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Distributions and impact factors of antimony in topsoils and moss in Ny-Ålesund, Arctic

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ABSTRACT

The distribution of antimony (Sb) in topsoil and moss (*Dicranum angustum*) in disturbed and undisturbed areas, as well as coal and gangue, in Ny-Ålesund, Arctic was examined. Results show that the weathering of coal bed could not contribute to the increase of Sb concentrations in topsoil and moss in the study area. The distribution of Sb is partially associated with traffic and historical mining activities. The occurrence of the maximum Sb concentration is due to the contribution of human activities. In addition, the decrease of Sb content in topsoil near the coastline may be caused by the washing of seawater. Compared with topsoils, moss could be a useful tool for monitoring Sb in both highly and lightly polluted areas.

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1. Introduction

Antimony (Sb), a trace element, is ubiquitous in the environment because of natural processes and human activities (Filella et al., 2009). It has been found in both organic and inorganic species in soil and water systems, and the two dominant oxidation states in environmental materials are +3 and +5. Sb has been increasingly recognized as a toxic environmental pollutant and also implicated in cancer development (Gurnani et al., 1994; Gebel, 1997). Moreover, Sb and its compounds are considered as pollutants of high priority by the US Environmental Protection Agency (USEPA, 1979) and the European Union (Council of the European Communities, 1976). Recently, Sb has attracted increasing attention as being transported through the atmosphere (Filella et al., 2009). Many research efforts have been aimed at studying the distribution, speciation, biogeochemistry and ecotoxicity of Sb since 1990s (Reimann et al., 2010).

According to Nriagu (1989), 41% of Sb emission to the air can be attributed to natural sources (e.g., soil particles, volcanoes, sea-salt spray, forest fire, and biogenic sources); the remaining 59% is considered to be related to anthropogenic sources (e.g., mines, smelters, fertilizers, traffic). Mining and smelting are thought to be the greatest emission sources (Adriano, 1986); thus, research of the concentration and distribution of Sb in coals is urgently needed. The mean concentration of Sb in coals (3 mg/kg worldwide (Swaine, 1990; Valković, 1983)) seems to be much higher than that in the earth crust (0.3 mg/kg) (Wedepohl, 1995). However, Sb value in coals is quite variable, with the minimum concentration of about 0.007 mg/kg (Ren et al., 2006) and the maximum of about 17 000 mg/kg (Qi et al., 2008).

The distribution of Sb in topsoils and vegetations is easily affected by human activities. Various researches have been done, especially in characterizing distributional patterns in heavily polluted areas so as to investigate Sb transfer mechanism among different materials (Okkenhaug et al., 2011; He, 2007). Sternbeck et al. (2002) have shown that Sb was mainly released from the wearing of the brake lining around traffic road, and the deposition of road dust and aerosol enriched in Sb would respond to the increase of Sb concentration in topsoils (Bukowiecki et al., 2009). The different forms of Sb in different materials from known contamination sources and their surroundings have been extensively studied. However, why the activity of coal mining can lead to an increase in Sb concentration is still poorly understood. Moreover, the distribution of Sb and impact factors that would possibly influence its concentration in topsoils and vegetations remains to be understood.

The Svalbard Archipelago in Arctic has a large reserve of coal and phosphorite (Yuan et al., 2006), where coal mining started in as early as 1899 AD (Sun et al., 2006). Ny-Ålesund, which is located in the northwest of Svalbard, once had a coal mine which was closed

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in 1960s because of a tragic accident (Hisdal, 1998). Separated from the European continent by the Brents Sea and with reduced human activities, Ny-Ålesund is considered to be an ideal location for scientific exploration, and many countries have set research stations there. Studies on the heavy metal pollution in lake sediments and peat bogs from Ny-Ålesund have been reported (Jiang et al., 2010, 2011). However, previous work has paid limited attention to the distribution of pollutants (for example, Sb), especially in the surface environment (including the topsoils and vegetations). As a result, Sb concentration in local coals has been rarely studied.

In this paper, we investigate Sb contents in topsoils, *Dicranum anaqustum* (a typical tundra moss), coals and gangues collected from coal mine tailings in Ny-Ålesund. We discuss the biogeochemical process of Sb in different environmental materials, and explain the relationship between Sb distribution and anthropogenic activities.

2. Background of study area

The Svalbard Archipelago (74°∼81°N, 10°∼35°E), located between Barents Sea and Kara Sea, is one of the most northern places where humans live. It consists of the Spitsbergrn Island, the Nordauslandet, the Edgeoya, and dozens of small islands. With a total area of 62 700 km^2, about 60% of the Archipelago is covered by glaciers. Ever-frozen earth layer is up to 500 m thick; even in the summer time, only the 2–3 m surface layer is melt.

