EMEP Status Report 3/2007

June 2007

Persistent Organic Pollutants in the Environment

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EXECUTIVE SUMMARY

In accordance with the EMEP Work-plan for 2007, Meteorological Synthesizing Centre East (MSC-E) and Chemical Coordinating Centre (CCC) continued the investigations of the environmental pollution by polycyclic aromatic hydrocarbons (PAHs), polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs), polychlorinated biphenyls (PCBs), γ-hexachlorocyclohexane (γ-HCH or lindane) and hexachlorobenzene (HCB). The evaluation of POP contamination was based both on measurements and model calculations. The outcome of the studies is summarized in this Status Report.

In 2005 it was 6 sites measuring POPs in air and precipitaion, and altogether it was 14 measurement sites, 1 less than in 2004. The spatial distribution of measuerement sites in Europe is still unsatisfactory; there are no sites in east of Europe. Hopefully, the new EU directive on heavy metals and PAHs will have a positive effect on the number of EMEP measurement stations. In 2006 EMEP/CCC arranged a passive sampling campaign covering whole of Europe as well as Central Asia to evaluate the spatial patterns of POPs in air. The results from that campaign will be available and discussed next year.

The official data on POP emissions (PAHs, PCDD/Fs, HCB, PCBs and HCHs) for at least one year within the period from 1990 to 2005 were submitted by 35 Parties to the Convention. It should be pointed out that in recent years the number of countries that have submitted official information on spatial distribution of emissions and gridded sector data is increasing (for example, PAH and PCDD/F gridded emission data were reported in this year by 23 countries compared with 17 in the previous year). Besides, three countries – Denmark, Norway and Sweden – presented information on spatial distribution of sea emissions. According to official and unofficial data, emissions of considered POPs tend to decrease from 1990 to 2005. In particular, emissions of four indicator PAHs (benzo[a]pyrene (B[a]P), benzo[b]fluoranthene (B[b]F), benzo[k]fluoranthene (B[k]F), indeno[1,2,3-cd]pyrene (I_P)) have decreased by 23 - 28%, and emissions of PCDD/Fs have halved.

MSC-E continued the work on the improvement of POP models in accordance with the recommendations of of the EMEP/TFMM Workshop on the review of MSC-E models. This year the following investigations in the field of development of MCSE-POP model were carried out:

- enlargement of the number of land cover types considered within the model and improvement of the model description of particulate dry depositions to different types of underlying surface;
- investigations of possible contribution of re-suspension process to contamination of the European region;
- improvement of input data on atmospheric particles and OH-radical concentrations.

The modifications involved into the model have led to essential improvement of agreement between calculated and measured data on POP atmospheric concentrations and depositions.

Model evaluation of environmental pollution levels was performed for the four indicator PAHs and PCDD/Fs (regional scale), PCBs, γ-HCH and HCB (hemispheric scale) for 2005. The evaluation of contamination of the EMEP region and of source-receptor relationships for PCDD/Fs was carried out on the basis of hemispheric/regional approach. This allows taking into account contributions of non-EMEP anthropogenic sources and of re-emissions from the environmental media due to the contamination accumulated in the environment during preceding years. Namely, first PCDD/F transport for the period from 1970 to 2005 was simulated by hemispheric model version to obtain initial and boundary conditions for regional simulations. Then spatial distribution of contamination in 2005 was calculated by means of regional model version (50x50 km resolution) with obtained boundary and initial conditions. Pollution levels and source-receptor relationships for PAHs were evaluated at regional scale since these pollutants are mainly particle-bound. Evaluation of intercontinental transport of POPs was performed for three PCB congeners, HCB, and γ-HCH using hemispheric version of MSCE-POP model. Distribution of pollution from the selected groups of emission sources within the northern hemisphere was evaluated and contributions to the pollution of remote regions were estimated.

Modelling of environmental pollution by PCDD/Fs was made with the use of physical-chemical properties of the “indicator congener” 2,3,4,7,8-PeCDF. The levels of net deposition flux in Europe in 2005 differ from about 0.1 ng TEQ/m^2/y in northern Europe (Norway, northern parts of Sweden and Finland) to 3 ng TEQ/m^2/y and higher in central and southern Europe (Poland, the Czech Republic, Macedonia, Serbia and Montenegro, Portugal). High values of deposition levels (1 – 3 ng TEQ/m^2) due to high emission densities were calculated for the Ukraine and a part of Turkey.The transboundary transport of PCDD/Fs was evaluated taking into account national anthropogenic emissions of European countries, non-EMEP anthropogenic sources (USA and Canada) and re-emissions.

Calculations of pollution levels by PCDD/Fs for a long-time period allowed evaluating temporal trends of pollution for European countries. The results, in particular, indicate increasing role of re-emission in the countries with strong emission decrease. In particular, in 2005 re-emissions in the United Kingdom amount to about 10% and in the Czech Republic – to about 20% of the anthropogenic emissions.

Media response to possible emission scenarios for PCDD/Fs up to 2020 was evaluated. To do this, two emission scenarios **CR** – Base Line scenario with Current Legislation and **C**urrent **R**atification of the UNECE POP Protocol and **FI** – Base Line scenario with Current Legislation and **F**ull **I**mplementation of the UNECE POP Protocol prepared on the basis of TNO scenarios ([*Denier van der Gon et al*., 2005]) and official emission data were used. For CR scenario, main reduction of air contamination took place in Central European countries. At southeast of Europe some increase of air concentrations took place. Under CR scenario typical reduction of PCDD/F air concentrations from 2005 to 2020 were from 20% to 40%. On the opposite, for FI scenario, in addition to decrease of air concentration levels in Central Europe essential reduction of contamination levels in eastern and southeastern parts of Europe took place. In this case typical reduction of PCDD/F air concentrations in European countries was 40% − 60%.

The contribution of PCDD/F transboundary transport within the EMEP region typically ranges from 20% to 80%. The contributions of non-EMEP anthropogenic sources to the pollution of European countries can be noticeable and reach up to 30% for countries located close to EMEP boundaries. The input of re-emissions to depositions in European countries is typically in the range from 30% to 50%.

Annual mean B[a]P concentrations in the surface atmospheric layer vary from 0.1 to 1 ng/m^3 and more in Central and Southern Europe. High levels of contamination are characteristic of Poland, the Ukraine, parts of the Czech Republic and Slovakia (up to 1 ng/m^3 and higher). Spatial distribution of the rest three indicator PAHs (B[b]F, B[k]F, and I_P) in 2005 was similar to that of B[a]P. The levels of air concentrations of B[k]F in Europe are lower than for the rest three indicator compounds. The transboundary transport of B[a]P between European countries was evaluated by regional calculations (within the EMEP region). The contribution of the external sources to air concentrations and depositions of B[a]P in particular countries was essential and varies typically from 20 to 80%.

Model estimates of pollution levels at the hemispheric scale and contributions of intercontinental transport to the pollution of selected receptor regions were performed for three PCB congeners (PCB-28, PCB-118, PCB-153), HCB, and γ-HCH. Using available emission data the distribution of pollution from the selected groups of emission sources within the northern hemisphere was evaluated. In addition, the contributions of these source groups to the pollution of the Arctic region and of selected Central Asian countries were estimated.

Monitoring and model assessment of POP pollution in the EMEP region was carried out by the EMEP Centres in co-operation with the subsidiary bodies to the Convention (TFMM, TFHTAP, TF on POPs), international organizations (EU, HELCOM, OSPAR, SETAC, UNEP), as well as with national experts.

CONTENTS

INTRODUCTION

This report summarizes the main results of 2007 activities of EMEP Centres − Meteorological Synthesizing Centre-East (MSC-E) and Chemical Coordinating Centre (CCC) − in evaluation of contamination of the EMEP region by persistent organic pollutants (POPs). During 2007 the assessment of POP long-range atmospheric transport and transboundary fluxes on the basis of measurements, emission data and modelling were continued. Modelling studies in accordance with the EMEP Work-plan for 2007 [*ECE/EB.AIR/2006/10*] are performed for the following pollutants: polycyclic aromatic hydrocarbons (PAHs), polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs), polychlorinated biphenyls (PCBs), lindane (γ-HCH), and hexachlorobenzene (HCB).

The distribution of EMEP monitoring sites currently measuring POP concentrations in air and precipitation is unsatisfactory and requires further improvement. In particular, countries in Southern and Eastern Europe are still not covered by the monitoring network. It is believed that EMEP/CCC passive sampling campaign performed in 2006 and covering whole of Europe as well as Central Asia will significantly contribute to the evaluation of spatial patterns of POPs in air.

Taking into account the recommendations of the EMEP/TFMM Workshop on the review of MSC-E models and in order to refine the quality of pollution assessment in the EMEP region a number of modifications are to be performed in the MSCE-POP model. These modifications include refinement of information on chemical properties of selected POPs, development of model parameterization for POP re-suspension with aerosol particulates, and improvement of model description of POP degradation in the atmosphere, deposition processes, and volatilization from soils. The results of model development in this direction are presented in this report.

Important role in long-range transport of POPs in the atmosphere belongs to aerosol particles. In particular, information on aerosol concentrations is required for the description of gas/particle partitioning and degradation of POPs in the atmosphere. Refinement of spatial distribution and temporal variations of aerosol particles concentrations can significantly influence model results for POPs. Investigations of sensitivity of MSCE-POP model results to the refinement of this information are carried out on the example of B[a]P.

Input information on emissions for modelling is prepared on the basis of officially submitted emission totals and gridded emissions and available unofficial data. The most recent emission data are used to prepare spatial distribution of PAH and PCDD/F emissions within the EMEP region. For the evaluation of POP intercontinental transport and contribution of non-EMEP sources to the pollution of the EMEP domain, available emission data for PCDD/Fs, PCBs, γ-HCH and HCB within the northern hemisphere are compiled.

To assess the contributions of historical accumulation and non-EMEP emission sources model simulations for PCDD/Fs are carried out using developed nested hemispheric/regional modelling approach. The hemispheric MSCE-POP model is run for the period from 1970 to 2005 taking into account emissions of European region and North America (USA and Canada). On the basis of these calculations boundary and initial concentrations for regional modelling are obtained and evaluation of pollution levels in European countries and source-receptor relationships (country-to-country matrices) is carried out taking into account contributions of re-emissions and non-EMEP sources. Since selected PAHs are mainly particle-bound, modelling for these pollutants is performed by the regional MSCE-POP model for 2005 only. The evaluation of source-receptor relationships for PAHs is exemplified by B[a]P.

In order to verify modified model and test the agreement with observations the comparison of modelling results with available measurement data of EMEP monitoring network for 2005 is carried out. The comparison is performed on the level of annual and monthly mean concentrations of B[a]P to check how the model predictions agree with annual mean levels of pollution and their seasonal variations.

With the help of long-term calculations, trends of contamination by PCDD/Fs in European countries for the period from 1990 to 2005 are examined and evaluation of media response to possible emission scenarios up to 2020 is performed. Two emission scenarios (**CR** – Base Line scenario with Current Legislation and **C**urrent **R**atification of the UNECE POP Protocol and **FI** – Base Line scenario with Current Legislation and **F**ull **I**mplementation of the UNECE POP Protocol) are prepared on the basis of scenarios worked out by TNO [*Denier van der Gon et al*., 2005]) and official emission data.

Further elaboration of hemispheric/regional POP modelling approach is based on the nesting of hemispheric and regional MSCE-POP model simulations.

Hemispheric MSCE-POP model is appled for the evaluation of PCB, γ-HCH, and HCB intercontinental transport using available emission data for 2005 and updated information on emissions for previous years. Obtained distribution of pollution from the selected groups of emission sources within the northern hemisphere is used to evaluate intercontinental transport and their contributions to the pollution of remote regions (the Arctic). In addition, the information on pollution of selected Central Asia countries, namely, Kazakhstan, Kirgizstan, Tajikistan, Turkmenistan, and Uzbekistan, is prepared. At further stages of the work, pollution levels of PCBs, γ-HCH, and HCB for European region will be evaluated with finer spatial resolution 50x50 km using the developed nested hemispheric/regional modelling approach for POPs. It is believed that application of this approach will permit to improve the agreement of model results for these POPs with measurements available for European region.

MSC-E in cooperation with MSC-W started the development of a global modelling approach. At current stage the elaboration of this approach is focused on the preparation of necessary meteorological and geophysical input data for modelling at the global scale. In particular, data on land use and land cover are being compiled and meteorological drivers for the preprocessing of meteorological input data are tested. Developed global POP model will substitute the current hemispheric MSCE-POP model at further stages of work and will permit to investigate transport and accumulation of POPs on the global scale. Currently available emission inventories for selected POPs (PCBs, HCHs) with spatial resolution 1°x1° will make it possible to obtain more detailed distribution of POP pollution levels in comparison with currently used hemispheric approach.

In the field of evaluation of POP pollution levels within the European region, the EMEP Centres closely co-operated with the subsidiary bodies to the Convention, international organizations and programmes as well as with national experts.

In framework of co-operation with the Task Force on Hemispheric Transport of Air Pollution MSC-E is taking part in the coordinated multi-model intercomparison study of intercontinental transport of air pollutants. Following the requirements of source-receptor experiment of this study MSC-E has carried out modelling of PCB-153 and α-HCH and submitted obtained modelling results for the analysis.

The results of the work carried out during this year are presented in the Technical Reports of the EMEP Centres [*Aas and Breivik*, 2007; *Gusev et al*., 2007] as well as on the Internet *www.emep.int* and *www.msceast.org*.

The outline of the report is as follows.

Chapter 1 is devoted to the description of Centres' activities in the field of monitoring. Here the description of EMEP monitoring network for 2005 and the analysis of POP pollution levels in the EMEP region based on measurements is given.

