Dynamics of gaseous elemental mercury during polar spring and winter

Abstract
Among pollutants, mercury is a major environmental concern due to its ecological hazard. The mercury can reside in the atmosphere for a long time, and it is a reason of its global propagation in the Northern Hemisphere and elevated mercury concentrations are reported in the Arctic environment. First time, in 1995, the effect of atmospheric mercury depletion in the troposphere was found at the Canadian station Alert. This phenomenon (called the Atmospheric Mercury Depletion Event – AMDE) is observed during April–June, when the solar radiation decreases till the end of the snowmelt. The same effect was reported for other polar stations situated northly than 60° N. Since 2001, the analyzer was placed at Andermans station 69.46° N, 64.31° E, Yugor Peninsula, Nenets Autonomous Region, Russia (distances (from 8.9 to 0.2 km) from the coast of the Kara Sea (see Figure 1). It is necessary to note that such experiment was carried out for the first time during the monitoring in surface layer atmosphere the Russian coastal station (Pankratov et al., 2013).

Long-term continuous monitoring of gaseous elemental mercury in the surface air at the polar station Andermans using the analyzer Tekron 257A has been conducted from June 2001 to date. Individual measurements were collected every 30 minutes. It has been shown, that after 11 years of observations AMDEs were observed every year, from the end of March till early June. For the winter season (Dec-Feb) these events of the atmospheric mercury depletion were registered from 2010 to 2013, which had not been observed before (Fig. 2). A large number of hours during the day, when the concentration of mercury was recorded at level of below 1 ng/m, during Dec-Feb. However, the sun declination above the horizon is negative for these seasons, and solar activity is still not enough to tell the photochemical reactions, but nevertheless AMDEs are registered in winter seasons (Fig. 2, E-F) (Pankratov et al., 2013).

Fig. 1. Network of atmospheric mercury monitoring station in the Northern Hemisphere with corresponding to time series of measurements (AMAP, 2011). Geographical locations of the Tekran analyzer for observation period from 2001 to 2013 at the polar station “Andermans”.

Atmospheric mercury measurements

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Fig. 2. Long-term series of atmospheric mercury measurement at the Andermans station from 2001-2013, a linear approximation the annual trend in mercury concentration (green dashed line).

For the winter (December-January) period, the maximum number (in total, 495) of lowered values of mercury concentration and AMDEs (32 events) were recorded in 2010–2011. Such situation was previously observed only in winter of 2006–2007 (13 events). As there is no direct sunlight in mentioned period, the removal of mercury from the atmosphere may be caused by combination of physical and chemical processes that are not related to photochemistry. Starting mid-January, although the sun declination increases and the incoming solar energy is sufficient to activate photochemistry, the number of AMDEs (about 30% of measurements), while Lumex RA-915A registered as AMDEs only 5% of measurements (R2 = 0.95) at mid-latitudes. During the winter and spring 2015-2016 Tekran 2527A registered the expected correlation between parallel measurements of Tekran 2527A and Lumex RA-915AM of low GEM concentrations (Fig. 5).

Fig. 3. Number of decreased values of mercury concentration in the atmosphere during the day (bar chart). The purple line is duration of the day (hours), the red line is declination of the sun above the horizon (°) for the period December-January 2010-2011 (a) and March-May 2011 (b) (Pankratov et al., 2013).

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Fig. 4. Dynamic of daily mercury concentration (ng/m) at the spring 2010 (a) and 2011 (b). Solid line is a polynomial trend line. Dashed red line and dash dotted purple line are polynomial trend lines of solar activity in March and May, respectively.

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Fig. 5. Daily dynamics of AMDEs number using GEM analyzers Tekran 2537A and Lumex RA-915AM during winter period time from September 2015 to July 2016.

Conclusions
1. The results raise the issue of the problem of registration of AMDEs in the Arctic.
2. For the first time, as a result of parallel measurements of GEM by the Tekran 2527A and Lumex RA-915AM analyzers, the differences in the number of registered cases of AMDEs was revealed.
3. Lumex RA-915AM uses a direct GEM registration system in the ambient air, while Tekran 257A uses an additional sorption concentrating phase.
4. The observed effect requires confirmation and further parallel measurements of GEM in other polar regions using mercury analyzers of various recording systems.

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