Ny-Ålesund is located at 78°55′N, 11°56′E, in the northwestern part of Svalbard Archipelago. Due to Atlantic warm waters, mean annual temperature of Ny-Ålesund is around 4 °C. Compared with areas with similar latitude in both hemispheres, Ny-Ålesund is populated with more plants, including 168 species of vascular plants, at least 373 species of bryophyte, 606 lichen species, 705 fungi, and over 1100 terrestrial, freshwater, and marine algae and *Cyanobacteria* (Rønning, 1996). In Ny-Ålesund, there is a sparse and low-growing cover of *Salix polaris*, *Cerastium arcticum*, *Saxifraga cemua*, *S. cespitosa*, *S. oppositifolia*, *S. hirculus*, *Luzula arcuata*, *L. arctica*, and *Poa arctica*, as typical in the northern arctic (Bieks, 2001). The predominant flow here is from the east-southeast (Beine et al., 2011).

After the coal mine was closed in 1960s, several countries have set up research stations in Ny-Ålesund (Fig. 1). To date, there are nearly 160 workers and researchers in Ny-Ålesund during summer time. The common transportation tools are motor vehicles and bicycles.

3. Materials and methods

3.1. Sample collection

As shown in Fig. 1, samples collected in Ny-Ålesund were divided into four series, A series (with 27 sampling sites) around the coal mine, B series (with 25 sampling sites) around the airport, C series (with 7 sampling sites) to the west of the human settlements, and D series (with 22 sampling sites) far away from the settlements. Moss and topsoil samples were collected in pairs within 0.5 m from each other. A series was designed to describe the possible influence made by the past coal mine activities and the traffic roads. B, C and D series were added to discuss other potential factors, such as the altitudes and the ocean waves.

Four coal samples and four coal gangue samples were collected from the coal tailings. Moreover, one moss sample collected in A series (Fig. 1) was divided into 2 parts. The top 1.5 cm green part was named A–G, and the yellow part was named A–Y. It is believed that the A–Y was much older than A–G.

3.2. Methods

Moss samples, cleaned by deionized water, were dried and powdered into small pieces. HNO_3–H_2SO_4–HF is used to pretreat and dissolve grinded samples by using micro-wave oven (CEM MARS-5). Topsoil (<2 mm in size) samples, after dried and grinded, were pretreated in the same way as for moss samples. Coal and gangue samples were pretreated with H_2SO_4 and HNO_3, and heated with electric board. All the reagents used are of extra pure grade. The concentration of Sb was determined with Ordinal Interaction Two-pass Atomic Fluorescence Spectrophotometer (AFS-930, Beijing Jitian Instrument Co., China). To validate the procedure, national standards GBW07403, GBW07404, GBW07603, GBW07605, and GBW07106 were used as quality control with a duplicate error of 5%. The experiment was performed in the Institute of Polar Environment at the University of Science and Technology of China.

4. Results and discussion

4.1. Sb concentrations in coals and gangues

Sb concentrations of coal and gangue samples from Ny-Ålesund and several coal producing countries of the world are presented in

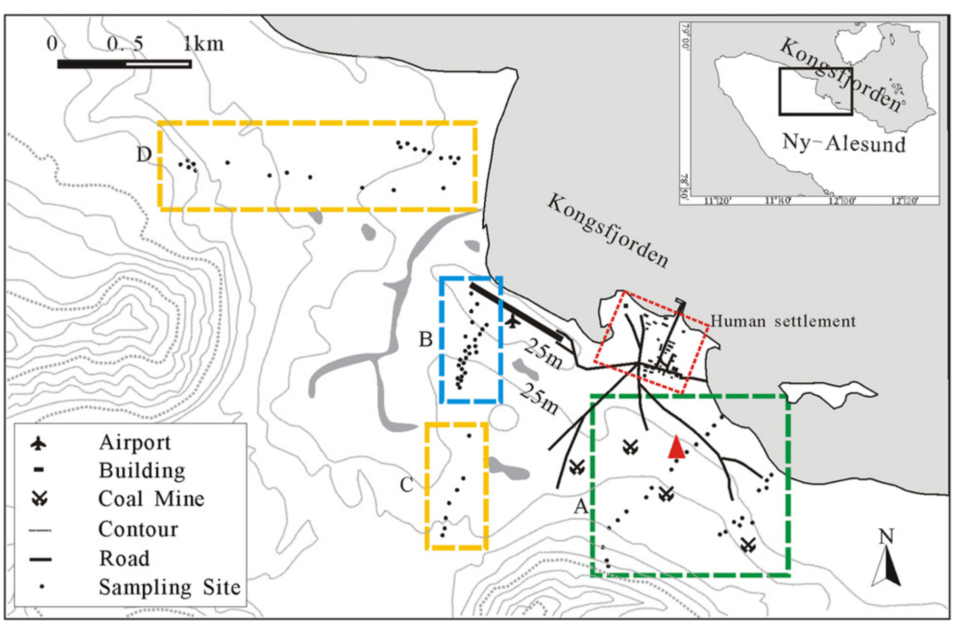

Fig. 1. Location of sampling sites. In total 81 topsoil samples and 75 moss samples were collected. According to the characteristics of the sampling site, all samples were divided into 4 series, A series, B series, C series and D series. The triangle indicates the sampling site of A–Y and A–G.

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