Chapter 2 describes official emission data submitted by Parties to the Convention to the UN ECE Secretariat and emission data used in modelling both on regional and hemispheric scales.

In Chapter 3 model modifications made in accordance with the recommendations of the model review are presented. Here the description of model modifications concerning dry deposition to different types of underlying surface, refinement of input data on concentrations of atmospheric aerosols and OH-radicals and investigation of contribution of re-suspension process to POP pollution levels were done.

Chapter 4 shows the results on evaluation of pollution levels and source-receptor relationships in the EMEP domain for PAHs and PCDD/Fs, and on evaluation of hemispheric contamination and intercontinental transport for PCBs, γ-HCH and HCB. In addition, trends of contamination by PCDD/Fs in European countries from 1990 to 2005 and evaluation of media response of these pollutants to various emission scenarios up to 2020 were considered.

Chapter 5 is devoted to the description of main directions of collaboration with subsidiary bodies to the Convention (Task Force on POPs, and Task Force on Measurements and Modelling and Task Force on Hemispheric Transport of Air Pollutants), with international organizations (UNEP, HELCOM) and with national experts.

Chapter 6 contains a brief description of future activities in the field of POPs proposed by MSC-E for 2008.

In the end of the report short summary of the results of the work carried out in 2007 is presented.

The report is complemented by three Annexes. Annex A contains the requirements of the EMEP work plan for 2007 concerning evaluation of European contamination by POPs. Annex B presents the full set of data on country-to-country deposition matrices for PCDD/Fs and B[a]P. Annex C is devoted to the decisions of the joint MSC-W/MSC-E technical meeting.

Acknowledgements

The authors of the report are grateful to Prof. I Holoubek for active participation in the comparison of modelling results and measurements. A great contribution to the technical preparation of the report was made by Ms. I. Strizhkina.

1. MONITORING OF POPs IN EMEP

1.1. Measurement network

POPs were included in the EMEP's monitoring program in 1999. However, earlier data has been available and collected, and the EMEP database thus also includes older measurements. A number of countries have been reporting POPs within the EMEP area in connection with different national and international programmes such as HELCOM, AMAP and OSPARCOM. Data from the open scientific literature are also used for model validation and complements the EMEP data.

The locations of the measurement sites, which have delivered POPs for 2005, are shown in Fig. 1.1. The measurement programs at the different sites are given in Table 1.1. Further details of the sites and the measurement methods are found in EMEP/CCC's data report on heavy metals and POPs [*Aas and Breivik*, 2007]. The sites are divided in those measuring both in air and precipitation, and those measuring only in one media. In 2005 it was 6 sites measuring POPs in both compartments, and altogether it was 14 measurement sites, 1 less than in 2004. But Spain has reported campaign data for one week in July, which is not presented here. It is quite evident from Figure 1 that the spatial distribution in Europe is still unsatisfactory; there are no sites in east of Europe, but hopefully, the new EU directive on heavy metals and PAHs will have a positive effect on the number of EMEP measurement stations as well.

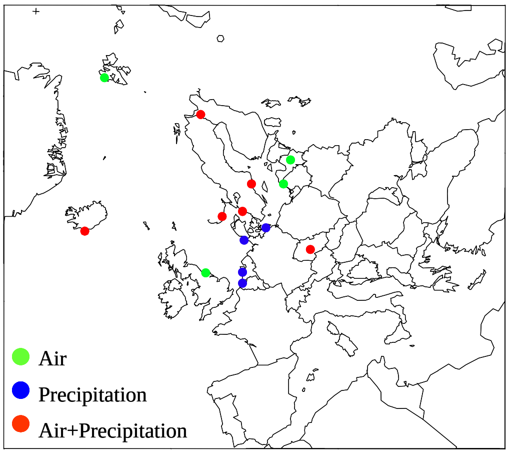


***Fig. 1.1.** Measurement network of POPs in EMEP, 2005*

In 2006 EMEP/CCC arranged a passive sampling campaign covering whole of Europe as well as central Asia to evaluate the spatial patterns of POPs in air. The results from that campaign will be available and discussed next year.

Table 1.1. *Measurements sites and programs for POPs in 2005*

Sites	POPs in air and aerosol	POPs in precipitation
BE04		Pesticides, HCHs
CZ03	PAHs, PCBs, pesticides, HCHs	PAHs, PCBs, pesticides, HCH
DE01		PAHs, PCBs, pesticides, HCB, HCHs
DE09		PAHs, PCBs, pesticides, HCB, HCHs
FI96	PAHs, PCBs, pesticides, HCHs	PAHs, PCBs, HCHs
GB14	PAHs, PCBs	
IS91	PCBs, pesticides, HCB, HCHs	PCBs, pesticides, HCB, HCHs
LV10	PAH (benzo-a-pyrene)	
LV16	PAH (benzo-a-pyrene)	
NL91		γ-HCH
NO01	PCBs, HCB, HCHs	PCBs, HCB, HCHs
NO42	PAHs, PCBs, pesticides, HCHs, HCB	
SE12	PAHs, PCBs, pesticides	PAHs, PCBs, HCHs
SE14	PAHs, PCBs, pesticides	PAHs, PCBs, HCHs

1.2. Measurement results of POPs in 2005

Details of the measurements results and methodology are found in the EMEP/CCC data report on heavy metals and POPs [*Aas and Breivik*, 2007]. Here there is also some more elaboration of the concentration levels observed. In Table 1.2 a summary of the results of the most common POP measurements in air is presented. It can be difficult to compare the results, especially for precipitation, from the different sites since the measurement programs can vary and the methodology differs. It is somewhat strange that the benzo-a-pyrene level is 10 times higher at LV10 compared to LV16. The differences are mainly seen during the winter period. To get an opinion of the quality of the EMEP data one may use the results from the laboratory intercomparison that was completed some years ago [*Manø and Schaug,* 2003]. It is recommended that this exercise should be repeated in a few years.

Table 1.2. *Annual average concentrations of selected POPs in 2004, (pg/m^3; ng/m^3 for benzo-a-pyrene (B[a]P)*

Stations	HCHs		PAHs	PCBs			Pesticides	
	α-HCH	γ-HCH	B[a]P	PCB-180	PCB-28	ratio 28/180	pp_DDD	pp_DDT
CZ3R	17.9	29.0	0.417	5.02	11.64	2	5.42	8.22
FI96R	9.9	2.7	0.013	0.05	1.94	37	0.11	0.25
LV10R			0.334					
LV16R			0.048					
GB14R			0.025	0.16	10.89	69		
IS91R	2.7	3.8		0.11	2.86	25	0.14	0.14
NO1R	12.7	8.9		0.27	1.55	6		
NO42G	15.3	2.4	0.003	0.04	2.84	77	0.03	0.09
SE12R			0.054	0.14	1.01	7		
SE14R	8.0	6.4	0.085	0.50	1.54	3	0.13	1.12

The concentration in the Czech Republic and the United Kingdom for PCBs is much higher than those observed in the Nordic countries. It is explained by the high historical usage of PCBs in central Europe [*Breivik et al.*, 2002a]. The atmospheric mobility of heavier PCBs (such as PCB-180) may exhibit a greater affinity for atmospheric particles than lighter PCBs (e.g. PCB-28), and they thus deposit faster in comparison to the lighter counterparts. Stations experiencing elevated levels of PCB-180 may thus be indicative of areas that are under influence of contemporary PCB emission source regions. With the exception of the UK, the PCB28/PCB180 ratio tends to increase from south to north. This confirms that there are marked differences in the long-range transport potential (LRTP) within the group of PCBs [*Wania and Dugani*, 2003].

The presence of HCH in environments far away from the sources is due to long-range atmospheric transport. The relatively high concentrations of α-HCH measured at higher latitudes have also been observed in seawater. Preferential deposition and accumulation in polar latitudes of α-HCH are expected according to the hypothesis of global fractionation and cold condensation [*Wania and Mackay*, 1996]. Iceland is influenced by westerly air masses, which explain the lower concentrations seen at IS0091.

For precipitation it is difficult to compare the results in Europe due to different methodology, e.g. Finland and Sweden are measuring deposition while others are measuring concentration in precipitation. In addition, the concentration levels in precipitation are very often below the detection. However the general picture is as for air components that the level decreases from central Europe and north to Scandinavia and Iceland.

2. EMISSIONS

Official data on the emission totals of PAHs, PCDD/Fs, HCB, PCBs and HCH were reported by 35 countries for the period from 1990 to 2005 (for at least one year). The officially reported emission data are available from WEBDAB (http://webdab.emep.int). It should be pointed out that in recent years the number of countries that submit official information on spatial distribution of emissions and gridded sector data is increasing. Besides, three countries – Denmark, Norway and Sweden – presented information on spatial distribution of sea emissions.

2.1. Polycyclic aromatic hydrocarbons

Official data on the emission totals of polycyclic aromatic hydrocarbons (PAHs) were submitted by 34 countries for 1990-2005 (for at least one year).

According to the Protocol on POPs for the purposes of atmospheric emission inventories four indicator compounds of PAHs should be used. They are benzo[a]pyrene (B[a]P), benzo[b]fluoranthene (B[b]F), benzo[k]fluoranthene (B[k]F) and indeno[1,2,3-cd]pyrene (I_P) [*ECE/EB.AIR/60, Annex III*). This year, model runs have been performed for all of them. The official information on total emission of these four PAHs is available for 26 European countries for 1990-2005 (for at least one year). 20 countries, namely, Belarus, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, France, Germany, Hungary, Iceland, Ireland, Latvia, Lithuania, Monaco, Poland, Republic of Moldova, Romania, Slovakia, Switzerland and the United Kingdom submitted emissions of each from four indicator compounds for the considered period (for at least one year). The Russian Federation submitted only B[a]P emissions. For the remaining countries, unofficial emission data were used [*Baart et al.*, 1995; *Denier van der Gon et al*., 2005].

The information about PAH spatial distributions was provided by 23 countries (Austria, Belarus, Belgium, Bulgaria, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Monaco, Netherlands, Norway, Poland, Slovakia, Spain, Sweden, United Kingdom). Among them 15 countries (underlined) submitted gridded sector data. For the first time, Belarus, Estonia, Germany, Ireland, Italy and Sweden reported gridded emission data. For other countries, unofficial emission data were used [*Denier van der Gon et al*., 2005].

According to the official and unofficial emission data for the period from 1990 to 2005, European emissions of four indicator PAHs decreased by 23% - 28% depending on pollutant (Fig. 2.1, Table 2.1).

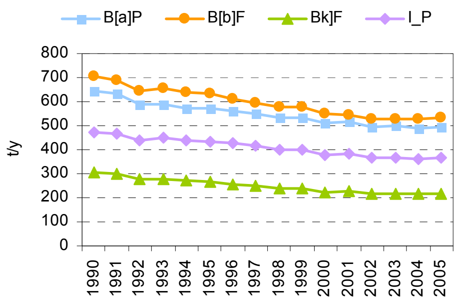


Fig. 2.1. *Time-series of PAH emissions*

Table 2.1. *Decrease of PAH emissions 1990-2005*

Pollutant	Decrease, %
B[a]P	24
B[b]F	24
B[k]F	28
I_P	23

Official information on emissions of four indicator PAHs by sectors in 2005 is available for 22 countries. The sector split for PAH emissions for these countries is presented in Fig. 2.2. The Residential sector is the major contributor, on average its share amounts to 65%. The predominant source in the Residential sector is combustion of wood. The second most important sector is the Metal Production. This sector is the largest source of PAHs for Norway and Switzerland.

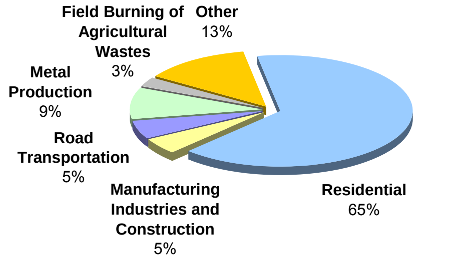


Fig. 2.2. *Sector split for PAHs emissions in 2005 (22 countries)*

The considerable contribution of the Residential sector to the total PAH emissions determines pronounced seasonal emission variation. At present, emission scenario taken from [*Baart et al.*, 1995], where the level of B[a]P emissions in winter is 10% higher than in summer is used for calculations and the same seasonal distribution of PAH emissions is used for all the countries. However, calculations, using this scenario, underestimate seasonal variations of B[a]P contamination levels (air concentrations and depositions) at some EMEP monitoring sites. The information on emission seasonal variations from Parties to the Convention is highly appreciated.

2.2. Dioxins and furans

Official data on total emissions of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) (sum of toxicities of 17 toxic PCDD/F congeners) were reported by 33 European countries and Canada for the period from 1990 to 2005 (for at least one year). For the remaining European countries, unofficial estimates of PCDD/F total emissions prepared by [*Denier van der Gon et al.*, 2005] were used. The PCDD/F emission value in the USA for 1995 is taken from the dioxin and furan inventories prepared by [*UNEP*, 1999].

The information about the spatial distribution of PCDD/F emissions was submitted by 23 countries (Austria, Belarus, Belgium, Bulgaria, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Monaco, Netherlands, Norway, Poland, Slovakia, Spain, Sweden, and the United Kingdom). Among them 16 countries (underlined) submitted gridded sector data. For the first time, Denmark, Estonia, Germany, Ireland, Italy and the United Kingdom reported gridded emission data. For the remaining European countries, unofficial data on spatial distribution of PCDD/F emissions were used [*Denier van der Gon et al*., 2005]. For the evaluation of the PCDD/F emission spatial distribution in the USA and Canada over the 2.5^0x2.5^0 calculation grid, data on the population density (1990) available in the Canadian Global Emissions Interpretation Centre (http://www.ortech.ca/cgeic) were used.

