Cooperation with Subsidiary Bodies of the Convention - Working Group on Effects

Heavy metals are toxic pollutants known for their adverse effects on human health and biota. Laboratory and experimental research established a link between heavy metal concentrations in the environment (soils, water) and their concentrations in tissues of living organisms. At certain concentrations in the environment (critical limits) the corresponding concentration in human body or tissues of other organisms may lead to harmful effects [*de Vries et al*., 2015]. Ecotoxicological effects of heavy metals include injuries of plant leaves, hampered growth of vegetation and changes of physiologic and microbiological conversion processes [*Hettelingh et al*., 2015]. Accumulation of cadmium in human body negatively affects kidney and bones, while lead and mercury are well-known neurotoxins [*WHO*, 2007]. Deposition fluxes, at which critical limit concentrations in the media are reached, are referred to as critical loads.

The critical loads approach is widely used for assessment of adverse effects of various pollutants on terrestrial and aquatic ecosystems in Europe [*De Vries et et al*., 1994; *Kuylenstierna et al.*, 1998; *Reinds et al*., 2008; *Holmberg et al*., 2013; *De Vries et al*., 2015] and other regions [*Hettelingh et al*., 1995; *Kuylenstierna et al*., 2001; *Bouwman et al*., 2002]. Recently, it was successfully applied for risk assessment of heavy metal (cadmium, lead and mercury) pollution on a regional scale within the EMEP region [*Hettelingh et al*., 2015]. The assessment was based on a collaborative work of the Coordination Centre for Effects (CCE) and MSC-E. This year MSC-E has continued the co-operation with CCE on evaluation of critical loads exceedances for heavy metals on regional and hemispheric scales.

EMEP region

In spite of large (around 80%) decline of lead deposition over the recent two decades, the fraction of ecosystem area where lead levels exceeded critical loads is still significant (about 20%) [*de Wit et al*., 2016; *Slootweg et al*. 2007]. At the same time measurements of heavy metal concentrations at ICP-IM sites demonstrates that lead content in forest soils tends to increase for the period from 1990 to 2013 [*Bringmark et al*., 2013].

Ecosystem-specific deposition of lead, cadmium and mercury is calculated annually for the EMEP region and individual EMEP countries to support work of the effect community. All variety of information is available at the MSC-E website (www.msceast.org). An example of simulated lead deposition to arable lands and forests in 2015 is shown in Fig. 1. As seen the highest lead deposition to both types of land cover is predicted in Central Europe (southern Poland), Southern Europe (northern Italy and the Balkans), and the Caucasus, where deposition fluxes exceed 1 kg/km^2/y for arable lands, and 2.5 kg/km^2/y for forests. Over the most part of Scandinavia and northern Russia the fluxes are below 0.2 kg/km^2/y.

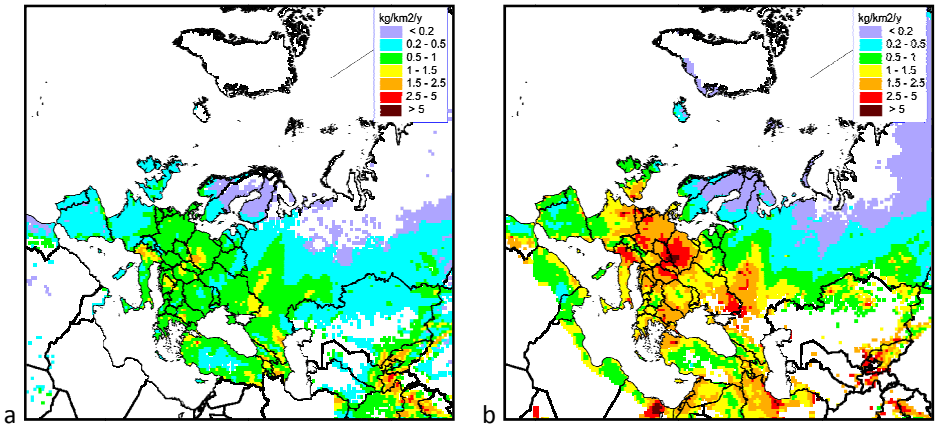

Fig. 1. *Annual lead deposition flux to arable lands (a) and forest (b) in 2015*

It is important to note that the most recent estimates critical load exeedances for heavy metals are outdated and relate to 2010. An update of information on heavy metal critical loads is needed for assessment of contemporary effects heavy metal pollution on biota and human health.

