

# The behavior dynamics of elementary mercury in the atmospheric surface layer in the Russian Arctic during eruption of the Eyjafjallajökull volcano in Iceland.

Fidel Pankratov<sup>1,\*</sup>, Alexander Mahura<sup>2</sup>, Oleg Katz<sup>3</sup>, Alexei Konoplev<sup>1</sup> Research and Production Association "Typhoon" of Roshydromet, Obninsk, Russia. <sup>2</sup>Danish Meteorological Institute, DMI Research Department, Lyngbyvej 100, Copenhagen DK-2100, Denmark. <sup>3</sup>B-Service Ltd, Chief Information Officer (CIO).

\* Corresponding author: Fidel Pankratov, E-mail: pankratov@typhoon.obninsk.ru



#### Abstract

Among pollutants mercury is a major environmental concern due to its ecological hazard. Since 2001, when the mercury analyzer has been installed in Amderma (Russia), the continuous measurements of gaseous elemental mercury in the surface layer of the atmosphere are conducted. The mercury can reside in the atmosphere for a long time high, and it is a reason of its global propagation in the Northern Hemisphere and elevated mercury concentrations are reported in the Arctic environment. For the first time the effect of mercury depletion in the troposphere was found at the Canadian station "Alert" in 1995. This phenomenon is observed during April-June when the Polar sunrise starts till the end of the snowmelt. The same effect was reported for other Polar stations situated to the north of 60° N. It is interesting that the decrease of the mercury concentration coincides with the decrease of the boundary layer ozone by time and pattern in polar and sub-polar regions. Increase of the mercury oxide species in atmospheric air and the total mercury in snow pack is observed during the gaseous mercury depletion event. These mercury species enter water systems during snowmelt and are carried away to the Kara Sea and the Arctic Ocean.

### Mercury Measurements



Fig 1. Network of atmospheric mercury monitoring stations in the Northern Hemisphere.

Since 2001 continuous measurements of elementary atmospheric mercury (using analyzer Tekran 2537A) were carried out at the polar station Amderma (69°45′N and 61°40′E, coast of the Kara Sea, Ugra Peninsula) of the Russian Arctic [1,2]. This station is one of the three international stations, which are conducting long-term continuous monitoring (Alert in Canada, from 1995 to present; and Nu-Alesund in Norway, from 2000 to present) of gaseous elementary mercury (Fig 1.). It was found, that long-term series of atmospheric mercury concentrations at the Amderma station (Fig 2.) has well identified similarities with those obtained from the Alert station (82°30'N and 62°20'W) in Canada. This can lead to similarities in explanation of atmospheric mercury transformation, occurring throughout the Arctic regios

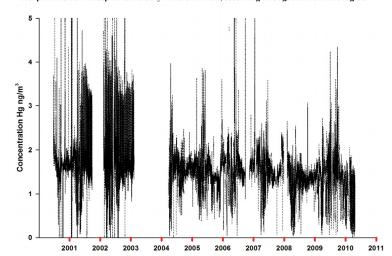


Fig 2. Long-term series of atmospheric mercury measurement at the Amderma station

# Episodes with Elevated Concentrations

During period of measurements, multiple the episodes with short-term elevated concentrations (up to 24 ng/m³) (Fig 3a,b) of atmospheric mercury were recorded. Such an increase in concentration has connection with potential local and remote sources; and hence, depends on patterns of local, regional, and hemispheric atmospheric transport. Remote sources of mercury can be associated with metallurgical industries situated in near Norilsk (Fig 3a) (atmospheric transport from the eastern sector), and on the Kola Peninsula (Fig 3b) (atmospheric transport from the western sector) of Russia (Fig 4b). Moreover, elevated concentrations of mercury might be explained by atmospheric transport from such sources as burning of associated gas during oil production. (i.e. Yamal Peninsula to the east (Fig 4a) and new oil field Varanded to the west, but is based on analysis of backward trajectories (calculated using HYSPLIT (Hybrid Single Particle Lagrangian Integrated Trajectory Model; <a href="http://www.arl.noaa.gov/HYSPLIT\_info.php">http://www.arl.noaa.gov/HYSPLIT\_info.php</a>) running at the on-line server of the NOAAAir Research Laboratory.

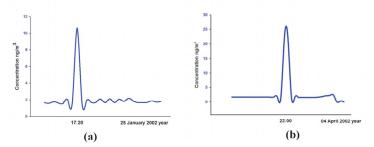


Fig 3. Shot-term elevated concentration: (a) 25 January 2002, (b) 4 April 2002.

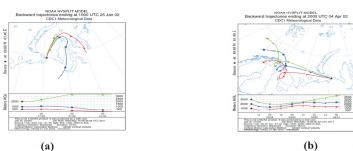


Fig 4. Backward trajectories arrived at Amderma: (a) 25 January 2002, (b) 4 April 2002.

### Atmospheric Mercury Depletion Events

Events of the atmospheric mercury depletion were registered in winter (December-January, from 2010 to 2011) which had not been observed before. A large number of hours during the day, when the concentration of mercury was recorded at 1 ng / m $^3$  and below were registered during December-February as shown in Fig. 5a. There is no sunlight at time, and the sun declination above the horizon is negative (see red line at the axis of time). From March to May the angle of the sun declination is increased above the horizon; so, the incoming radiation is sufficient for the occurrence of photochemical reactions (Fig. 5b). However, note, that correlation between the amount of solar energy and the number of AMDEs is not linear. Fig. 6b shows that the maximum of AMDEs is registered in April, but Fig. 6a shows also for January; although the solar activity is still not enough to trigger the photochemical reactions. That is why it can be suggested that:

1. Derivation of elemental mercury from the atmosphere may be caused by deposition of marine aerosol particles on the concentration of which increases in a case of exemption from the ice of the coastal zone (Kara Sea) and, simultaneously, at the time when the southern wind direction is prevailing.