According to the official and unofficial emission data, the total emissions of PCDD/Fs in the northern hemisphere including the USA, Canada and European region decreased by 40% and 50%, respectively between 1990 and 2005 (Fig. 2.3). The total emissions of PCDD/Fs used for calculation in the northern hemisphere amounted to 9.6 kg TEQ in 2005, including 6.8 kg TEQ/y in Europe and 2.9 kg TEQ/y in North America. The decrease of the northern hemisphere emission of PCDD/Fs is mainly due to reduction in emissions in France, the Czech Republic, the United Kingdom, the Netherlands, Belgium, Bulgaria and Canada.

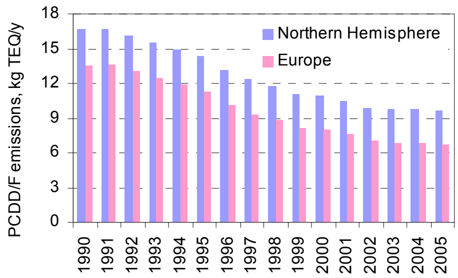


Fig. 2.3. *PCDD/F emissions in the northern hemisphere (USA and Canada) and European region for the period from 1990 to 2005*

According to the official data, PCDD/F emissions in most countries tend to decrease. The overall PCDD/F emissions in 24 countries reported data for both years 1990 and 2005 decreased by 75% (or 4 times). The maximum decrease of the PCDD/F emissions was reported by the Netherlands (27 times), and the maximum increase - by Latvia (2.7 times).

On the basis of the above data and using congener compositions of PCDD/F mixture in various European countries [*Pacyna et al.,* 1999] spatial distributions for all 17 toxic congeners of PCDD/Fs for the period from 1990 to 2005 were prepared.

Official information on emissions of PCDD/Fs by sectors in 2005 is available for 27 countries. The sector split for PCDD/F emissions for these countries is presented in Fig. 2.4. The largest contribution to the total PCDD/F emissions is made by the Residential sector (24%). This sector is the largest source of PCDD/Fs for Austria, Belgium, Denmark, Estonia, Lithuania, Norway, Poland and Slovenia. The next important sectors are the Manufacturing Industries and Construction, the Metal Production, the Waste Incineration and the Public Electricity and Heat Production.

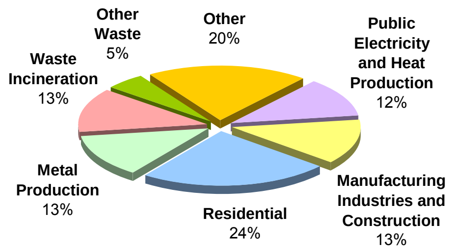


Fig. 2.4. *Sector split for PCDD/F emissions in 2005 (27 countries)*

2.3. Hexachlorobenzene

Official information about total emissions of hexachlorobenzene (HCB) was reported by 24 European countries and Canada for the period from 1990 to 2005 (for at least one year). For the remaining European countries and the European part of Russia, the HCB unofficial emissions prepared by [*Pacyna et al.*, 1999] were used. The HCB emission value in the USA is taken from the unofficial emissions by *R.Bailey* [2001]. The HCB emission value in Japan for 2002 is taken from the emission inventory of Japan prepared by *E.Toda* [2005]. The HCB emission values in China, Pakistan, Republic of Korea and the Asian part of Russia were estimated on the basis of the relationship of the gross domestic product and official HCB emission data for 2005 taken for countries with similar economic indexes. The HCB emission value in India is taken from the EMEP Technical Report 7/2005 [*Shatalov et al.*, 2005].

The information on the spatial distribution of HCB emissions was submitted by 12 countries (Austria, Belarus, Belgium, Bulgaria, Finland, France, Germany, Ireland, Latvia, Poland, Slovakia and Spain). Among them 8 countries (underlined) submitted gridded sector data. For the first time, Belarus, Bulgaria, Finland, Germany and Ireland reported gridded emission data. For the remaining European countries unofficial data on spatial distribution of HCB emissions were used [*Pacyna et al.,* 1999]. For the evaluation of the HCB emission spatial distribution in the northern hemisphere over the 2.5^o x2.5^o calculation grid, data on the population density (1990) available in the Canadian Global Emissions Interpretation Centre (http://www.ortech.ca/cgeic) were used.

For the evaluation of HCB intercontinental transport within the northern hemisphere spatial distribution of available emissions was aggregated into five groups of emission sources presented in Fig. 2.5.

According to the official and unofficial emission data, the total emissions of HCB in the northern hemisphere and European region decreased by 7% and 22%, respectively between 1990 and 2005 (Fig. 2.6). The total emissions of HCB in the northern hemisphere amounted to 89 t in 2005, including 11.8 t in North America, 36.4 t in Central Asia, 14.2 t in South-eastern Asia, 13.8 t in Europe and 12.8 t in Russia.

Following the official data, the total HCB emissions in 18 countries submitted data for both years 1990 and 2005 decreased 1.5 times. The maximum emission decrease was reported by France (65 times), and the maximum increase - by Estonia (2.5 times).

Fig. 2.5. *Splitting of HCB emissions into groups of sources*

Official information on emissions of HCB by sectors in 2005 is available for 21 countries (Fig. 2.7). The maximum contribution to the total HCB emissions is made by the Metal Production sector (22%). The second most important sector is the Residential. This sector is the largest source of HCB for Austria, Estonia, Germany, Latvia and Sweden.

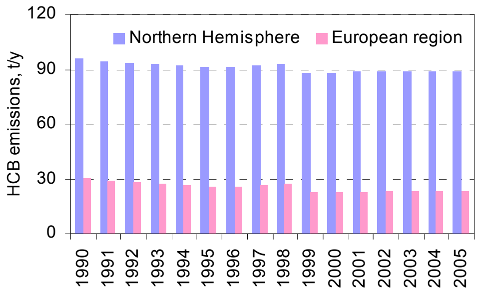


Fig. 2.6. *HCB emissions in the northern hemisphere and European region for the period from 1990 to 2005*

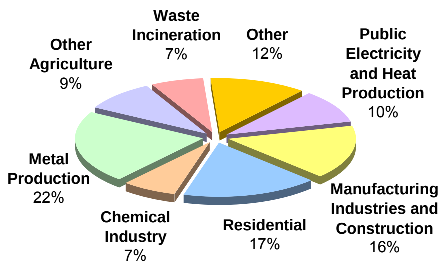


Fig. 2.7. *Sector split for HCB emissions in 2005 (21 countries)*

2.4. Polychlorinated biphenyls

Official information on total emissions of polychlorinated biphenyls (PCBs) was submitted by 20 countries for the period from 1990 to 2005 (for at least one year). According to the official data, the total PCB emissions in 13 countries submitted data for both years 1990 and 2005 decreased by approximately 60%. The most significant decrease of emission was reported by the Czech Republic (9.4 times), and the maximum increase - by Monaco (10%). The information about the spatial distribution of PCB emissions was submitted by <u>Belarus</u>, Bulgaria, Finland, <u>France</u>, <u>Germany</u>, <u>Latvia</u>, <u>Lithuania</u> and Poland. Among them 5 countries (underlined) submitted gridded sector data. For the first time, Belarus, Bulgaria, Germany and Poland reported gridded emission data.

Official information on emissions of PCB by sectors in 2005 is available for 15 countries. The maximum contribution to the total PCB emissions is made by the Metal Production sector (20%). The next important sector is the Residential. This sector is the largest PCB sources for Bulgaria, France and Latvia.

The modeling of PCB long-range transport for the period from 1990 to 2005 was performed for 3 individual PCB congeners (28, 118, 153). Emission data of 3 PCB congeners were taken from the global emission inventory of 22 PCB congeners [*Breivik et al.,* 2002b; *Breivik et al.,* 2007]. According to these unofficial emission data on PCB, total annual emission of PCB-153 within the northern hemisphere for 2005 amounted to 11 t, including 2.3 t in America, 5.1 t in Europe, 1.5 t in Africa and Central Asia, 0.7 t in South-eastern Asia and 0.9 t in Russia.

Fig. 2.8. *Splitting of PCB emissions into groups of sources*

For the evaluation of intercontinental transport of selected PCB congeners the spatial distribution of their emissions within the northern hemisphere was split into five groups (Fig. 2.8). For these five groups the gridded emissions for selected three PCB congeners were prepared.

2.5. Hexachlorocyclohexane

Official data on the emission totals of gamma-hexachlorocyclohexane (γ-HCH) were submitted by 11 European countries for the period from 1990 to 2005 (for at least one year). Official information on usage of technical HCH and lindane was reported by 11 European countries for the considered period (for at least one year). For the remaining European countries, the compilation of the unofficial emission data prepared by [*Pacyna et al.*, 1999] and [*Denier van der Gon et al.*, 2005] was used. The γ-HCH emission values in Canada, the USA, and Mexico for 1990 and China for 1990 and 1995 were estimated on the basis of the γ-HCH application in these countries [*Shatalov et al.*, 2003 (*Li et al.*, 1996; *Macdonald et al*., 2000) and *Gusev et al.*, 2005 (*Li et al.*, 2001)]. For Canada, the USA and Mexico for 2000 and 2002, unofficial estimates of γ-HCH emission prepared by [*Li,* 2004] were used.

The information on spatial distribution of γ-HCH emissions and gridded sector data was submitted by Belgium, Germany and Spain. For the first time, Belgium and Germany reported gridded emission data. For the remaining European countries unofficial data on spatial distribution of γ-HCH emissions were used [*Pacyna et al.*, 1999; *Denier van der Gon et al*., 2005]. The spatial distribution of γ-HCH emissions in North America was prepared by *Dr.Y.-F.Li* [2004]. For the evaluation of the γ-HCH emission spatial distribution in China over the 2.5^0x2.5^0 calculation grid, data on using cropland area (1990) available in the Canadian Global Emissions Interpretation Centre (http://www.ortech.ca/cgeic) were used.

For the evaluation of intercontinental transport γ-HCH sources of the northern hemisphere were split into three groups of emission sources, in particular, Europe, North America, and China (Fig. 2.9). For these groups gridded emission data for the period from 1990 to 2005 were prepared.

According to the official and unofficial emission data, the total emissions of γ-HCH in the northern hemisphere and European region decreased in period 1990-2005 by 79% and 98%, respectively. The total emissions of γ-HCH in the northern hemisphere amounted to 301 t in 2005, including 71 t/y in North America, 200 t/y in China and 30 t/y in Europe.

Official information on emissions of γ-HCH by sectors is available for Belgium, Croatia, Germany, Romania, Spain and the United Kingdom for the period from 1990 to 2005 (for at least one year). In Belgium and the United Kingdom the maximum contribution to the total γ-HCH emissions is made by the Solvent and Other Product Use (Other sector). In Croatia, Germany, Romania and Spain γ-HCH emissions from the Agriculture (Other sector) contributed most of all to the total γ-HCH emissions.

Fig. 2.9. *Splitting of γ-HCH emissions into groups of sources*

3. MODEL DEVELOPMENT

This year MSC–East continues further development of the MSCE-POP regional model in accordance with recommendations of the EMEP/TFMM Workshop on the review of MSC-E models. Main directions of model modification mentioned in the work plan are to refine datasets of physical-chemical properties used in modelling; to develop the model parameterization for POP re-suspension; to improve the model description of degradation in the atmosphere, deposition processes, volatilization from soils and seasonal variations of main processes.

The work on the refinement of photolytic degradation of POPs is being continued. It is found from the literature that photodegradation of PCDD/Fs on the airborne particles seems to be negligible. However, this process can be essential on leaf surfaces due to the presence of cuticular waxes. This process is planned to be investigated in future.

In the frame of the preparatory work on application of inverse modelling for selected POPs on the basis of measurement data, the elaboration of a tool for determination of main source regions with maximum contributions to the contamination at a given point for various time periods has been begun. This tool is based on calculations of backward trajectories of atmospheric transport from meteorological data used for applications of MSCE-POP model. This work is ongoing (see [*Gusev et al.*, 2007]).

This year the work on model development was focused on the refinement of model description of deposition to different types of underlying surface, on investigation of possible influence of re-suspension process to air concentrations and depositions of POPs, and on the refinement of data on specific aerosol surface.

3.1. Improvement of the land use input data

At present the following 9 land cover types are considered in the model:

- water (oceanic water and inland water);
- deciduous forest;
- coniferous forest;
- grassland;
- scrubs;
- arable land;
- bare soil;
- urban areas;
- permanent ice.

In comparison of previous model design, two land cover types – scrubs and arable lands – are added. It is important, in particular, for model parameterization of re-suspension process.

The scheme of calculating dry deposition velocities to each of the above listed land cover types was refined. In particular, values of friction velocity are calculated for each land use type separately. The details can be found in the description of HM model [*Travnikov and Ilyin,* 2005]. Parameterization of dry deposition requires also some characteristics of the ground surface depending on a land cover category (roughness length, height of vegetation canopy, displacement heights). These characteristics vary from season to season. In the model, five different seasonal categories are considered [*Gusev et al.*, 2007].

Widening of the list of land use types considered in the model allows also producing data on deposition of POPs to different ecosystems. As an example, deposition density for B[a]P in 2005 to deciduous forest and arable lands calculated by regional version of MSCE-POP model are shown in Fig. 3.1.

Calculations show that deposition densities can vary several times depending on surface type. For example, deposition densities to deciduous forests in Germany range from 20 to 200 g/km^2/y whereas depositions to arable lands are in the range from 5 to 50 g/km^2/y over the country. Such type of information may be useful for POP risk assessment for various ecosystems.