Northern Hemisphere

This year MSC-E has also started a new joint activity with CCE focused on evaluation of critical loads exceedances for mercury on a hemispheric scale. For this purpose, the centre performed modelling of mercury deposition to forests and (semi-)natural vegetation in the boreal and temperate region of the Northern Hemisphere under the current conditions (2010) and in future (2035).

Contemporary levels of mercury deposition were simulated using the global emissions inventory for 2010 [*AMAP/UNEP*, 2013]. Besides, a number of mercury emission scenarios for 2035 were considered in the study [*Pacyna et al.*, 2016]. They include the 'Current Policy' scenario (CP 2035) assuming that governmental policies and measures existing in 2010 have been adopted, including those that have not been fully implemented; the 'New Policy' scenario (NP 2035) assuming that policy commitments and plans announced by countries worldwide to reduce greenhouse gas emissions, as well as phase out fossil-energy subsidies, were fully implemented; and the 'Maximum Feasible Reduction' scenario (MFR 2035) set out a target of all counties reaching the highest feasible reduction efficiency in each emission sector. General discussion of the scenarios and forecasts of mercury pollution levels on global and regional scales were discussed in previous EMEP Status Reports [*Ilyin et al*., 2015; 2016].

Figure 2 illustrates the model assessment of mercury deposition flux to forests of the Northern Hemisphere in 2010 and in 2035 according to the selected emission scenarios. As seen, in 2010 mercury atmospheric load to forests in major part of Europe and North America varies within the range of 15-25 g/km^2/y (Fig. 2a). Similar deposition levels are predicted over tropical forests of Africa and South America. Considerably higher fluxes are characteristics of some areas in Central and Southern Europe (35-50 g/km^2/y) as well as in South Asia and East Asia (above 80 g/km^2/y). Relatively low mercury deposition was estimated for boreal forests of Scandinavia, Northern Russia and Canada (5-15 g/km^2/y).

Similar spatial pattern was simulated for mercury deposition to forests in 2035 according to the 'Current Policy' scenario (Fig. 2b). However, it is expected that deposition will decrease in Europe and North

America as well as increase in South and East Asia due to appropriate emission changes in these regions. In contrast, the NP 2035 scenario predicts significant deposition reduction in all regions of the Northern Hemisphere except for South Asia, where some increase of deposition to forests is still expected. The maximum decrease of mercury atmospheric load to forests is simulated in accordance with the MFR 2035 scenario. In this case deposition flux evenly decreases in all regions of the Northern Hemisphere and rarely exceeds the value of 25 g/km^2/y.