 $2. \ The \ element al \ mercury \ deposits \ on \ particles \ of the \ anthropogenic \ aerosols \ transported \ from \ the \ middle \ and \ low \ latitudes.$ 

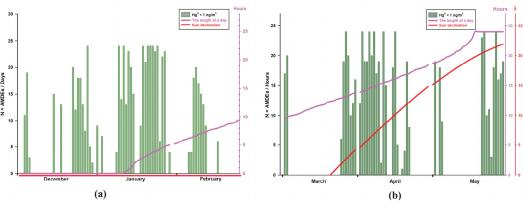


Fig 5. Dependence of the AMDEs, duration the length of a day, the declination of the sun above the horizon on time

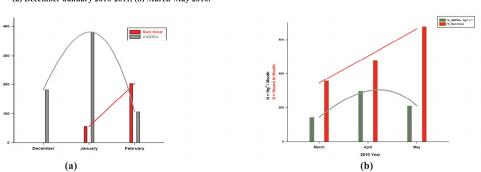


Fig 6. Number of AMDEs and of hours of solar activity from March to May 2010. (a) December-January 2010-201, (b) March-May 2010.

## Icelandic Volcanic Emissions vs. Amderma Mercury Measurements

During episode (4 Mar - 24 Apr, 2010) long-time and high concentrations of atmospheric mercury were registered at Amderma(Fig 7a). During spring time, both lowered (AMDEs events) and elevated concentration events could occur, where the latter can be associated with atmospheric transport patterns from remote sources of mercury. The mercury concentration varied from 1.8 to 2.9 ng/m<sup>3</sup>. The days with measured higher concentrations at Amderma station can be linked with, limited time of the active phase of the Eyjafjallajökull volcano (Iceland) eruption and direction of atmospheric transport. For that, to determine potential source of elevated mercury concentration a set of HYSPLIT atmospheric backward trajectories was calculated and analyses (Fig 7b). Preliminary evaluation of the time-series of gaseous elementary mercury concentration and associated atmospheric transport patterns showed that the Eyjafjallajökull volcano can be a potential source for increased mercury concentrations at measurement stations in the Arctic regions, and especially followed an active phase of cruption.

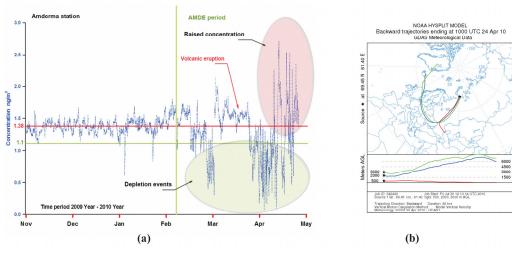


Fig 7. High concentration of atmospheric mercury were registered at Amderma.
(a) Long-term series November - May 2009-2010, (b) Backward trajectories arrived at Amderma 24 April 2010.

#### References

- 1. Ф.Ф. Панкратов, А.В. Коноплев. Исследование эффекта уменьшения концентрации атмосферной ртути в атмосфере Российской Арктики. Сборник трудов Международной конференции по измерениям, моделированию и информационным системам для изучения окружающей среды. ENVIROMIS – 2008, 28 июня – 6 июля 2008 г., Томск.
- ENVIROMIS 2008, 28 июня 6 июля 2008 г., Томск.
  2. Ф.Ф. Панкратов, А.В. Конопалев. Вланяше температуры на уменьшение концентрации атмосферной ртути весной в атмосфере Российской Арктики.: Сборник трудов международной конференции рамках III Международного Поларного Гола (МПГ), 11-14 июабра 2008 г., Санкт-Петербург.
  3. Ф.Ф. Панкратов, А.В. Конопалев. Долговременный мониторинг атмосферной ртути в атмосферном воздух Российской Арктики; Материалы международного симполума Ртуть в биосфере: Эколого-теохимические аспекты, стр. 114 119. Россия, Москва, ТЕОХИ РАН, 7 9 сентябра 2010 года.
  4. Втоокs, S. В., Saiz-Lopez, А., Skov, Н., Lindberg, S. E., Plane, J. M. C., and Goodsite, М. Е. G.: The mass balance of mercury in the springtime arctic environment, Geophys. Res. Lett., 33, L13812, doi:10.1109/29005GL025525, 2006.
  5. Cobbett, F. D., Steffen, A., Lawson, G., and Van Heyst, B. J.: GEM Fluxes and Atmospheric Mercury Concentrations (GEM, RGM and Hgp)in the Canadian Arctic at Alert, Nunavut, Canada (February June 2006), Atmos. Environ., 41(11), 2270-2282, 2007.
  6. Skov, H., Goodsite, M. E., Lindberg, S. E., Meyers, T. P., Landis, M., Larsen, M. R. B., and McConville, G.: The fluxes of Reactive Gaseous mercury measured with a newly developed method using relaxed eddy accumulation, Atmos. Environ., 40, 5452–5463, 2006.
  7. Steffen, A., Schroeder, W. H., Macdonald, R., Poissant, L., and Konopley, A.: Mercury in the arctic atmosphere: an analysis of eight years of measurements of GEM at Alert (Canada) and a comparison with observations at Amderma (Russia) and Kuuijuarapik (Canada), Sci. Total Environ., 342, 185–198, 2005.