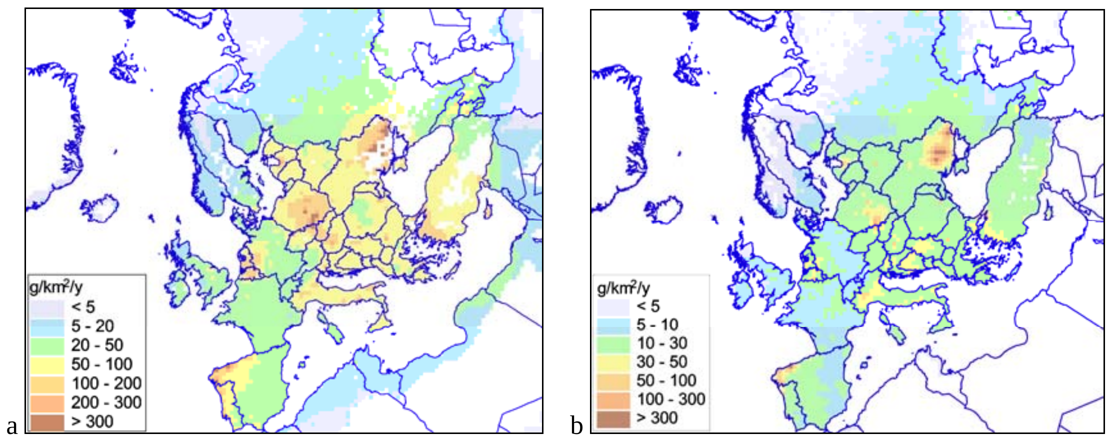


Fig. 3.1. *Depositions of B[a]P to deciduous forests (a) and arable lands (b) in 2005 (annual means), g/km^2/y*

3.2. Evaluation of resuspension process for B[a]P

To evaluate the contribution of re-suspension process to calculated values of air concentrations and depositions, the following calculation experiment was performed. Two model runs for calculations of the B[a]P transport in 2004 with and without taking into account re-suspension process with the same emission and initial data were performed. In these runs a preliminary parameterization of re-suspension process is used. Parameterization of particulate flux from soil and seawater [*Travnikov and Ilyin*, 2005] is applied. Then re-suspension flux is evaluated using particulate flux and concentrations of B[a]P in soil and seawater. According to the model parameterization, re-suspension can occur from arable lands, bare soil and urban territories.

The map of soil concentrations calculated in the EMEP region for 2004 together with the map of annual re-suspension flux are shown in Fig. 3.2.

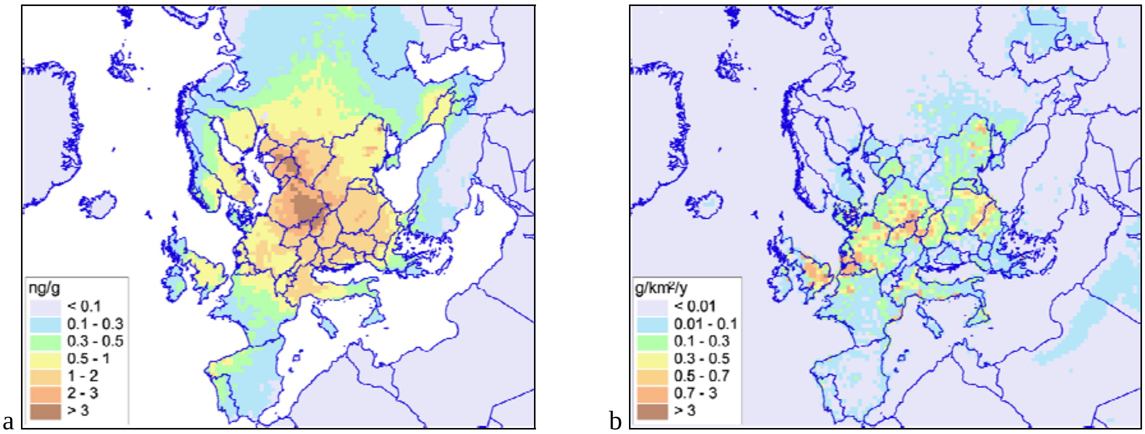


Fig. 3.2. *Soil concentrations of B[a]P, ng/g (a) and re-suspension flux, g/km^2/y (b) in 2004*

It is seen that the spatial distribution of re-suspension flux correlates with that of soil concentrations. Higher values of re-suspension flux in northern Africa where soil concentrations are very low are explained by elevated dust flux in this region.

It should be mentioned that re-suspension flux is considerably lower than the flux of anthropogenic emissions in 2004 (Fig. 3.3).

However, due to low values of emission flux and relatively high re-suspension flux in the UK, the values of re-suspension and anthropogenic emission fluxes in this region are comparable.

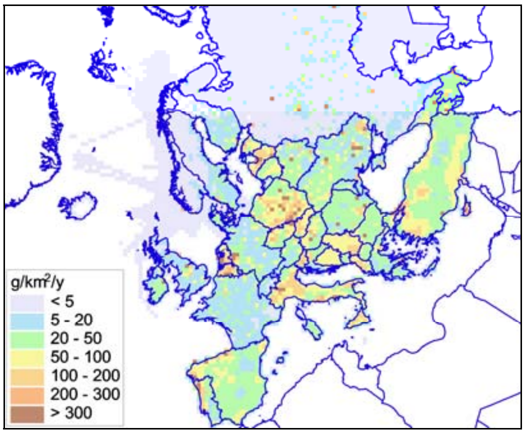


Fig. 3.3. *Anthropogenic emissions of B[a]P, in 2004, g/km^2/y*

For more detailed comparison of re-suspension flux with the flux of anthropogenic emissions three grid cells were chosen. First cell is located in the United Kingdom (cell 52, 39), second – on the border between France and Germany (cell 66, 40) and the third – in the Netherlands (cell 60, 45). The ratio of re-suspension flux to anthropogenic emissions for the three considered cells is presented in the plot in Fig. 3.4.

The latter plot shows that the influence of re-suspension in cell (52, 39) can lead to noticeable changes in the model output (air concentrations and depositions) since re-suspension flux in this cell is considerable in comparison with the anthropogenic emissions (it amounts to about 17% of emissions). On the opposite, the influence of re-suspension to air concentrations and depositions will be negligible in the rest two cells due to higher emissions and lower values of re-suspension flux.

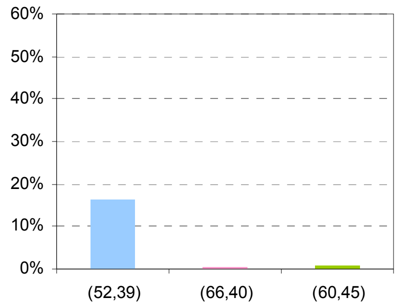


Fig. 3.4. *Ratio of re- suspension flux to anthropogenic emissions in the three considered cells*

The input of B[a]P to the atmosphere is determined by three processes: anthropogenic emissions and re-suspension and re-volatilization from the underlying surface. The last two processes are considered as re-emissions (or secondary emissions). To analyze the influence of re-suspension on model output the contributions of re-suspension process to the overall re-emission flux was also evaluated.

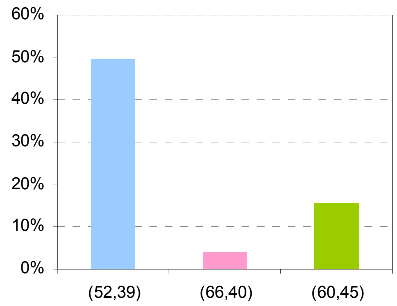


Fig. 3.5. *Contribution of re- suspension flux to re-emissions in the three considered cells, %*

The contribution of re-suspension flux to total re-emissions is displayed in Fig. 3.5. Calculations show that maximum contributions of re-suspension to total re-emission flux (about 50%) takes place in cell (52, 39). The contribution of re-suspension to re-emission flux in cell (60, 45) is much lower – 15%. Finally, the contribution of re-suspension in cell (66, 40) is almost negligible – 5% only. So again it is seen that the influence of re-suspension will be maximum in cell (52,39) located in the UK among the three considered cells.

Let us consider the influence of re-suspension to the model output for the UK as a whole. The contribution of re-suspension flux in the UK to overall re-emission flux amounts up to 70% and more depending on location (Fig. 3.6).

Essential re-suspension flux in the UK leads to diminishing of net depositions since the pollutant is partly removed from UK soils by re-suspension process therefore diminishing B[a]P loads to the territory of the country. The decrease of net deposition flux reaches about 20 – 30% (Fig. 3.7).

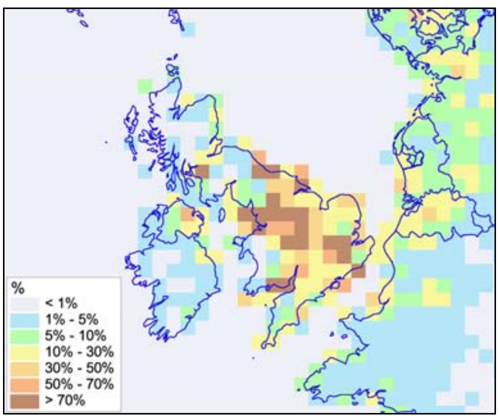


Fig. 3.6. *Contributions of re-suspension flux to re-emissions in the UK, %*

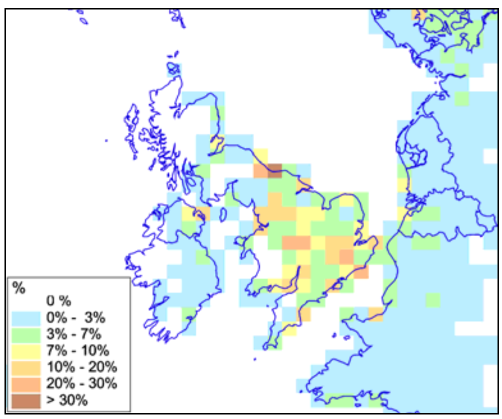


Fig. 3.7. *The decrease of net deposition flux in UK, %*

Concerning balance values, it was found that they are not noticeably changed by the inclusion of re-suspension process to the model. In particular, air content on the monthly level is changed not more than by 0.5%, the re-emission flux over the whole Europe has been increased not more than by 7%. Besides, slight decrease of soil concentrations due to re-suspension takes place.

The reason of such low sensitivity of balance values to the inclusion of re-suspension process can be explained by the fact that re-suspension intensity for POPs is considerably lower than the intensity of re-volatilization. According to calculations, re-suspension velocity (determined by the value of dust flux from the surface) is one or two orders of magnitude lower than re-volatilization velocity [*Gusev et al.*, 2007]. However, under some specific conditions re-suspension can contribute essentially to the total re-emission flux.

So, the contribution of re-suspension flux can be valuable under specific conditions in some areas inside the EMEP grid. The work on refinement of model parameterization of re-suspension process is ongoing.

3.3. Refinement of aerosol and OH-radical spatial distribution

Aerosol. Spatial and temporal distribution of atmospheric particles used in modelling strongly influences model results. In particular, values of specific aerosol surface determine model description of gas/particle partitioning. This in turn makes an impact upon degradation rates since degradation of POPs in gaseous and particulate phases comes with different speed. So, refinement of spatial and temporal resolution of the data on specific aerosol surface can lead to essential refinement of model description of seasonal variations of pollution.

An attempt to solve this problem was made with the help of CMAQ (Community Multiscale Air Quality modeling system) developed by the US Environmental Protection Agency (US EPA). This system is widely used by modelling community and can be adapted to calculations in the EMEP grid.

With the help of CMAQ model data on 3d-spatial and temporal distribution of specific aerosol surface in the EMEP grid (50 × 50 km) with temporal resolution of 6 hours were prepared for 2000.

Spatial distributions of specific aerosol surface (PM 2.5) in the lower atmospheric layer and temporal variations of this parameter averaged over land territories within the EMEP grid are shown in Fig. 3.8.

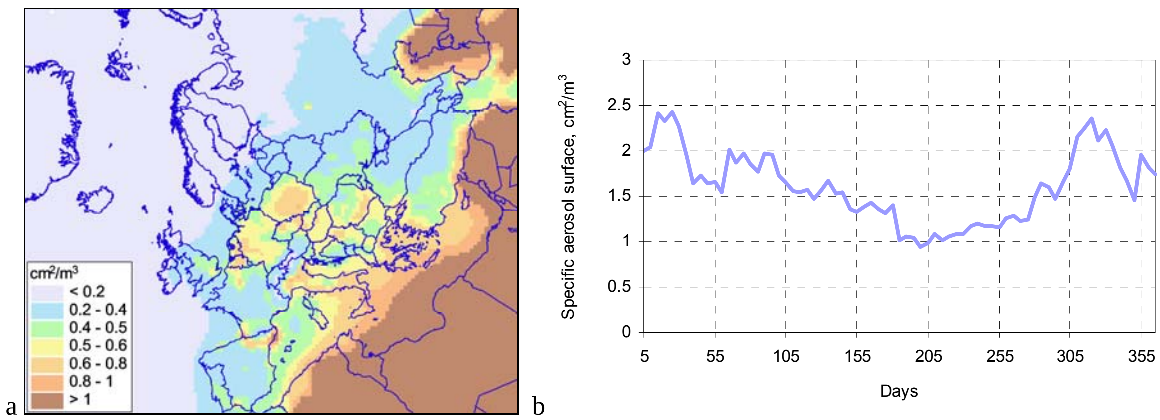


Fig. 3.8. *Spatial distribution of annual averages of specific aerosol surface (a) and its temporal variations (b), cm^2/m^3*

It is seen that high values of specific aerosol surface are characteristic of southern region of the EMEP domain (in particular, of Sahara region), see Fig 3.8a. Relatively high values of specific aerosol surface are calculated for some regions of central and southern Europe. Northern and western parts of Europe are characterized by low values of specific aerosol surface.

