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Polychlorinated biphenyls in surface soil in urban and background areas of Mongolia

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ABSTRACT

Polychlorinated biphenyls (PCBs) were measured in soil in some industrial towns (Ulaanbaatar, Suhbaatar, Erdenet, Darhan, Tsetserleg, Hovd, Ulaangom, Altay, Bayanhongor, Arvayheer, Saynshand, Choybalsan) and in background and rural areas of Mongolia. The average sum of all investigated PCB congeners in soil of Mongolia comes to 7.4 ng/g dry weight (DW) and varies from 0.53 ng/g DW till 114 ng/g DW. PCB levels in soil from towns are significantly higher than those in soil from background and rural areas. The PCB homological composition in soil sampled in highly-PCB-polluted sites is similar to the PCB homological pattern in Sovol and Aroclor 1254. Significant correlation between soil organic carbon and low chlorinated PCB both for towns and background sites was found. Significant differences in PCB means in soil in different natural zones were found.

1. Introduction

Mongolia is located in the central part of Asia and contiguous with Russia to the north and with China to the south. The total area of Mongolia comes to about 1564 thousands km^2 (National Atlas of MNR, 1990). The relief of the country contains a combination of different types and size of mountain ridges, depressions and high plains. The climate of Mongolia is dry continental and is defined by the continental location far from seas and oceans and by the relief of the country and contiguous territory (National Atlas of MNR, 1990). The description of some climate indexes is presented in Supporting Information. There are six natural zones in Mongolia including high mountain, mountain taiga, forest-steppe, steppe, Govi (the Gobi) and desert zones (Geographic Atlas of Mongolia, 2004).

At present Mongolia is a country with an economy in transition (NIP, 2006). Agriculture plays an important role in the economy of the country, but the significance of industrial production has increased in recent years. Some of the industrial and agricultural activities can be sources of polychlorinated biphenyls (PCBs) as by-products. PCBs have never been intentionally produced in Mongolia (NIP, 2006). Electrical equipment including PCB-containing transformers was purchased in other countries (NIP, 2006). Such PCB-containing electric equipment might be used in Mongolia at present (NIP, 2006). 96 percent of the total number of transformers used in Mongolia were produced in Russia in 1968–1980s (NIP, 2006). The remaining transformers used in Mongolia were produced in China, Japan, Germany, Bulgaria, Romania, Korea, Czechoslovakia and Hungary (NIP, 2006). About 80 percent of the transformers are used or stored in large cities in Mongolia. At present PCB containing equipment is still used at enterprises. Mothballing and elimination of PCB containing equipment is planned to be completed by 2020 (NIP, 2006).

Inadequate conditions of use, storage and disposal of obsolete PCB containing equipment and fluids might result in the pollution of the environment. For example, the Erdenet Mining Corporation used 2 tons of waste transformer oil containing PCBs on the roads in order to reduce road slipperiness in winter (NIP, 2006). Analyses of soil samples showed PCB concentrations of more than 50 ppm (NIP, 2006).

In addition PCBs can be transported over long distances (Wania and Mackay, 1996). Mongolia adjoins with China and Russia where

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some POPs were widely used in the past or are being used at present (Breivik et al., 2002; AMAP, 2000). Previous investigations of PCBs in environmental media in Mongolia indicate that the compounds can arrive in the region as a result of atmospheric transport and local emission sources (Mamontova et al., 2009, 2011).

The aim of the study is to investigate the peculiarities of PCB spatial distribution in Mongolian soil.

2. Material and methods

2.1. Soil sampling

Surface soil samples (0–5 cm) were collected during three expeditions in Mongolia in 2010–2011 (Fig. 1, Table S1). The sampling sites were located in five existing natural zones from six zones in Mongolia. The high mountain zone was not included in the sampling area due to difficulty of access. The soil was collected with a metallic tube sampler of 5 cm diameter. Five cores were taken at each site. The soil cores were pooled to obtain one representative sample for the sample location, wrapped in aluminum foil, and sealed in plastic bags.

2.2. PCBs analysis

All solvents used were distilled and checked for interference prior to use. Individual PCB congeners and PCB mixture standards were purchased from the Dr. Ehrenstorfer Laboratory (Ausburg, Germany). Aluminum oxide and silica gel for column chromatography were purchased from MERCK (Darmstadt, Germany).

2.2.1. Sample preparation

The soil samples were dried at room temperature to constant weight. Then soil samples were sieved through a 2 mm mesh. The fraction <2 mm was taken for analysis. The pretreatment of soil samples was performed in a laboratory of the Institute of Chemistry and Chemical Technology, Mongolian Academy of Sciences. Then soil samples were transported to the Institute of Geochemistry in Irkutsk (Russia) and stored at −30 °C prior to analysis.

2.2.2. Sample extraction and clean-up

The soil samples were extracted in a Soxhlet extractor for 10 h with *n*-hexane:acetone (1:1). Surrogate standards (35.7 ng PCB 14 and 15.2 ng PCB 65) were added to the sample before extraction.

The samples were cleaned up using two liquid chromatography columns: a gel permeation chromatography column filled with bio-bead S-X3 and a chromatographic column containing silica gel (3 g), aluminum oxide (3 g), and anhydrous Na_2SO_4 (3 g) (Mamontova et al., 2007). Al_2O_3 and SiO_2 were activated for 9 h at 900 °C and 450 °C, respectively. The fraction containing the PCBs was evaporated to 30 μl under purified nitrogen.

