GMOS Project: Long-term Air Mercury Monitoring at Listvyanka Station, Siberia

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Introduction

The **GMOS** (Global Mercury Observation System) project has the overall goal to develop a coordinated observing system to monitor mercury on a global scale to assess its emissions to atmosphere, transport, atmospheric chemistry, and deposition processes. The Listvyanka station is one of more than 40 ground-based stations involved in the GMOS monitoring network http://www.gmos.eu/ [1]. The station is located at a shore of Lake Baikal, Siberia, far away from the existing mercury monitoring sites in Asia (**Fig. 1**). The long-term air mercury monitoring started in October 2011.

a) b) c)

Fig. 1. GMOS ground-based monitoring sites (a); Listvyanka monitoring station at the Lake Baikal shore in summer (b) and winter (c).

1. Experimental

Measurements were made using Lumex **RA-915 AM** air mercury monitor (**Fig. 2a**) [2], which provides continuous background **GEM** (gaseous elemental mercury) monitoring in compliance with EN 15852 standard [3]. Principle of operation of the **RA-915 AM** mercury monitor as well of multifunctional **RA-915M** analyzer (**Fig. 2c**) is based on differential atomic absorption spectroscopy with Zeeman background correction [4].

a) b) c)

Fig. 2. RA-915 AM air mercury monitor (a) and an example of aerosol filter direct analysis (b) with RA-915M multifunctional analyzer (c).

2. Seasonal Variations

The long-term mercury monitoring at the Listvyanka site started on 24th October 2011. The data observed during 2011-2017 show obvious seasonal variation of the background mercury concentration in air, increasing in the winter season with a monthly average maxima of 1.4 - 1.8 ng/m³ in January-February, and decreasing in summer with the monthly minima of 1.1 – 1.2 ng/m³ in August-September (**Fig. 3**). The overall average mercury concentration at the Listvyanka site from October 2011 to October 2017 is 1.36 ng/m³.

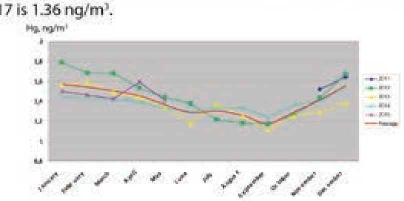


Fig. 3. Listvyanka: Seasonal Variation of the Mercury Concentration (GEM) in 2011 – 2017, monthly average. Cav. = 1.39 ng/m³. Warm seasons: Cav. = 1.22 ng/m³; Cold seasons: Cav. = 1.48 ng/m3. Cold – Warm: 1.48 - 1.22 = 0.26 ng/m³.

The same seasonal variation shows particulate bound mercury (**PBM**), which is being measured since January 2016, **Fig. 4**:

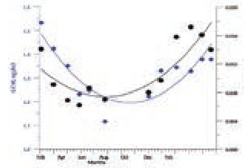


Fig. 4. Listvyanka: Seasonal Variation of the GEM and PBM 20.01.2016-20.03.2017, monthly average.

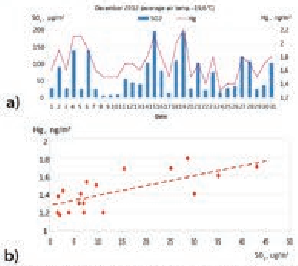
During this period, the GEM averaged at 1.31 ng/m³, whereas the PBM concentration was 0.011 ng/m³ on the average, comprising about 0.8% of the total (GEM) mercury concentration.

The long-term monitoring shows trend to decreasing of average annual Hg concentration throughout 6-years of observation (**Fig. 5**), which is an evidence of the mercury emissions decreasing in the Northern hemisphere.

Fig. 5. Listvyanka: Long-term trend of the air mercury concentration in 2011 – 2017. Annual average.

3. Short-Term Variations

Coal-fired power plants of Irkutsk and Angarsk cities are main sources of the short-term Hg concentration rises. A positive correlation between mercury and SO_2 concentrations is observed both in the short-term variations and monthly average concentrations (**Fig. 6**).



a) b)

Fig. 6. Correlation between Hg and SO_2, daily (a) and monthly (b) average.

The short-term variations clearly show the possibility of a long-distance, up to hundred(s) kilometers, mercury transfer from coal-fired power plants with the so-called low-level atmospheric jets [6]. The evidence of the mercury and acid gases transfer from the coal-fired power plants by the low- level atmospheric jets is also confirmed by the positive correlation of the mercury concentration with NOx and the negative correlation with ozone. In contrast to industrial emission, during forest fires a positive correlation between mercury and ozone is observed.

4. Diurnal Variations

Data processing reveals a moderate, statistically significant, diurnal cycle of the mercury concentration both in the warm and cold seasons. Minimum concentration is observed at 1 – 6 a.m. local time, and then the concentration increases by 0.05 ng/m³ during daytime (**Fig. 7**).

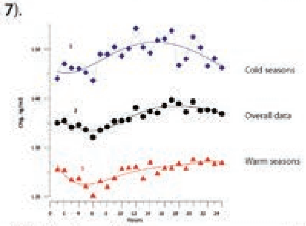


Fig. 7. Diurnal behavior of the mercury concentration (local time, UTS +8).

The statistics are following:

1- Cold seasons (01.12.2013-28.02.2014 + 01.12.2014-28.02.2015). Each point is the average over 170 hours (2040 individual 5-min readings).

2- Overall data (01.04.2013-01.04.2015). Each point is the average over 650 hours (7800 individual 5-min readings).

3- Warm seasons (01.07-30.09.2013 + 01.07.-30.09.2014). Each point is the average over 150 hours (1800 individual 5-min readings).

Mercury concentration and its variability are higher at the daytime. Most probably, the increase in the concentration is caused by the elevation of the surface temperature and intensity of the anthropogenic emission.

Conclusion

- The GMOS monitoring station Listvyanka, Irkutsk region, Siberia, has been put into operation since October 2011.
- The average total (GEM) concentration throughout 2011-2017 of observation is 1.36 ng/m³. Particulate bound mercury (PBM) comprises about 0.8 % of GEM.
- Annual average air mercury concentration tends to decreasing throughout the six years of monitoring.
- The daily average concentration of GEM varies within a range of 1.2 to 1.7 ng/m³ and that of PBM in a range of 7.8 – 15 pg/m³ in the warm and cold seasons, respectively, which is an evidence of the elevated mercury emissions from coal combustion during the cold season.
- Statistical data processing shows the moderate diurnal cycling of the mercury concentration at a lower level at night and higher level at daytime.
- The space-time distribution and short-term variations of the mercury concentration indicate the long-distance mercury transfer from the sites where the coal-fired power plants are located.
- The coal combustion plants are the main sources of the elevated mercury concentration at Listvyanka site, which is confirmed by the evident correlation between the average Hg and SO_2, NOx, and O_3 concentrations.

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