Temporal variations of specific aerosol surface in the lower atmospheric layer (averaged over land territories) are shown in Fig. 3.8b. It is seen that averages over land vary within a year about 2.5 times. Higher values of specific aerosol surface are calculated for winter time and lower values – in summer time.

To evaluate changes in calculations of pollution levels due to refinement the data on specific aerosol surface, model runs for B[a]P in 2000 with previous and refined data were performed. Emission and meteorological data in both of these runs are one and the same. Calculation results were then compared with available measurements.

The comparison of calculated and measured values at some EMEP sites is shown in Fig. 3.9.

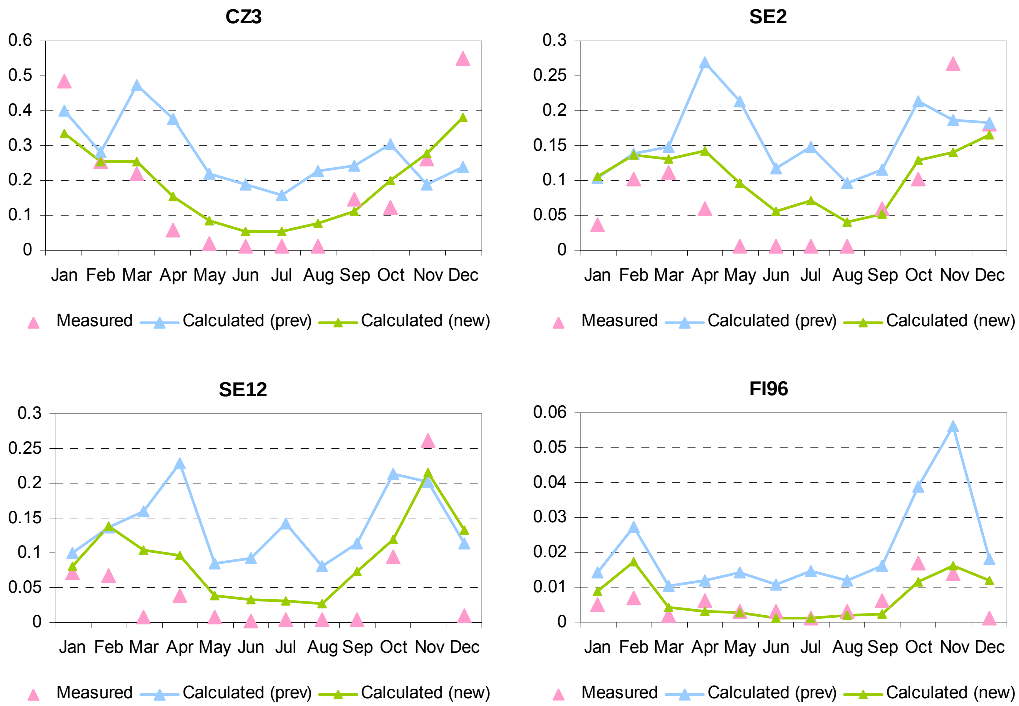


Fig. 3.9. *Comparison of air concentrations of B[a]P calculated with previous and refined data on specific aerosol surface with measurements at EMEP sites for 2000, ng/m*^{3}

It is seen that the refinement of the data on specific aerosol surface leads to essential improvement of the agreement between measurements and calculations.

OH-radical. Another parameter strongly influencing model output is atmospheric concentrations of OH-radical. These concentrations determine model description of atmospheric degradation of POPs and, as a consequence, affect calculated values of atmospheric concentrations and depositions.

Spatial distribution of OH-radical concentrations in surface air layer (annual averages) calculated with the help of CMAQ model is presented in Fig. 3.10. These concentrations are characterized by pronounced latitudinal distribution with lower values at high latitudes.

Concentrations of OH-radical are subject to strong temporal variations. As an example, variations of OH-radical concentrations in February and July with temporal resolution 6 hours for the grid cell located in southern part of Italy are shown in Fig. 3.11. One can see that, first, concentrations in a cold period of year are essentially lower than in warm one and, second, that OH-radical concentrations are subject to significant diurnal variations. The day/night difference of OH-radical concentrations can reach more than an order of magnitude.

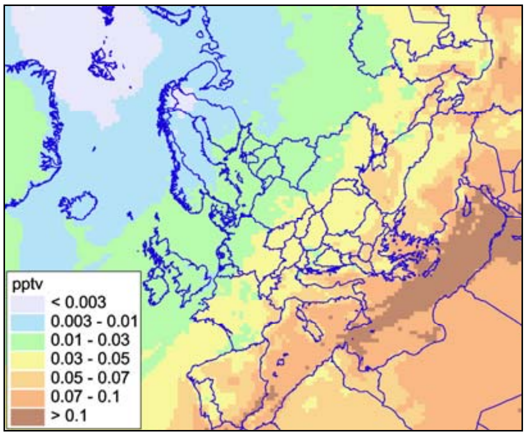
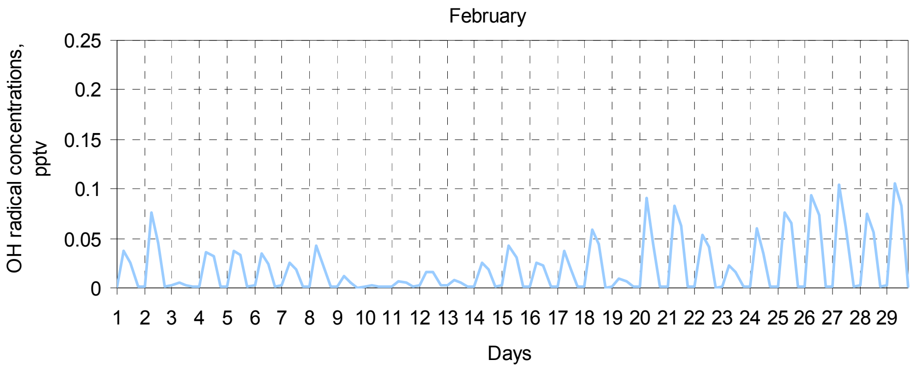
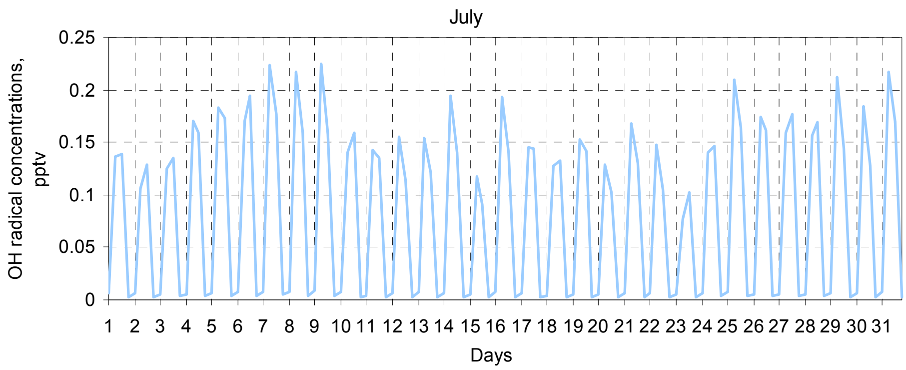


Fig. 3.10. *Spatial distribution of OH-radical concentrations in surface air layer, pptv*

Evaluation of the generated data on OH-radical concentrations with regard to their use in MSCE-POP model calculations is now ongoing.



a



b

Fig. 3.11. *Trend of OH-radical concentrations in cell (90, 36) (southern part of Italy) in February (a) and July (b), pptv*

4. EVALUATION OF POP TRANSPORT AND POLLUTION LEVELS IN THE ENVIRONMENT

Environmental contamination and transboundary transport of PAHs (4 indicator congeners), PCDD/Fs (the sum of toxic congeners), PCBs, γ-HCH and HCB for 2005 are evaluated. The calculations are performed by the improved version of MSCE-POP model (see Chapter 3). Emission data used in modelling are described in Chapter 2. For PCDD/Fs trends of pollution from 1990 to 2005 and possible emission reduction scenarios up to 2020 under different emission scenarios are examined.

Calculations for PAHs are carried out at regional scale for 2005 only. The results are compared with available measurement data from EMEP monitoring network.

For PCBs, HCB, and γ-HCH the emphasis was put on the evaluation of intercontinental transport of these pollutants.

4.1. Pollution levels and source-receptor relationships in the EMEP domain

This section presents the results of the evaluation of pollution levels of PCDD/Fs and four indicator PAHs (B[a]P, B[b]F, B[k]F, and I_P) within the EMEP region for 2005. For B[a]P and PCDD/Fs (with properties of “indicator congener” 2,3,4,7,8-PeCDF) source-receptor relationships in 2005 are investigated. In addition, trends of PCDD/F contamination in European countries and the influence of possible emission scenarios to the contamination of the EMEP domain up to 2020 are examined.

4.1.1. Polychlorinated dibenzo(p)dioxins and dibenzofurans (PCDD/Fs)

Calculations of pollution levels of polychlorinated dibenzo(p)dioxins and dibenzofurans (PCDD/Fs) in the EMEP region were performed for total PCDD/F toxicity with use of physical-chemical properties of “indicator congener” 2,3,4,7,8-PeCDF. Usage of such an approach allows evaluating spatial distributions of the total PCDD/F toxicity in the atmosphere with difference not more than 20% compared with the results of simulations of all 17 toxic congeners (see EMEP Status Report [*Dutchak et al.,* 2004]). The emission data used in the calculations are based on official and unofficial emission data when official information is not available (see Section 2).

Evaluation of pollution levels of PCDD/Fs in Europe was carried out with the help of hemispheric/regional approach. Namely, first PCDD/F transport for the period from 1970 to 2005 was simulated by hemispheric model version to obtain initial and boundary conditions for regional simulations. Spatial distribution of air concentrations in the Northern Hemisphere and in the EMEP region in 2005 is shown in Fig. 4.1. We recall that at present only emissions of USA and Canada are considered as non-EMEP sources.

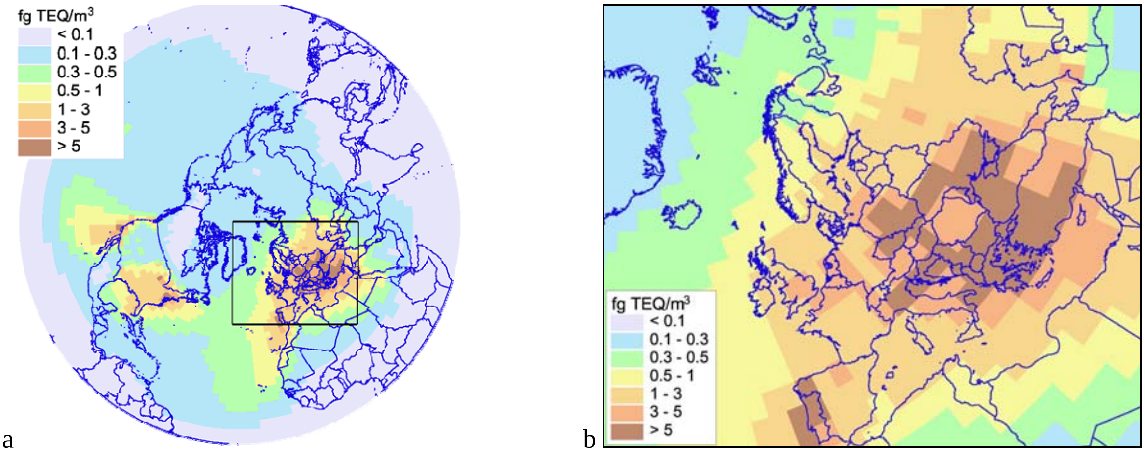


Fig. 4.1. *Air concentrations of PCDD/Fs in 2005 within the northern hemisphere (a) and in the EMEP region (b), fg TEQ/m^3*

The results of the hemispheric calculations were used for obtaining initial and boundary conditions for regional evaluation of pollution levels and source-receptor relationships in the EMEP domain. These results allow encountering the influence of non-EMEP sources (USA and Canada) and of pollutant accumulated in the environmental media within the preceding period (re-emission). These results were also used for evaluation of long-term trends of pollution within the whole northern hemisphere and in particular European countries.

Long-term trends of pollution

Calculations of pollution levels by PCDD/Fs for a long-time period allow evaluating temporal trends of media pollution in the northern hemisphere as a whole and for particular European countries.

The trends of air and soil content in northern hemisphere for the period prior to 2005 in comparison with trend of emissions is shown in Fig. 4.2.

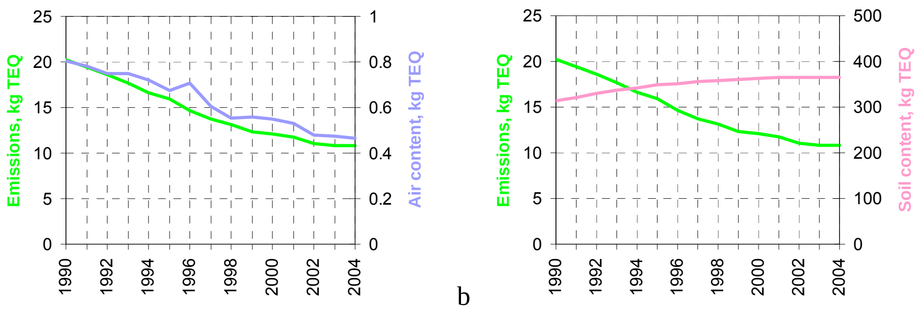


Fig. 4.2. *Comparison of PCDD/F emission trend in the northern hemisphere with the contents in the atmosphere (a) and soil (b), kg TEQ*

Calculated trends show that under emission reduction of about 47% in the northern hemisphere air content was reduced by about 42% only, and no decrease of soil content within the considered period takes place. This leads to a conclusion that PCDD/F air pollution levels are supported by re-emission from soils. The role of re-emission process in a particular country is different and is determined by its geographic location, reduction of national emissions, meteorological conditions and other reasons. Let us illustrate this by the examples of two European countries: the UK and the Czech Republic.

