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Assessment of the level of mercury contamination from some anthropogenic sources in Ulaanbaatar, Mongolia

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ABSTRACT

Ulaanbaatar (UB), the capital city of Mongolia in the central Asia, is a coal-based city which has 3 coal-fired thermal power plants and about 100,000 dwellings using lumps of lignite for their heating and cooking. So it is possible to be contaminated with mercury (Hg) caused by emission from coal combustion. The purpose of this study is to assess the level of Hg contamination in UB. Soil and dust samples collected from 33 sites within and around the city were analyzed for Hg by following US EPA Method 7473. The concentration level of Hg in soil and dust was in the range of 19.7–672.6 ng/g Hg, and 19.1–161.4 ng/g Hg, respectively. Especially in the urban district of the central part of the city, the median values of Hg in soil and dust are 69.1 ng/g, and 98.7 ng/g, respectively. On the other hand, the levels of Hg in control area were in the range of 16.9–24.3 ng/g in soil, and 28.2–28.9 ng/g in dust. The result of Hg contamination assessment is classified as "moderately polluted" according to the indices of 'geoaccumulation index (I_{geo})' and 'enrichment factor (EF).' The coal combustion of power plants and dwellings is the potential source of Hg contaminations in soil and dust in UB, although the level of Hg in this city is a little lower than the other cities with analogous circumstances. This comes from not only the lower concentration of Hg in used coal (34.0 ng/g and 55.1 ng/g Hg), but also obvious spatial and temporal trends in coal usage in UB. And it is certain that the level of Hg in soil and dust should be increasing year by year owing to upward trend of coal consumption of the city. It is necessary to manage the risk caused by Hg contamination of various environmental compartments, and to control the anthropogenic sources of Hg emission.

1. Introduction

Human activity is one of the main reasons to emit mercury (Hg) to the air. Mercury is used in batteries, fluorescent lamps, thermometers, dental amalgam, medium and gold flux, and even in chloride–alkali industry, the leather industry and pesticide industry (Rivera et al., 2003; Zahir et al., 2005). Refining of metals, burning coals, chemical medicine synthesis and waste disposal is also regarded as main anthropogenic sources to emit an amount of Hg (ATSDR, 2007; Clarkson et al., 2003a, 2003b). According to several research, the level of Hg emission from industry period has increased rapidly as much as 3–24 times than before (Bindler, 2003; Hermanson, 1998; Heyvaert et al., 2000; Wang et al., 2004). AMAP/UNEP(2008) assumed that the level of Hg in air from anthropogenic sources was about 1480 tons in 2005. Power generation facilities, industrial and residential heating facilities where coal combustion occurs, account for the largest part of various anthropogenic factors of Hg emission. Among the total amounts of Hg emission (1480 tons in 2005), about 59% (880 tons Hg) were discharged from the stationary combustion (AMAP/UNEP, 2008).

The world average of Hg value in coal is 100 ± 10 ng/g Hg. Although the concentration of Hg in coal is considerably lower than other trace elements, it has been studied most frequently due to Hg toxicity and accumulation through the food chain (Yudovich and Ketris, 2005). EPA (Environmental Protection Agency) gave a report that coal-fired power plants were the largest anthropogenic source of Hg among the remarkable pollutants (USEPA, 1998). Mercury could be emitted into the air from the various kinds of anthropogenic activities including coal and/or fossil fuel combustion, and sometimes could be precipitated in ground soil and dust or surface water. Thus the amount and kind of chemical forms of Hg in urban environmental media such as dust and soil could be the important indices of environment contamination.

The target area of this study is Ulaanbaatar (UB), the capital city of Mongolia in Central Asia. The dwellers in the city are using lumps of lignite as a main energy source for their heating and cooking. And three coal-fired thermal power plants, some HOB (heat-only-boiler)s, and brickyards using coal located in the city could cause serious air pollution

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including Hg emission. The purpose of this study is to assess the level of Hg contamination in soil and dust collected within and around the city.

2. Material and methods

2.1. Background of study area

The annual average temperature of UB is presently typically around 0 °C, the world's coldest capital city. Monthly average temperatures are typically −20 °C for winter season (January and February), and night time temperatures can go as low as −40 °C. Annual precipitation falling mostly during the short summer period is scarce (about 200 mm), and winter season is extremely dry (Worldbank, 2009). The population of UB in the year of 2009 was about 1.11 million inhabitants. About half of the inhabitants live in apartments and the other half in traditional tents (gers) and small individual houses. About 80% of inhabitants living in apartments are using central heating and hot water from three thermal power plants which are located in the city center, and the rest of the inhabitants of apartments are using their heating boilers and individual stoves. On the other hand the rest of the population living in gers and individual houses are using their individual stoves. They usually install a stove inside in two different ways. The first one is the method of transferring radiant heat to the room or converting the air in the room through the wall after inserting the stovepipe into the wall. The other one is the way to provide or convert heating air to the room by setting the stove pipe line outside of houses after pulling out of the wall (Fig. 1).

The residents of UB mainly use coal as an energy source for heating, hot water and cooking. The coal supplied in UB is usually produced in the Baganuur coal mine 120 km apart to the east of UB, and the Nalaikh coal mine in the outskirts of UB. The Baganuur coal is supplied to the power plant and the Nalaikh coal is consumed for the civilian demands of heating.

Annual average PM_{10} (particulate matter under 10 μm) concentration in UB air was 141 μg/m^{3}n in the year 2006, 151 μg/m^3 in 2007, and 279 μg/m^3 in 2008. On the other hand during winter season daily average PM_{10} is increased to extremely high levels up to 700–800 μg/m^3 (2500 μg/m^3 per hour). The particulate matter has characteristics to absorb moisture due to the presence of atmospheric sulfur. The sulfur dioxide (SO_2) emitted from coal burning is adsorbed to the particles and converted to sulfate causing high relative humidity (RH) during evening/night/morning hours. At the RH above 67%, the hygroscopic particles grow much larger due to the water absorption, and this reduces the visibility considerably, sometimes forming dense fogs (Worldbank, 2009). Based on the study of Lindqvist and Rodhe (1985) that Hg deposition to the ground could be catalyzed due to the high humidity, it is possibly assumed that Hg level in soil and dust could be high during the winter season of UB.

In previous studies, SO_2 concentrations have possibly been regarded as a marker of coal combustion in UB (Allen et al., 2011; Davy et al., 2011; Worldbank, 2009) and SO_2 has a clear seasonal variation. The dominating source of ground level SO_2 concentrations is the coal burning in the gers and HOBs. Occasionally peaks can be expected also from the power plant stacks (Worldbank, 2009). In comparing Hg with SO_2 concentrations in the vicinity to each other, though there are only 4 stations to observe and obtain the data for SO_2 level in UB, the correlation between Hg and SO_2 can be mentioned. And to do so, it can be more clearly revealed whether the coal combustion is the source of Hg concentration in UB.

2.2. Sampling and analysis

Dust and soil samples were collected from 29 spots within and around UB. Those spots covered nearby coal-fired power plants, ger district and roadsides in UB. In addition, the control samples were taken at the suburbs of UB. The detailed sampling spots are presented in Fig. 2. The dust and soil sampling was conducted during April of 2012, avoiding the rain or snow in the middle of April. The lump coal samples from the Baganuur and the Nalaikh coal mines were analyzed to determine the level of Hg in coals.

The dust samples were taken by using polyethylene brush and tray, and the soil samples was collected by hands with a latex glove and put

Fig. 1. Various types of stove heaters in gers and individual houses in Mongolia.