2.2.3. Instrumental analysis

GC/ECD analyses were performed on a HP 5890A Series II gas chromatograph using a DB-5 capillary column (J&W Scientific, 0.25 μm film thickness, 0.25 mm inner diameter, 60 m long). The carrier gas was He and the make-up gas was N_2. The temperatures of the detector and the injector were 320 °C and 270 °C, respectively. The temperature program was: start at 90 °C (2 min hold), increasing to 170 °C at 22 °C/min and then increasing to 280 °C at a rate 1.32 °C/min (17 min hold).

The soil samples were analyzed for the following PCB congeners (IUPAC no., listed in homological groups): di-CB: 5/8; tri-CBs: 28, 31, 37; tetra-CBs: 44, 49, 52, 70/76, 74; penta-CBs: 82, 85, 87/115, 97, 99, 101/90, 105, 77/110, 118; hexa-CBs: 128, 138, 153, 156, 158; hepta-CBs: 170/190, 179, 180, 183, 187, 189; and pair of tetra + penta-CBs: 95/66 (the list of PCB congeners and their levels are presented in Table S2). Reference to the total PCB and the sum of homolog groups in our paper considers the quantified PCB congeners.

Method recoveries were also determined using spiked samples. They lay between 80% and 120% for the most compounds. Procedural blanks were run with every batch of 10–12 samples to check the contamination from solvents and glassware. Only samples in which the analyzable compound level exceeded the level in the blank 3.5 times were taken into consideration.

The method was validated using internal laboratory reference material for soil from the accredited laboratory at the Department of Applied Environmental Science (ITM), Stockholm University, Stockholm, Sweden (Mamontova et al., 2007). There was a good agreement between the ITM average values and the values measured in Irkutsk (Mamontova et al., 2007; Polychlorinated Biphenyls…, 2005).

2.3. Soil organic carbon analysis

Soil organic carbon (SOC) was determined by TOC Analyzer Eltra.

The results are presented in three manners: in weight bases, concentrations normalized to the cross-sectional area of the cores taken to measure the spatial distribution of PCB inventory in Mongolian soil, and normalized to organic carbon content in the soil samples. Statistical analysis was performed using STATISTICA'6.

3. Results and discussions

3.1. The comparison of PCB levels in Mongolian surface soil with world PCB levels and sanitary standards

The average sum of 37 quantified PCB congeners in soil of Mongolia comes to 7.4 ng/g dry weight (DW) and varies from 0.53 ng/g DW in the western part of Mongolia (Ms460) to 114 ng/g DW in the eastern part of the country in the town of Choybalsan (Ms512) (Table S3). Highest ΣPCB_{37} levels were found in three Mongolian industrial towns and their suburbs and at one rural site

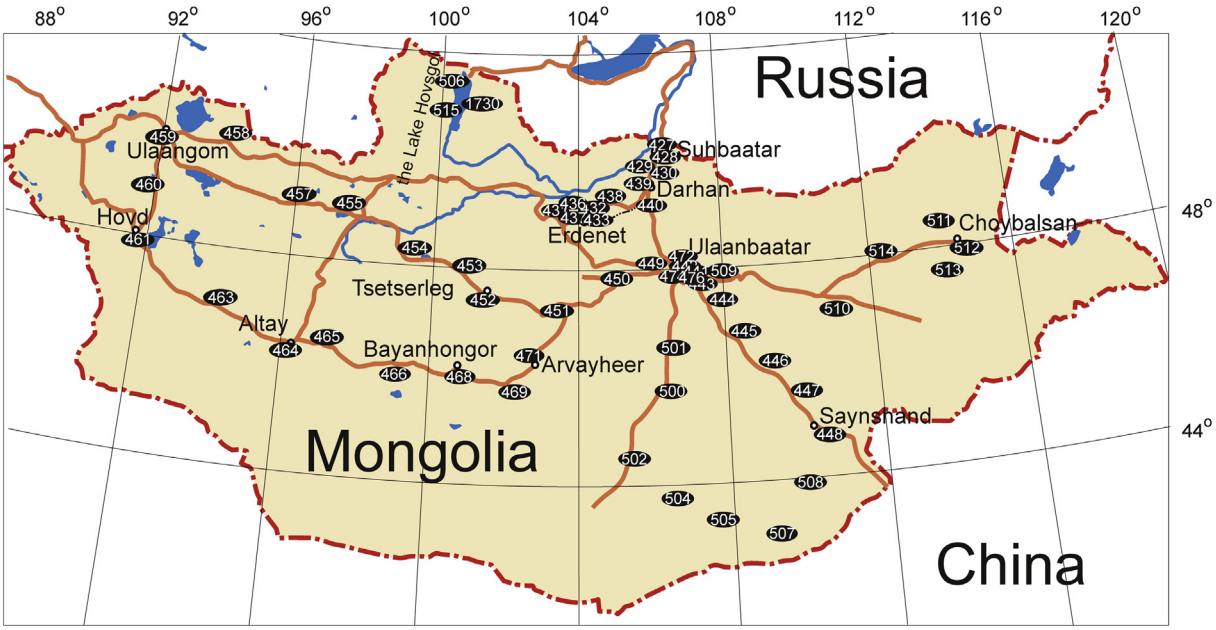

Fig. 1. The location of the soil sampling sites in Mongolia in 2010–2011.