Trends of air and soil concentrations in **the United Kingdom** in comparison with that of emissions are shown in Fig. 4.3.

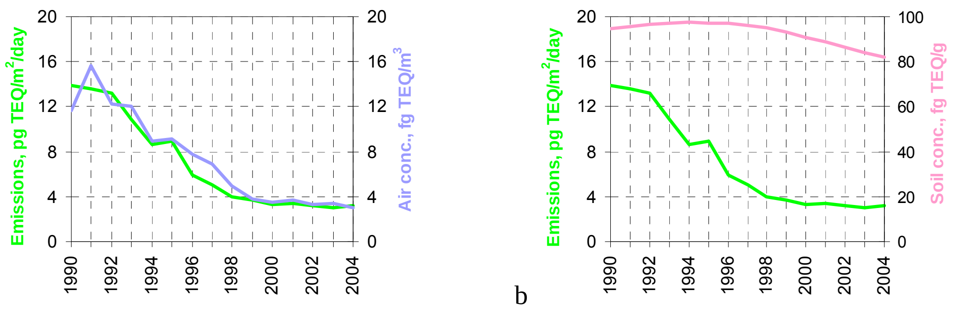


Fig. 4.3. *Comparison of PCDD/F emission trend in the United Kingdom with the concentrations in the atmosphere (a) and soil (b)*

Strong emission decrease is characteristic of the UK. Within the period from 1990 to 2004 UK emissions have been reduces 4.4 times. It is seen that the trend of atmospheric concentrations in general follows emission trend (Fig.4.3a). In contrast to the case of the whole Europe, soil concentrations are characterized by decreasing trend beginning from 1996 (Fig.4.3b). This decrease goes much slower than the decrease of emissions. Strong emission reduction together with slow decrease of soil concentrations leads to the increasing role of re-emission in contamination of the country. The plot of re-emission/emission ratio in the UK is shown in Fig. 4.4.

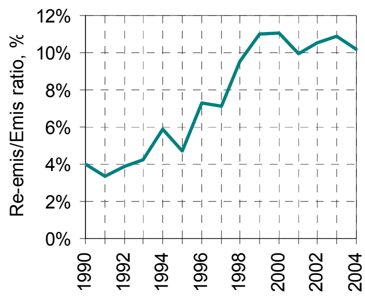
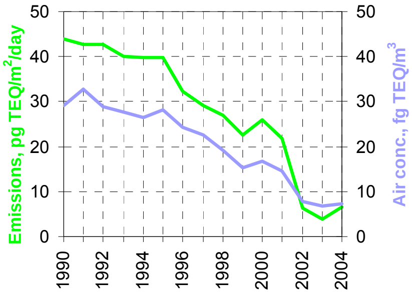


Fig. 4.4. *Re-emission/emission ratio in the United Kingdom, %*

It is seen that in the end of evaluation period re-emissions amount to about 10% of the anthropogenic emissions. Hence, in evaluation of source-receptor relationships for PCDD/Fs re-emissions are to be taken into account.

The decrease of emissions in the Czech Republic is even stronger than in the UK (Fig. 4.5). In the Czech Republic PCDD/F emissions reduced 6.7 times in comparison with 1990. Under such strong emission reduction the decrease of air concentrations is much slower (4 times only). The decrease of soil concentrations begins later than in the UK – in 1998. So, it can be expected that the contribution of re-emissions to the atmospheric contamination of the Czech Republic is higher than for UK.



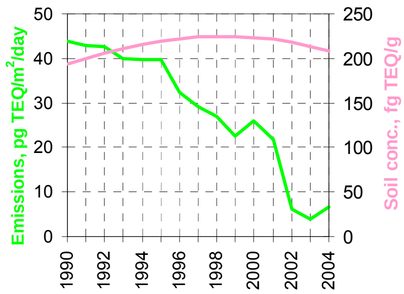


Fig. 4.5. *Comparison of PCDD/F emission trend in the Czech Republic with the concentrations in the atmosphere (a) and soil (b)*

Calculations show that re-emission/emission ratio in the end of evaluation period is 20%. It is also interesting that this parameter is subject to strong seasonal variations. The plot of monthly averaged re-emission/emission ratio for the Czech Republic is given in Fig. 4.6.

It is seen that re-emission flux in the Czech Republic varies from 5% in winter time to about 45% in summer time.

More detailed information about trends of PCDD/F pollution in the EMEP region can be found in [*Gusev et al.*, 2007].

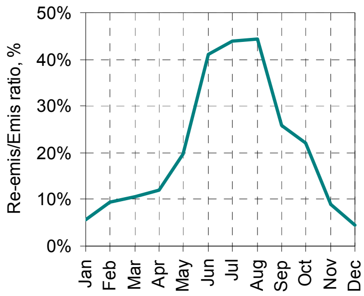


Fig. 4.6. *Seasonal variations of re-emission/ emission ratio in the Czech Republic, %*

Pollution levels in the EMEP region in 2005

Calculations of pollution levels of PCDD/Fs in 2005 was performed by regional MSCE-POP model with initial and boundary conditions obtained by the above-described hemispheric model run (1970 – 2005). Such an approach allows encountering the contributions from non-EMEP sources (USA and Canada) and of re-emissions due to long-term accumulation in the environmental media.

The map of spatial distribution of PCDD/F toxicity in depositions in the EMEP region is presented in Fig. 4.7.

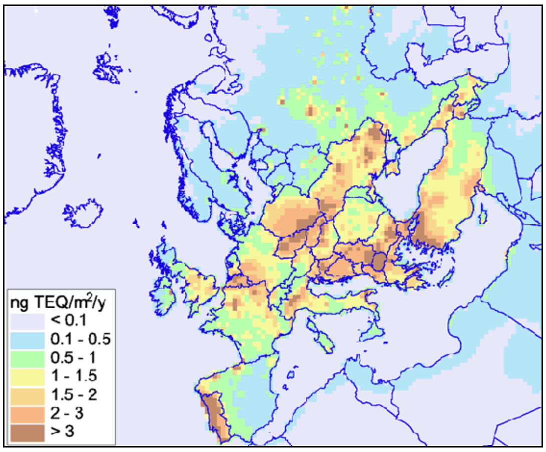


Fig. 4.7. *Calculated deposition fluxes of PCDD/Fs in 2005, ng TEQ/m^2/y*

The levels of net deposition flux in Europe in 2005 are low enough (about 0.1 ng TEQ/m^2/y) in northern Europe (Norway, northern parts of Sweden and Finland). Higher values of deposition levels (1 – 3 ng TEQ/m^2) due to higher emission densities are calculated for Ukraine and part of Turkey. The highest depositions (up to 3 ng TEQ/m^2/y and higher) are calculated for central and southern Europe (Poland, Czech Republic, Macedonia, Serbia and Montenegro, Portugal).

Pollution levels calculated for 2005 are considerably less than the results earlier obtained for 2004. The reason is that the total value of refined emissions of PCDD/Fs in Europe decreased by about 40% compared that used in calculations in the preceding year. Most essential changes of official emission data take place for Germany (73.7 g TEQ instead of 3280 g TEQ in the former year). Emission data for PCDD/F require further refinement for sources both of European countries and of the entire northern hemisphere.

Contamination levels of PCDD/Fs obtained by calculations are formed by various groups of sources. These are anthropogenic emission sources of European countries, hemispheric anthropogenic sources located outside the EMEP region (USA and Canada) and re-emissions due to long-term accumulation. Contributions of all these sources to the contamination of EMEP region will be considered in the following section.

Transboundary transport

Here we present evaluation of contributions of different source categories to the pollution levels of each European country. The following source groups are considered for evaluation of source-receptor relationship for PCDD/Fs:

- Anthropogenic sources of each European country.
- Anthropogenic sources including emissions outside the EMEP region (emissions of USA and Canada further referred as non-EMEP sources).
- Re-emission due to accumulation of PCDD/Fs in the environmental media from anthropogenic emission sources of the entire northern hemisphere during the preceding years.

Each European country is considered as a separate receptor.

Source-receptor matrices for PCDD/Fs in 2005 were calculated both for deposition and for air concentrations. Below we illustrate source-receptor relationships by the example of deposition matrix. The full set of data on source-receptor deposition matrix is given in Annex B. The data on source-receptor matrix for air concentrations and depositions are available in the Internet (www.msceast.org).

As a result of the model calculations we obtain the set of spatial distributions of pollution caused by each particular source (anthropogenic emissions of each European country, anthropogenic emissions of all non-EMEP sources and re-emissions). On the basis of spatial distribution of depositions caused by each source, source-receptor relationships in the EMEP region are evaluated. Further we characterize export of pollution from and import to each European country.

Export means the contribution of anthropogenic emission sources of each particular country (source) to the depositions to the territories of other countries (receptors).

Import is the set of contributions of particular sources (EMEP countries, non-EMEP sources and re-emissions) to deposition levels in a given country (receptor).

Below the results of calculations of source-receptor relationships are presented.

Export. For first (rough) evaluation of export from a country total depositions to EMEP region from national anthropogenic sources are split to the following two values: depositions to the territory of the country and depositions to the rest EMEP territory (Fig. 4.8).

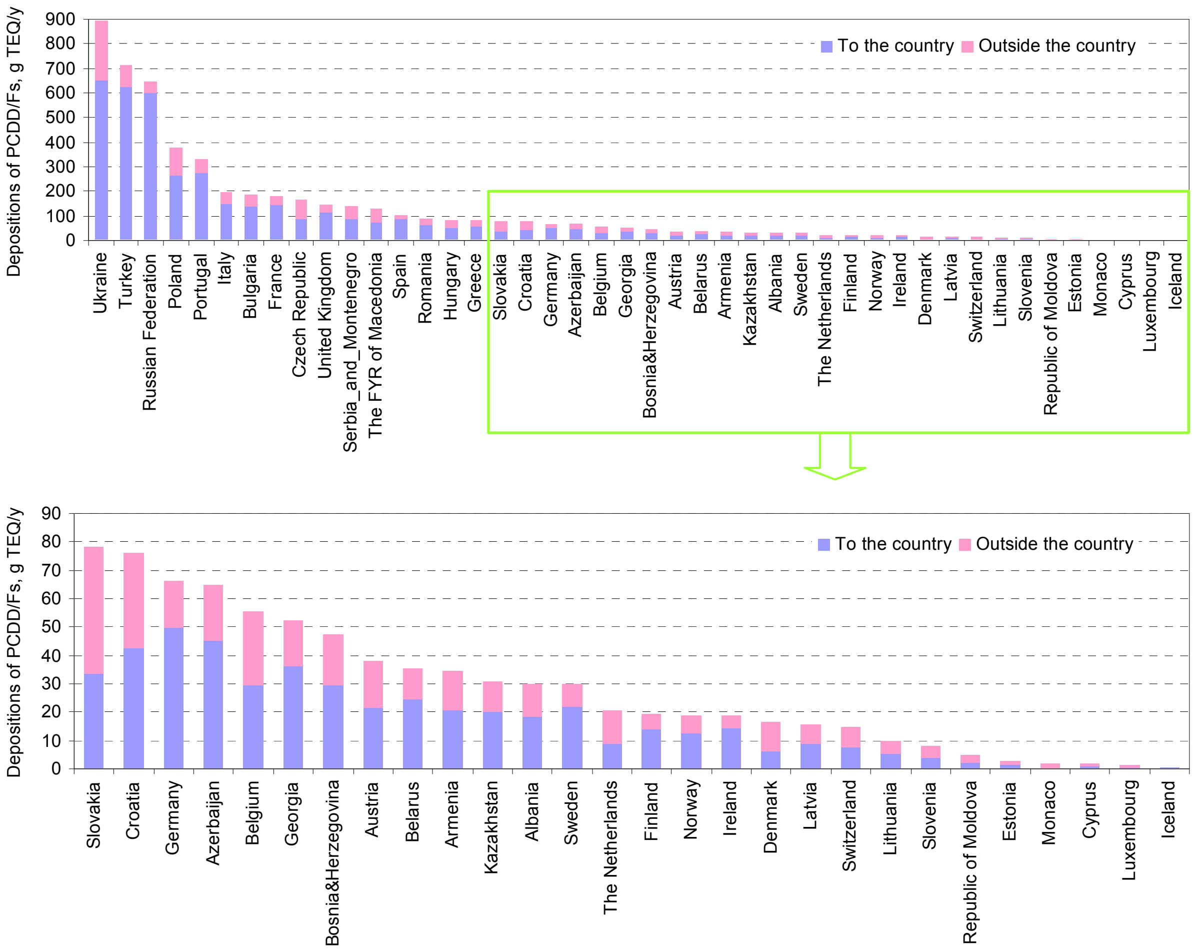


Fig. 4.8. *Depositions of PCDD/Fs to the own territory and to the rest EMEP territory due to national emissions of European countries, g TEQ/y*

The values of depositions to the entire EMEP region caused by sources of particular European countries vary from 1 g TEQ/y to about 900 g TEQ/y.