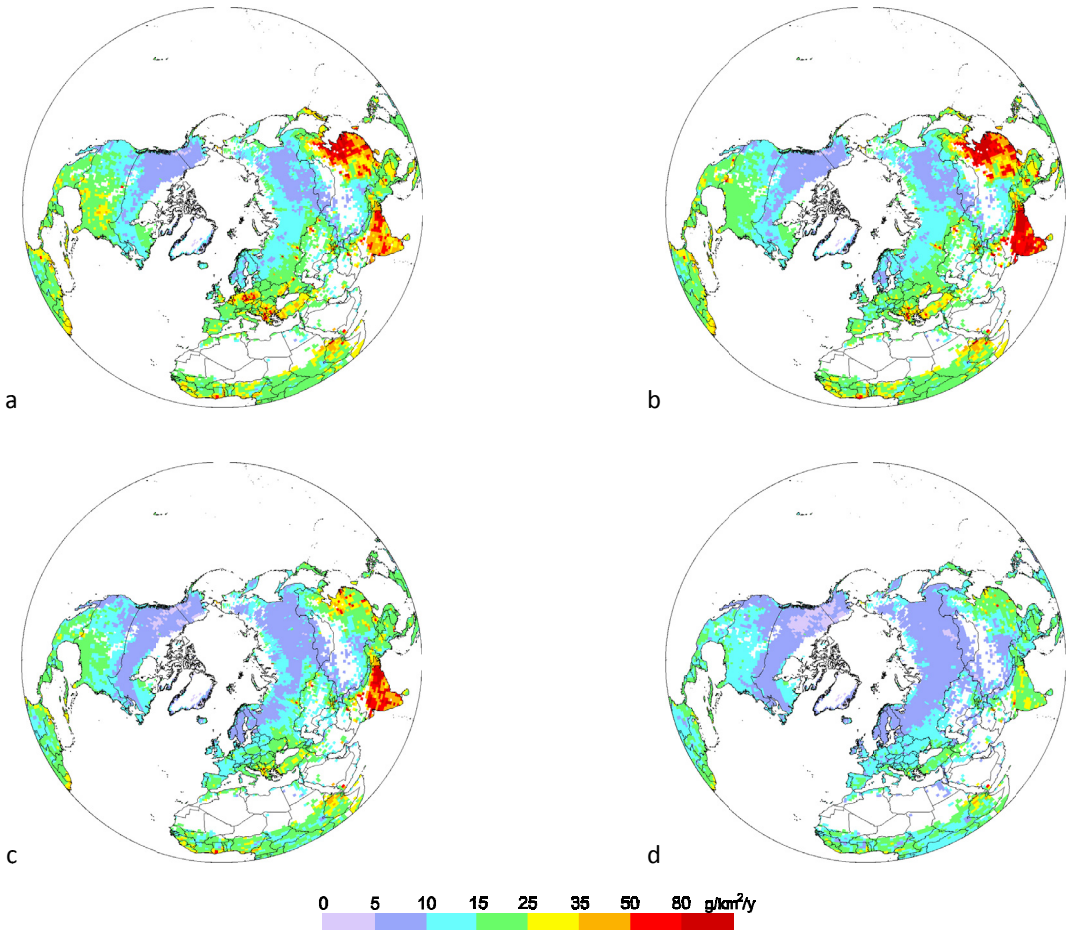

Fig. 2. *Mercury deposition flux to forests in the Northern Hemisphere in 2010 (a) and in 2035 according to different emission scenarios: (b) – CP 2035; (c) – NP 2035; (d) – MFR 2035*

Quantitative characteristics of changes of mercury deposition to forest between 2010 and the future scenarios are given in Fig. 4.17 in the form of probability distribution of deposition fluxes over the whole forested territories of the Northern Hemisphere. The probability density corresponding to the current conditions (2010) is characterized by bi-modal distribution with the major maximum at 10 g/km^2/y and the secondary maximum at 18 g/km^2/y (Fig. 3a). The former corresponds to deposition over large territories of boreal forests of Scandinavia, Northern and Eastern Russia and Canada; the latter characterized deposition to temperate forests of Europe and North America as well as tropical forests of Africa and South America.

As it was mentioned above the CP 2035 scenario does not expect significant changes of mercury deposition (Fig. 3b). Decrease of deposition fluxes in Europe and North America leads to slight shift of

the secondary peak to smaller values. The increase of forest areas with high deposition (above 50 g/km^2/y) in South and East Asia is not seen as it falls beyond the scope of the plot. Deposition changes according to the NP 2035 scenario with respect to 2010 appear on the graph by shifting both peaks toward smaller values, 8 and 15 g/km^2/y, respectively (Fig. 3b). Besides, forest areas where mercury deposition exceeds 20 g/km^2/y reduce considerably. The MFR 2035 scenario is characterized by even larger shift of the peaks (7 and 13 g/km^2/y) and limitation of mercury deposition flux by 30 g/km^2/y over all forests of the Northern Hemisphere (Fig. 3c).

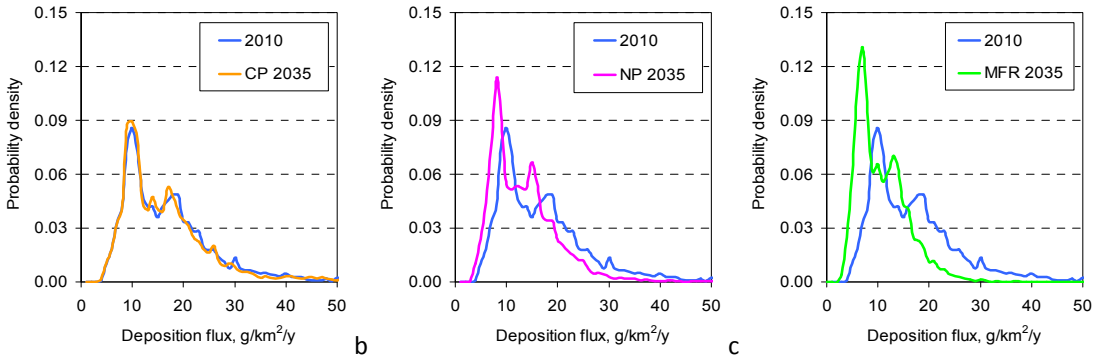

Fig. 3. *Probability distribution of mercury deposition flux to forests of the Northern Hemisphere in 2035 in comparison with 2010 according to different emission scenarios: (a) – CP 2035; (b) – NP 2035; (c) – MFR 2035*

This collaborative work will be continued next year. Results of the study can be used both for risk assessment of mercury pollution in the EMEP region and to support international efforts to protect human health and the environment from the adverse effects of mercury on a global scale.

References: EMEP Status Report 2/2017