1. Introduction

The first EMEP Centres Joint Report for HELCOM was delivered in 1997 (Tarrason *et al*. 1997) and was followed by thirteen annual reports (Bartnicki *et al*. 1998, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010 and 2011). The present EMEP Centres Joint Report for HELCOM is focused on the year 2010. It is based on the modelling and monitoring data presented to the 36th Session of the Steering Body of EMEP in Geneva in September 2012.

Following decisions of the 9th HELCOM MONAS Meeting held in Silkeborg in 2007, the main deliverables expected from the EMEP Centres are the Indicator Fact Sheets for nitrogen, heavy metals and PCDD/Fs. These Indicator Fact Sheets include time series of emissions and depositions of selected pollutants, and can be found on the HELCOM web pages (links shown in Appendix C). In this report we present additional important information about emissions, depositions and source allocation budgets for nitrogen, heavy metals and PCDD/Fs in the year 2010.

Eight countries have submitted data from all together eighteen HELCOM stations for 2010 (Fig. 2.1). This is three less sites than for 2009. The stations are distributed in the five sub-basins. Eight countries have submitted data for 2010 from altogether eighteen HELCOM sites. These are three less sites than for 2009. The stations are distributed in the five sub-basins. Not all sites measure all HELCOM relevant parameters. Twelve sites measure reduced and oxidized nitrogen in air and seventeen in precipitation. For heavy metals there were twelve stations with cadmium and/or lead in air, as well as in precipitation, though these sites are not necessarily co-located. There were five sites with mercury measurements in precipitation and four in air. All the data can be downloaded from ebas.nilu.no.

The EMEP model has been used for all nitrogen computations presented here (Simpson et al., 2012). In 2011, the model name has been changed from EMEP Unified to EMEP/MSC-W model. The earlier model versions have been documented in detail in EMEP Status Report 1/2003 Part I (Simpson *et al.* 2003) and in EMEP Status Report 1/2004 (Tarrasón *et al*., 2004). In EMEP Status Report 1/2003 Part II (Fagerli *et al.* 2003) we presented an extensive evaluation of the acidifying and eutrophying components for the years 1980, 1985, 1990 and 1995 to 2000. In EMEP Status Report 1/2003 Part III (Fagerli *et al.* 2003), a comparison of observations and modelled results for 2001 was conducted, and in EMEP Status Report 1/2004 (Fagerli, 2004) we presented results for 2002 with an updated EMEP Unified model, version 2.0. This version differed slightly from the 2003 version, as described in EMEP Status Report 1/2004 (Fagerli, 2004), however the main conclusions on the model performance was the same. In 2005, we presented results for the year 2003 in EMEP Status Report 1/2005 (Fagerli, 2005) and in 2006 we presented results for 2004 in EMEP Status Report 1/2006 (Fagerli *et al.*

2006). It has been shown that the EMEP model performance is rather homogeneous over the years (Fagerli *et al.* 2003), but depend on geographical coverage and quality of the measurement data. The EMEP model has also been validated for nitrogen compounds in Simpson *et al.*, 2006, and for dry and wet deposition of sulphur, and wet depositions for nitrogen in Simpson *et al*., 2006b with measurements outside the EMEP network.

The version rv4.0 of the EMEP/MSC-W Eulerian model has been used for all nitrogen computations presented in this Chapter (EMEP, 2012). Compared to the model version rv3.6, used in 2012 for computing 2010 deposition, many changes have been introduced into the present model. The most important are: the change of vertical distribution of emissions and a “degree-day” system introduced to handle time variations, a secondary organic aerosol (SOA) added in the standard model, new calculation of H+ and ph in cloud water from the acid-base balance, new mass median diameter of coarse nitrate (3 µm), some changes in chemical scheme and 10 other changes/improvements. The model evaluation on 2009 measurement data was presented in the supplementary material to EMEP Status Report1/11 (Gauss et. al., 2011). The comparison between this model version results and observations for 2009 gave similar correlation coefficients and bias as the comparisons performed for earlier years. The previous evaluations of the model are thus still valid.

In 2008, the Steering Body adopted an extension of the official EMEP domain to facilitate the inclusion of countries in Eastern Europe, Caucasus and Central Asia (EECCA) in the EMEP calculations (ref. ECE/EB.AIR/GE.1/2007/9, Item 3 of the provisional agenda of thirty-first session of the EMEP Steering Body, available from http://www.unece.org/env/lrtap/emep/emep31_docs.htm). Thus from 2008, the official 50 x 50 km^2 polar stereographic EMEP grid has been extended from 132 x 111 to 132 x 159 grid cells, following Stage 1 in ECE/EB.AIR/GE.1/2007/9. In geographical projection it leads to an extension eastward as well as northward. Both the old and new extended EMEP domains are presented in Figure 1.1.