The export from a particular country can be also characterized by export fraction. This is the fraction of all depositions caused by national sources falling to the territory of the rest European countries. The plot of export fractions for all European countries is displayed in Fig. 4.9. These fractions depend significantly on the geographic location of a given country, size of its territory, and spatial distribution of emission sources within the country. Typically, about 30 – 50% of depositions caused by national emission sources of a country are deposited outside this country. Significant export fractions (about 60% and more) are characteristic of Monaco, Luxembourg and Denmark.

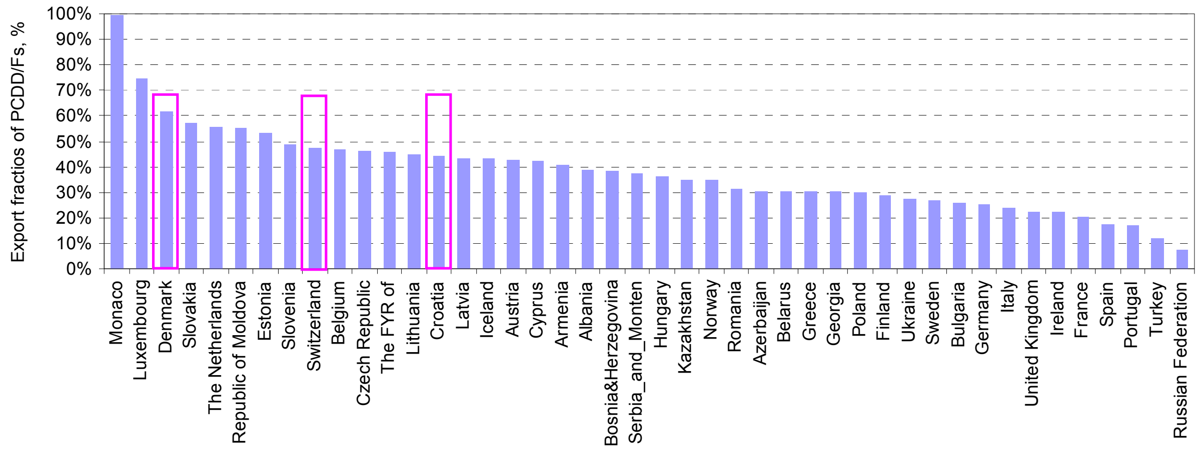


Fig. 4.9. *Export fractions of PCDD/Fs for European countries, %*

The information on the export can be presented in a more detailed way representing the distribution of depositions due to the country's sources between surrounding countries. For illustration three countries (marked in Fig. 4.9) − Denmark, Switzerland and Croatia − are chosen. The plots of export from these countries are shown in Fig. 4.10.

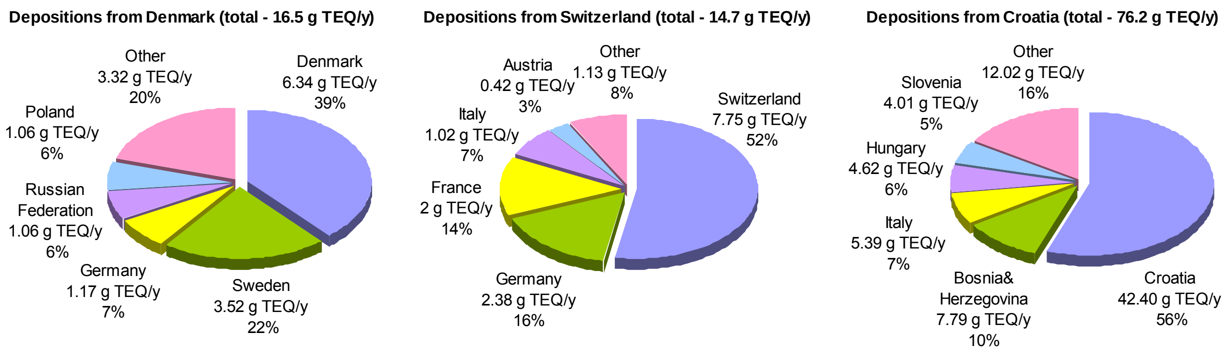


Fig. 4.10. *Export from some countries, % of depositions*

For example, for Denmark depositions originated from national sources (totally 16.5 g TEQ/y) are distributed between Denmark itself (39%), Germany (16%), France (14%), Italy (7%), Austria (3%) and other European countries (8% altogether).

Further details of export can be obtained from spatial distributions of PCDD/F annual depositions originated from anthropogenic emission sources of particular countries. These distributions for the three chosen countries are shown in Fig. 4.11.

Switzerland Denmark Croatia

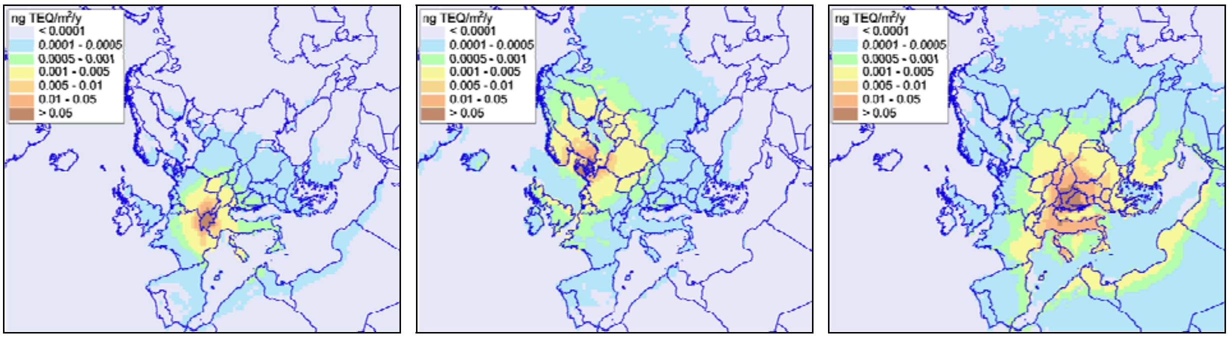


Fig. 4.11. *Annual total depositions of PCDD/Fs originated from national emissions of Switzerland, Denmark and Croatia in 2005, ng TEQ/m^2/y*

Import. Total depositions of PCDD/Fs to a country can be split to depositions due to various source categories: sources of the country itself (internal contribution), anthropogenic sources of other European countries (EMEP transboundary), sources of USA and Canada (non-EMEP sources) and pollutant accumulated in the environment during preceding years (re-emission). This splitting is shown by the plot in Fig. 4.9

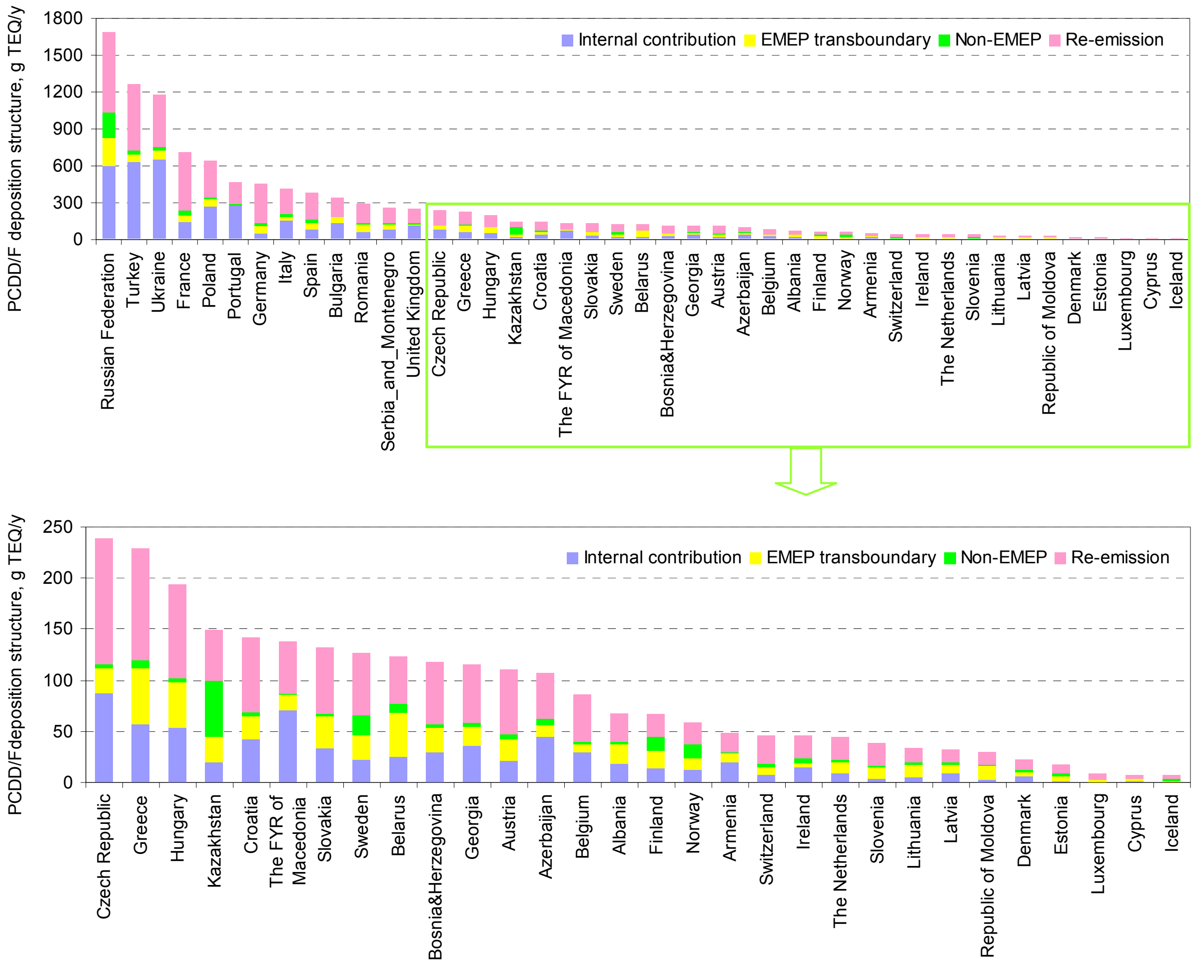


Fig. 4.9. *Contributions of various source categories to total annual depositions of PCDD/Fs for each European country, g TEQ/y*

The contribution of internal sources to total depositions to the country varies from 5% to 60%, of transboundary transport from other EMEP countries − from 1% to 45%, of transport from non-EMEP sources − from 1% to 35%, and of re-emission − from 30% to 70%.

The contributions of re-emission process to annual total depositions over European countries for 2005 are presented in Fig. 4.10. These contributions are high enough and should be taken into account in the assessment of pollution levels in European countries.

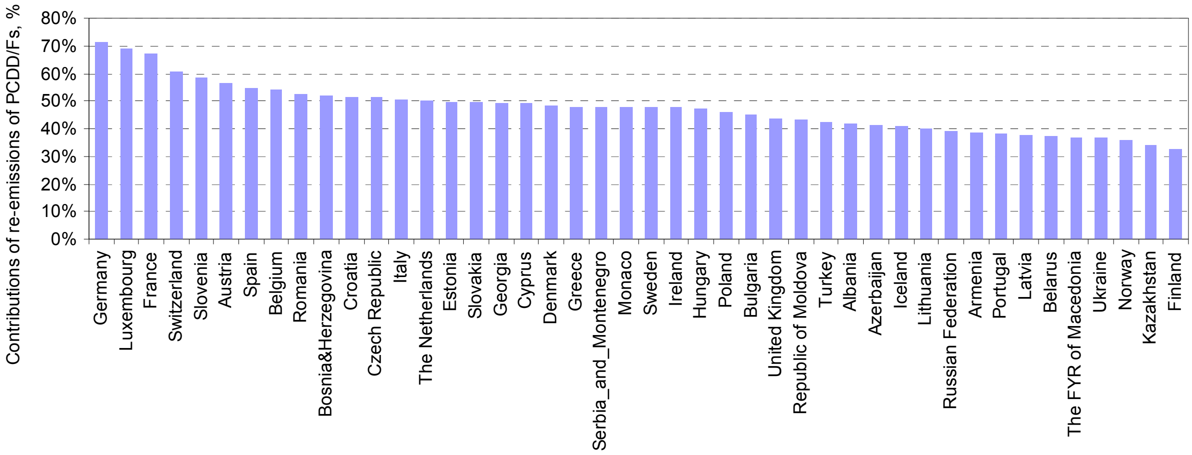


Fig. 4.10. *Contributions of re-emissions of PCDD/Fs to depositions to European countries, %*

For the analysis of transboundary transport re-emission fraction is excluded from total depositions to European countries, so that from now on only the transport of anthropogenic emissions (from European countries and non-EMEP sources − USA and Canada) is considered. Contributions of transboundary transport (both from EMEP and non-EMEP sources) to each European country are displayed in Fig. 4.11.

