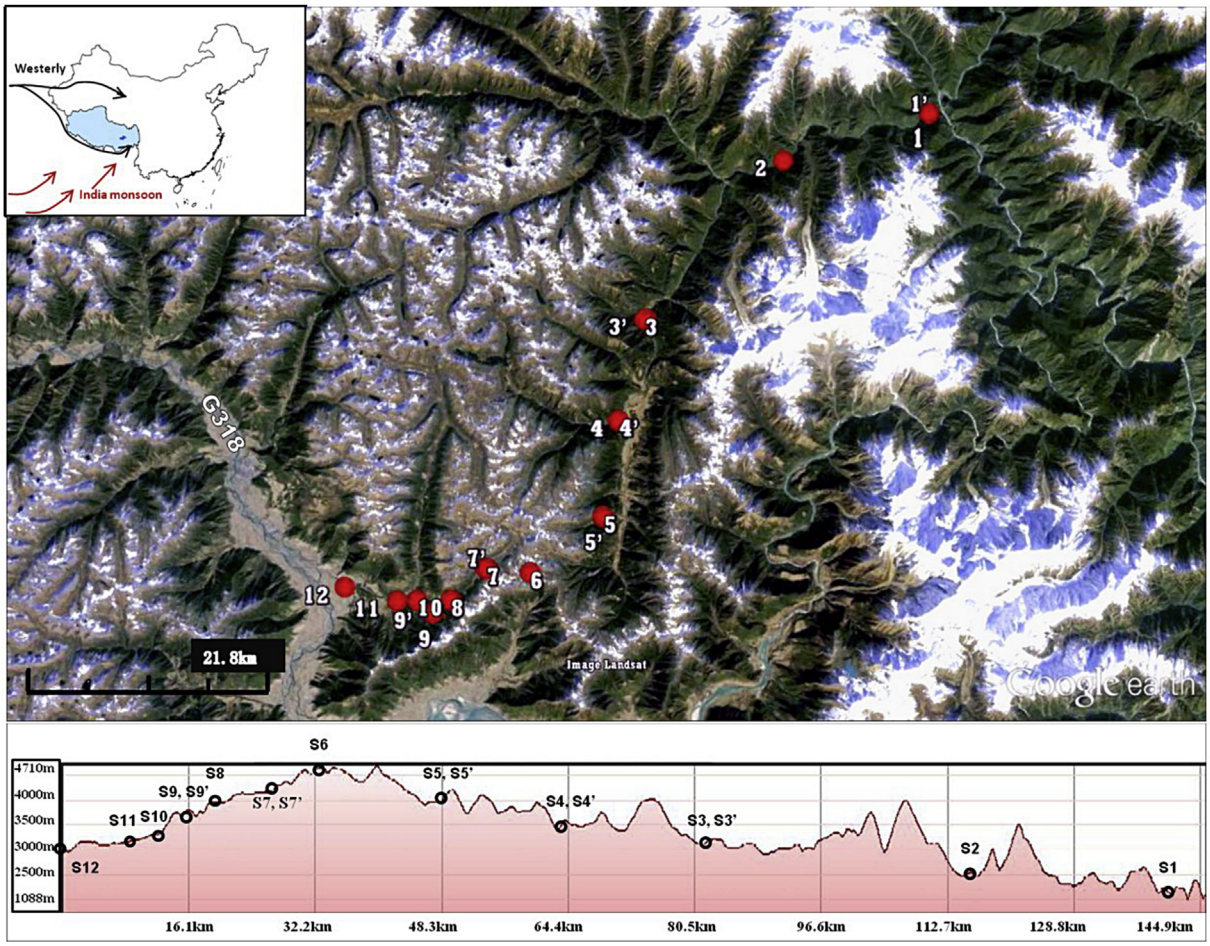

Fig. 1. Sampling sites in the Shergyla Mountain, southeast of the Tibetan Plateau, China. Site 6 was the mountaintop site, and sites 1–5 were on the eastern slope of Shergyla Mountain while sites 7–12 were on the western slope. Sites 1, 2, 3, 4, 5, 7, 8, 9, 10 were located in the forest, and sites 1′, 3′, 4′, 5′, 6, 7′, 9′, 11, 12 were located out of the forest.

Often called the roof of the world (with an average altitude of 4000 m above sea level), the Tibetan Plateau lies north of the Himalayas and is one of the coldest and most pristine regions in the world. On accounting of the sparse human population and minimal to nonexistent industrial activities, most of POPs have no perceivable local sources in this high mountain region except for some OCPs (Li et al., 2008). Atmospheric transport is considered to be the most important approach for external source of POPs and novel organic pollutants to the Tibetan Plateau (Gong et al., 2010; Wang et al., 2008; Xiao et al., 2012). Previous works have found that POPs and other contaminants might particularly exist in the plateau due to the orographic cold-trapping effect (Liu et al., 2010; Wang et al., 2009; Yang et al., 2008). Shergyla Mountain is located in southeast of the Tibetan Plateau and is one of the main forest zone in the Tibetan Plateau. Due to the variable impact of the large moisture passage of the Yarlung Tsangpo Valley and the mountain block, the eastern and western slopes of the Shergyla Mountain show obviously different climates. The rainfall on the eastern slope (about 1000 mm per year) is about 40% higher than that of the western slope.

The purpose of the present work is to investigate the air concentrations of OCPs, PCBs, PBDEs, and HBCDs by XAD-PAS along elevation gradients in Shergyla Mountain, further to study the possible transport mechanism of target POPs under the influence of various environmental parameters i.e., temperature, precipitation, monsoon and vegetation. It is expected that the study will gain insight into the source, atmospheric transport and cold-trapping/condensation effect of POPs in the atmosphere in this high mountain area. Investigations on the atmospheric concentrations of HBCDs in remote environments are very scarce. The only available researches for background levels of HBCDs originated from Europe and the United States and used active air samplers to measure HBCDs air concentrations for repeated short-periods (Hoh and Hites, 2005; Remberger et al., 2004). To our knowledge, this was the first work to provide the background levels of HBCDs in the high mountain areas of the Asia region.

2. Experimental section

2.1. Sampling

The sampling was carried out in the Shergyla Mountain, southeast of the Tibetan Plateau during the period of July 2010 to May 2011 (Fig. 1). The altitude of the sampling sites ranged from 1983 to 4553 m above sea levels, with steep gradients at the mountain sides. Considering the influence of the snowstorm on the sampling, XAD-2 PAS were deployed for two time-integrated sampling periods, including a 4-month summer period (July–October, 2010) and a 7-month winter period (November of 2010–May of 2011). Sampling sites are located on the eastern and western slopes of the Shergyla Mountain. The sampling inside the forest and corresponding outside the forest was also concerned to investigate the potential forest filter effect. In all, 36 air samples were collected. Triplicate blanks were also prepared by fixing the XAD-2 resin-filled stainless mesh cylinder into the sampler housing during the sampling. The assemblage and use information of XAD-2 resin based PAS has previously been described in details (Zheng et al., 2010). The samples were stored in insulation ice boxes (polyester) and immediately taken back the laboratory