The present extension of the EMEP modelling area has many advantages, but also recognized drawbacks. Min advantage is a possibility of taking into account much larger part of the Russian emissions in the extended model domain. The main drawback is that the current extended EMEP domain still only partly covers the Russian Federation. It is also recognized that results on air pollution in central Asian countries are highly dependent on sources outside the calculation domain. Countries in Central Asia are contiguous with other Asian countries like China, India, Pakistan and Iran that significantly affect pollution levels over the ECCA territories but are not included directly in the calculations. Consequently, the current EMEP modelling capacity for EECCA countries and the related grid domain is an interim solution until 2013. In 2014, a new EMEP official domain covering adequately transport of pollution to all 12 EECCA countries is expected to be adopted.

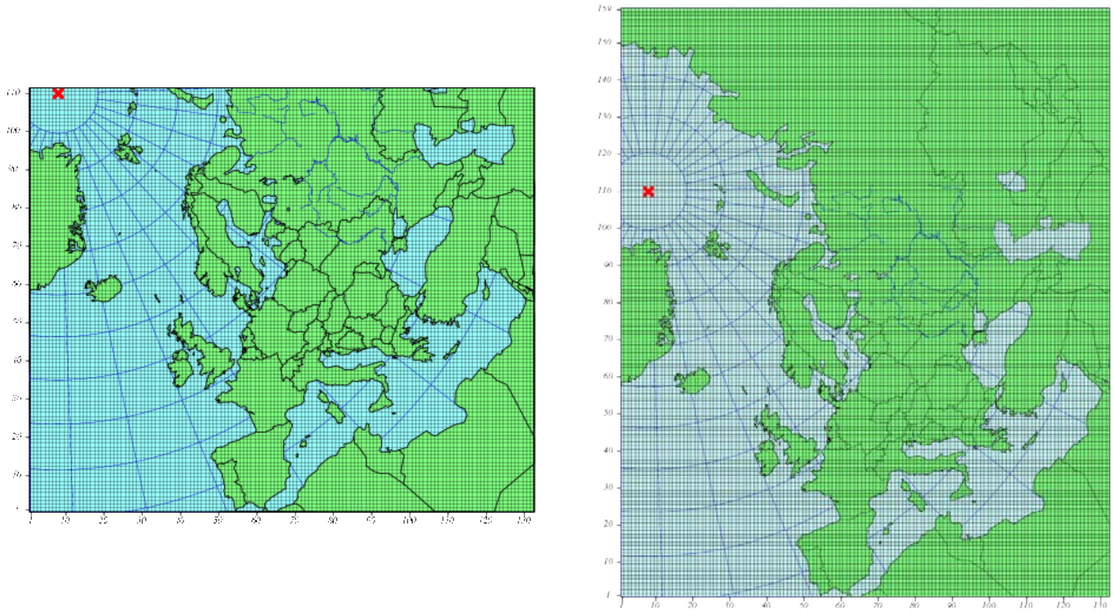

Figure 1.1. Comparison of old (used before 2007) official EMEP domain on the left side and new official EMEP domain on the right side. The new model domain was used for all computations for 2009 presented in this report.

Atmospheric input and source allocation budgets of heavy metals (cadmium, lead, and mercury) to the Baltic Sea were computed using the latest version of MSCE-HM model. MSCE-HM is the regional-scale model operating within the EMEP region. This is a three-dimensional Eulerian-type chemistry transport model driven by off-line meteorological data. The model considers HM emissions from anthropogenic and natural sources, transport in the atmosphere, chemical transformations (of mercury only) both in gaseous and aqueous phases, and deposition to the surface. The model domain is defined on polar stereographic projection and covers the standard EMEP region by a regular grid with 50x50 km spatial resolution at 60º latitude. For national scale applications finer resolution is applied (e.g. 5x5, 10x10 km). Vertical structure of the model is formulated in the sigma-pressure coordinate system, particularly, 15 irregular sigma-layers are used in the model covering the whole troposphere. Detailed description of the model is available in (Travnikov and Ilyin, 2005) and in the Internet on EMEP web page http://www.emep.int under the link to information on Heavy Metals.

It is assumed in the model that such HMs as lead and cadmium and their compounds are transported in the atmosphere in composition of aerosol particles. It is believed that possible chemical transformations of lead and cadmium do not change properties of carrying particles with regard to removal processes. On the contrary, for mercury the model considers its transformations in the atmosphere including transitions between the gaseous, aqueous and solid phases, and chemical reactions in the gaseous and aqueous environment. Model description of removal processes includes dry deposition and wet scavenging. The dry deposition scheme is based on the resistance analogy and allows taking into account deposition to different land cover types. The model distinguishes in-cloud and sub-cloud wet scavenging of particulate species and highly soluble reactive gaseous mercury. Wind re-suspension of particle-bound lead and cadmium from soil and seawater is an important process which affects essentially ambient pollution levels, particularly, in areas with low direct anthropogenic emissions. The model includes parameterization of HM re-suspension with dust aerosol particles from soil and generation of sea-salt and wind suspension of HMs from sea surface.

Evaluation of PCDD/F atmospheric input to the Baltic Sea was carried out using the latest version of MSCE-POP model. Similar to MSCE-HM model the MSCE-POP model is a three-dimensional Eulerian multimedia POP transport model operating within the geographical scope of EMEP region with spatial resolution 50 km at 60º latitude. Both models share the same description of atmospheric transport and structure of the atmospheric compartment. The MSCE-POP model considers the following environmental compartments: air, soil, sea, vegetation and forest litter fall. The following basic processes are included in the model to describe POP fate: emission, advective transport, turbulent diffusion, dry and wet deposition, gas/particle partitioning, degradation, and gaseous exchange between the atmosphere and the underlying surface (soil, seawater, vegetation). Detailed description of MSCE-POP model is given in EMEP report (Gusev et al., 2005) and in the Internet on EMEP web page http://www.emep.int under the link to information on Persistent Organic Pollutants.

The formulation of MSCE-HM and MSCE-POP models and their performance were thoroughly evaluated within the framework of activity of EMEP/TFMM on the EMEP Models Review (ECE/EB.AIR/GE.1/2006/4). One of the main conclusions of the TFMM Workshop held in Moscow in 2005 was that MSCE-HM and MSCE-POP models represent the state of the science and fit for the purpose of evaluating the contribution of long-range transport to the environmental impacts caused by HMs and POPs.

Along with the regional-scale models there is ongoing development of the global multiscale modelling approach for HMs and POPs at the MSC-E. The Global EMEP Multi-media Modelling System (GLEMOS) is being elaborated to evaluate HM and POP pollution at different scales (global, regional, and local) and substitute MSCE-HM and MSCE-POP in future.

As decided by HELCOM all depositions, as well as, source allocation budgets have been calculated for the six sub-basins and catchments of the Baltic Sea. Names and acronyms of these regions, often used in the report are given below:

1. Gulf of Bothnia (GUB)
2. Gulf of Finland (GUF)
3. Gulf of Riga (GUR)

4. Baltic Proper (BAP)
5. Belt Sea (BES)
6. The Kattegat (KAT)

In the results presented in the present report country, source and receptor names are often abbreviated. The list of these abbreviations is given below together with the EMEP identification number.

CODE	**EMEP ID**	**NAME**
AL	1	Albania
AT	2	Austria
BE	3	Belgium
BG	4	Bulgaria
FCS	5	Former Czechoslovakia
DK	6	Denmark
FI	7	Finland
FR	8	France
FGD	9	Former German Democratic Republic
FFR	10	Former Federal Republic of Germany
GR	11	Greece
HU	12	Hungary
IS	13	Iceland
IE	14	Ireland
IT	15	Italy
LU	16	Luxembourg
NL	17	Netherlands
NO	18	Norway
PL	19	Poland
PT	20	Portugal
RO	21	Romania
ES	22	Spain
SE	23	Sweden
CH	24	Switzerland
TR	25	Turkey
FSU	26	Former USSR
GB	27	United Kingdom
VOL	28	Volcanic emissions
REM	29	Remaining land Areas
BAS	30	Baltic Sea
NOS	31	North Sea

ATL	32	Remaining North-East Atlantic Ocean
MED	33	Mediterranean Sea
BLS	34	Black Sea
NAT	35	Natural marine emissions
RUO	36	Kola & Karelia
RUP	37	St.Petersburg & Novgorod-Pskov
RUA	38	Kaliningrad
BY	39	Belarus
UA	40	Ukraine
MD	41	Republic of Moldova
RUR	42	Rest of the Russian Federation
EE	43	Estonia
LV	44	Latvia
LT	45	Lithuania
CZ	46	Czech Republic
SK	47	Slovakia
SI	48	Slovenia
HR	49	Croatia
BA	50	Bosnia and Herzegovina
CS	51	Serbia and Montenegro
MK	52	The former Yugoslav Republic of Macedonia
KZ	53	Kazakhstan in the former official EMEP domain
GE	54	Georgia
CY	55	Cyprus
AM	56	Armenia
MT	57	Malta
ASI	58	Remaining Asian areas
LI	59	Liechtenstein
DE	60	Germany
RU	61	Russian Federation in the former official EMEP domain
MC	62	Monaco
NOA	63	North Africa
EU	64	European Community
US	65	United States
CA	66	Canada
BIC	67	Boundary and Initial Conditions
KG	68	Kyrgyzstan
AZ	69	Azerbaijan
ATX	70	EMEP-external Remaining North-East Atlantic Ocean
RUX	71	EMEP-external part of Russian Federation
RS	72	Serbia

ME	73	Montenegro
RFE	74	Rest of Russian Federation in the extended EMEP domain
KZE	75	Rest of Kazakhstan in the extended EMEP domain
UZO	76	Uzbekistan in the former official EMEP domain
TMO	77	Turkmenistan in the former official EMEP domain
UZE	78	Rest of Uzbekistan in the extended EMEP domain
TME	79	Rest of Turkmenistan in the extended EMEP domain
CAS	80	Caspian Sea
TJ	81	Tajikistan
ARO	82	Aral Lake in the former official EMEP domain
ARE	83	Rest of Aral Lake in the extended EMEP domain
ASM	84	Modified Remaining Asian Areas in the former official EMEP domain
ASE	85	Remaining Asian Areas in the extended EMEP domain
AOE	86	Arctic Ocean in the extended EMEP domain
KZT	92	Kazakhstan
RUE	93	Russian Federation in the extended EMEP domain (RU + RFE + RUX)
UZ	94	Uzbekistan
TM	95	Turkmenistan
AST	96	Asian areas in the extended EMEP domain (ASM + ASE + ARO + ARE + CAS)
FYU	99	Former Yugoslavia
BEF	301	Belgium (Flanders)
BA2	302	Baltic Sea EU Cargo o12m
BA3	303	Baltic Sea ROW Cargo o12m
BA4	304	Baltic Sea EU Cargo i12m
BA5	305	Baltic Sea ROW Cargo i12m
BA6	306	Baltic Sea EU Ferry o12m
BA7	307	Baltic Sea ROW Ferry o12m
BA8	308	Baltic Sea EU Ferry i12m
BA9	309	Baltic Sea ROW Ferry i12m
NO2	312	North Sea EU Cargo o12m
NO3	313	North Sea ROW Cargo o12m
NO4	314	North Sea EU Cargo i12m
NO5	315	North Sea ROW Cargo i12m
NO6	316	North Sea EU Ferry o12m
NO7	317	North Sea ROW Ferry o12m
NO8	318	North Sea EU Ferry i12m
NO9	319	North Sea ROW Ferry i12m
AT2	322	Remaining North-East Atlantic Ocean EU Cargo o12m

AT3	323	Remaining North-East Atlantic Ocean ROW Cargo o12m
AT4	324	Remaining North-East Atlantic Ocean EU Cargo i12m
AT5	325	Remaining North-East Atlantic Ocean ROW Cargo i12m
AT6	326	Remaining North-East Atlantic Ocean EU Ferry o12m
AT7	327	Remaining North-East Atlantic Ocean ROW Ferry o12m
AT8	328	Remaining North-East Atlantic Ocean EU Ferry i12m
AT9	329	Remaining North-East Atlantic Ocean ROW Ferry i12m
ME2,	332,	Mediterranean Sea EU Cargo o12m
ME3	333	Mediterranean Sea ROW Cargo o12m
ME4	334	Mediterranean Sea EU Cargo i12m
ME5	335	Mediterranean Sea ROW Cargo i12m
ME6	336	Mediterranean Sea EU Ferry o12m
ME7	337	Mediterranean Sea ROW Ferry o12m
ME8	338	Mediterranean Sea EU Ferry i12m
ME9	339	Mediterranean Sea ROW Ferry i12m
BL2	342	Black Sea EU Cargo o12m
BL3	343	Black Sea ROW Cargo o12m
BL4	344	Black Sea EU Cargo i12m
BL5	345	Black Sea ROW Cargo i12m
BL6	346	Black Sea EU Ferry o12m
BL7	347	Black Sea ROW Ferry o12m
BL8	348	Black Sea EU Ferry i12m
BL9	349	Black Sea ROW Ferry i12m
GL	601	Greenland

Calculated depositions of nitrogen compound, heavy metals and PCDD/F show significant variation from one year to another due to different meteorological conditions. In order to avoid or at least limit the influence of meteorology on calculated depositions, the so called “normalised” depositions were calculated in 2012 for the first time. These normalised depositions are presented in the Indicator Fact Sheets with the links given in Appendix C. The method used for calculating normalised depositions is explained in Appendix D.