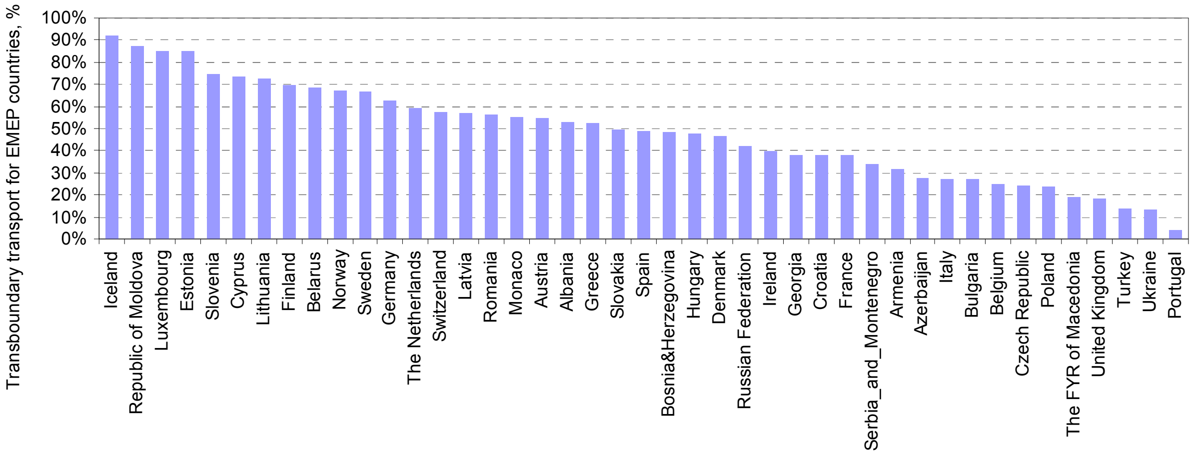


Fig. 4.11. *Contributions of transboundary transport to total annual depositions of PCDD/Fs from EMEP and non-EMEP emission sources for each European country, %*

Contributions of other European countries to the deposition levels of a particular country are significant for the majority of European countries. Typically they vary from 20% to 80%.

It is interesting also to evaluate contributions of non-EMEP sources (USA and Canada) to total depositions to European countries from anthropogenic sources of the current year. The corresponding fractions are shown by the plot in Fig. 4.12.

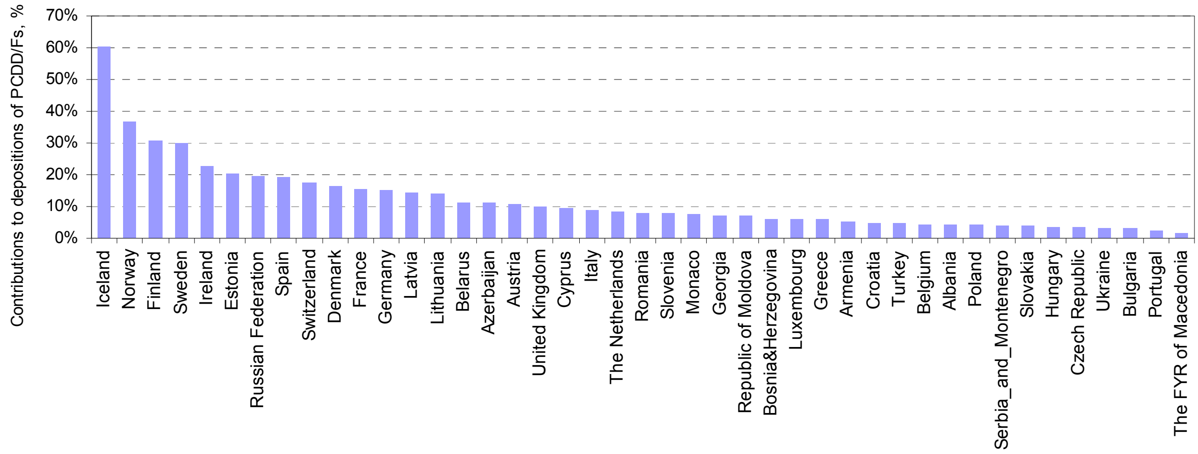


Fig. 4.12. *Contributions of non-EMEP sources of PCDD/Fs to depositions to European countries, %*

Considerable contributions of non-EMEP sources (30% and more) to depositions take place for countries located near the borders of the EMEP domain: Iceland, Norway, Finland and Sweden.

Similarly to the export, the information on import of PCDD/F depositions to European countries due to atmospheric transport can be presented in a more detailed way. Namely, for each country the fractions of total annual deposition determined by emissions of other European countries and non-EMEP sources are calculated. This information is exemplified below by import diagrams for Denmark, Switzerland and Croatia (Fig. 4.12).

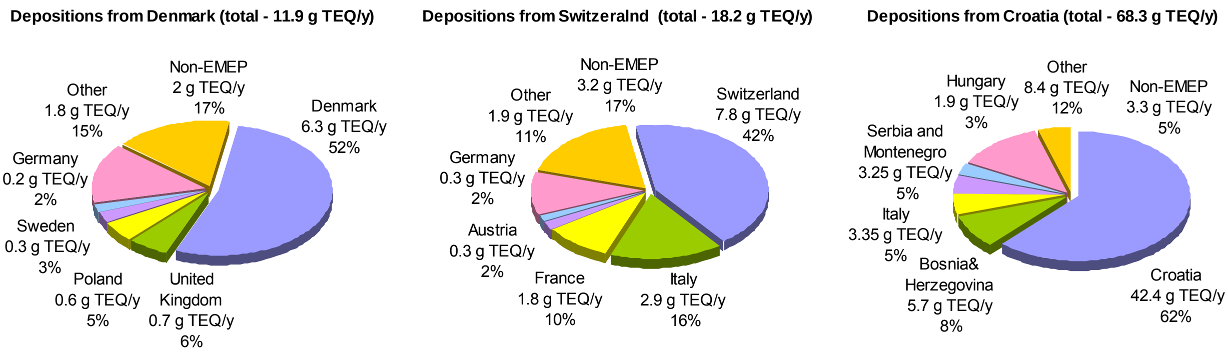


Fig. 4.13. *Import of PCDD/F depositions originated from atmospheric transport for Denmark, Switzerland and Croatia*

Country-specific information. Putting together contributions of the atmospheric transport and re-emissions it is possible to evaluate total depositions for each European country in 2005 and contributions of all above categories of sources (European anthropogenic sources, non-EMEP sources and re-emissions) to these depositions. Examples of import fraction for some European countries for all source categories are presented in Fig. 4. 14.

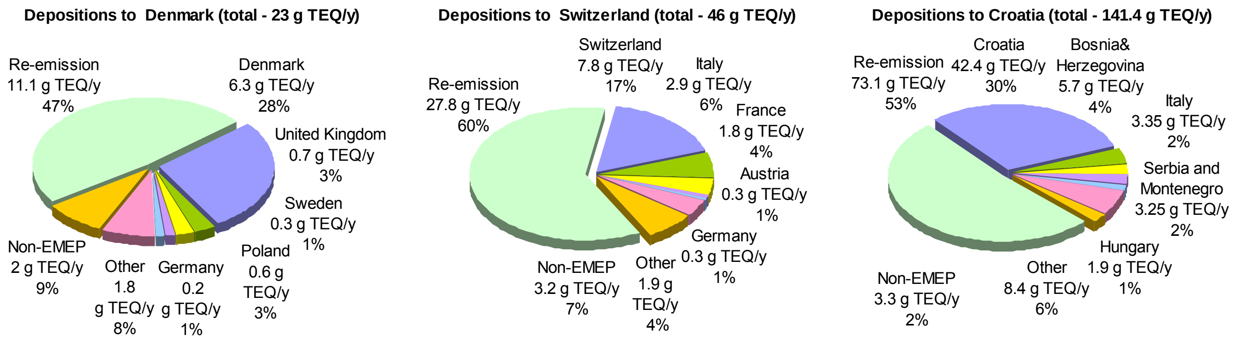


Fig. 4.14. *Contributions of all emission sources to PCDDF depositions over the territories of Denmark, Switzerland and Croatia*

Peculiarities of spatial distribution of total annual PCDD/F depositions and contributions of transboundary transport for a particular European country are exemplified in Fig. 4.15. Distribution of total annual depositions over Denmark together with distribution of deposition fractions due to transboundary transport from European and non-EMEP anthropogenic sources and re-emissions is presented. Along with that spatial distribution of PCDD/F emissions of Denmark in 2005 is shown in the figure.

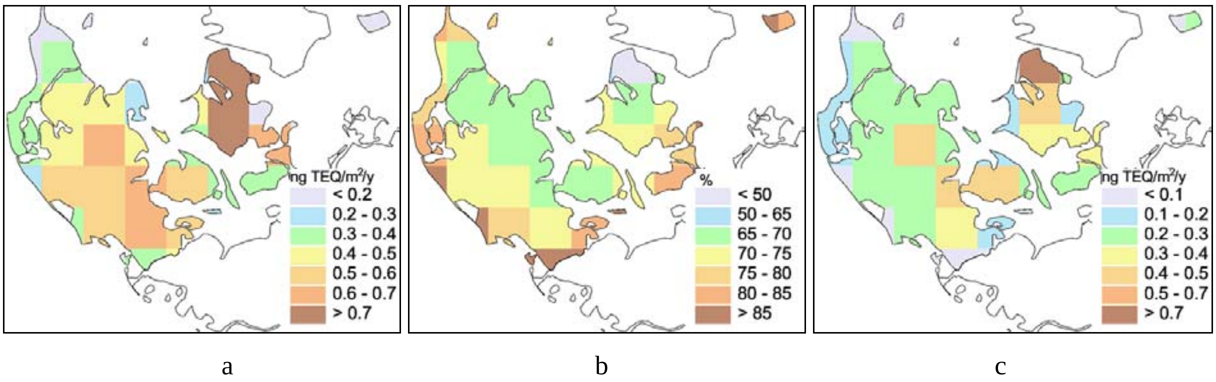


Fig. 4.15*. Spatial distribution of annual total depositions of PCDD/F to Denmark, ng TEQ/m^2/y, (a); contribution of transboundary transport to depositions over Denmark, % (b); annual emission of PCDD/F in Denmark, ng TEQ/m^2/y, (c)*

On the average, the joint contribution of transboundary transport (including non-EMEP sources) and re-emission for Denmark is about 70%. However, inside the country this contribution can vary significantly. Highest contribution of non-EMEP sources together with re-emission (up to 85% and higher) is characteristic of regions with low levels of national emissions and for regions located close to the country borders.

The information on source-receptor relationships for PCDD/F depositions for all European countries can be found in the Internet www.msceast.org.

Projections from 2005 to 2020

Here the results of the evaluation of environmental response to future emission scenarios are presented. These calculations were performed in the beginning of the year and, since emission data for 2005 were not available to the moment, 2004 was chosen as a base year for projections. For this purpose several model runs are performed by means of hemispheric version of MSCE-POP model:

- Calculations of atmospheric transport and accumulation in the environment of PCDD/Fs for the period from 1970 to 2004. These calculations are needed to simulate initial accumulation of PCDD/Fs in the environment taking into account high persistence of PCDD/Fs in environmental media (particularly in soil).
- Calculations of atmospheric transport and redistribution between environmental media for the period from 2005 to 2020 according to two different emission scenarios.

In calculations physical-chemical properties of the “indicator congener” 2,3,4,7,8-PeCDF were used. For future years (2005 – 2020) the meteorological data of 2000 was used for modelling.

Emission data for the period from 1970 to 2004 were compiled on the basis of the data officially reported by European countries complemented by unofficial data. Future emission scenarios for calculations are prepared on the basis of two emission scenarios: **CR** – Base Line scenario with Current Legislation and **C**urrent **R**atification of the UNECE POP Protocol and **FI** – Base Line scenario with Current Legislation and **F**ull **I**mplementation of the UNECE POP Protocol prepared by TNO [*Denier van der Gon et al*., 2005]. These scenarios were modified to take into account official emission data submitted by countries to the UN ECE Secretariat. The description of emission data for calculations can be found in Chapter 2 of this report.

According to scenario **CR**, the total emission of PCDD/Fs in the Northern Hemisphere decreases by 55% since 1990 and amounts to 9.1 kg TEQ/y in 2020 (Fig. 4.16). In compliance with scenario **FI** the total emission of PCDD/Fs in the Northern Hemisphere decreases by 67% and amounts to 6.7 kg TEQ/y in 2020.

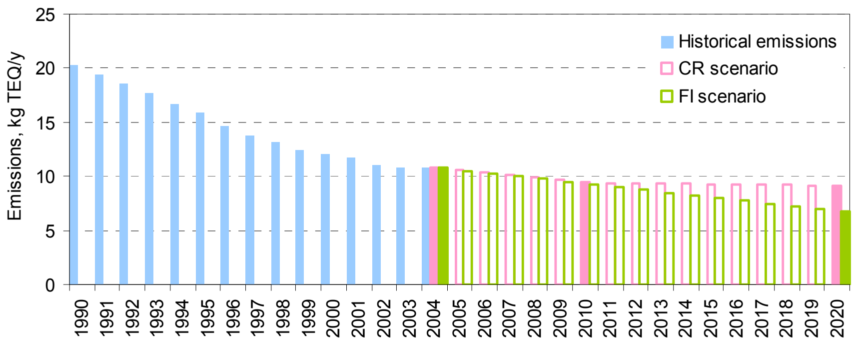


Fig. 4.16. *PCDD/F emissions in the Northern Hemisphere for the period from 1990 to 2020, kg TEQ/y*

The spatial distribution of the emissions of PCDD/Fs in the EMEP region in 2004 and 2020 for both scenarios is given in Fig. 4.17. It is important to note that there are differences between the TNO estimates and the official data on spatial distribution of PCDD/F emissions. For instance, information on spatial distribution of emissions connected with shipping activities is not available in TNO estimates.

According to **scenario CR**, in 2020 PCDD/F emission intensity in majority of countries is the same as in 2004. Significant changes of emission (> 50%) intensity take place in Slovenia, Greece, Slovakia, Belgium, Romania, the UK, Switzerland, Iceland, Portugal and Estonia.

According to **scenario FI**, in contrast to scenario CR, PCDD/F emission intensity in majority of countries in 2020 is significantly lower than in 2004. Essential PCDD/F emission intensity (> 1ng TEQ/m^2/y) in 2020 is characteristic of the Czech Republic, Portugal, Luxembourg, Bulgaria, Denmark and Croatia.

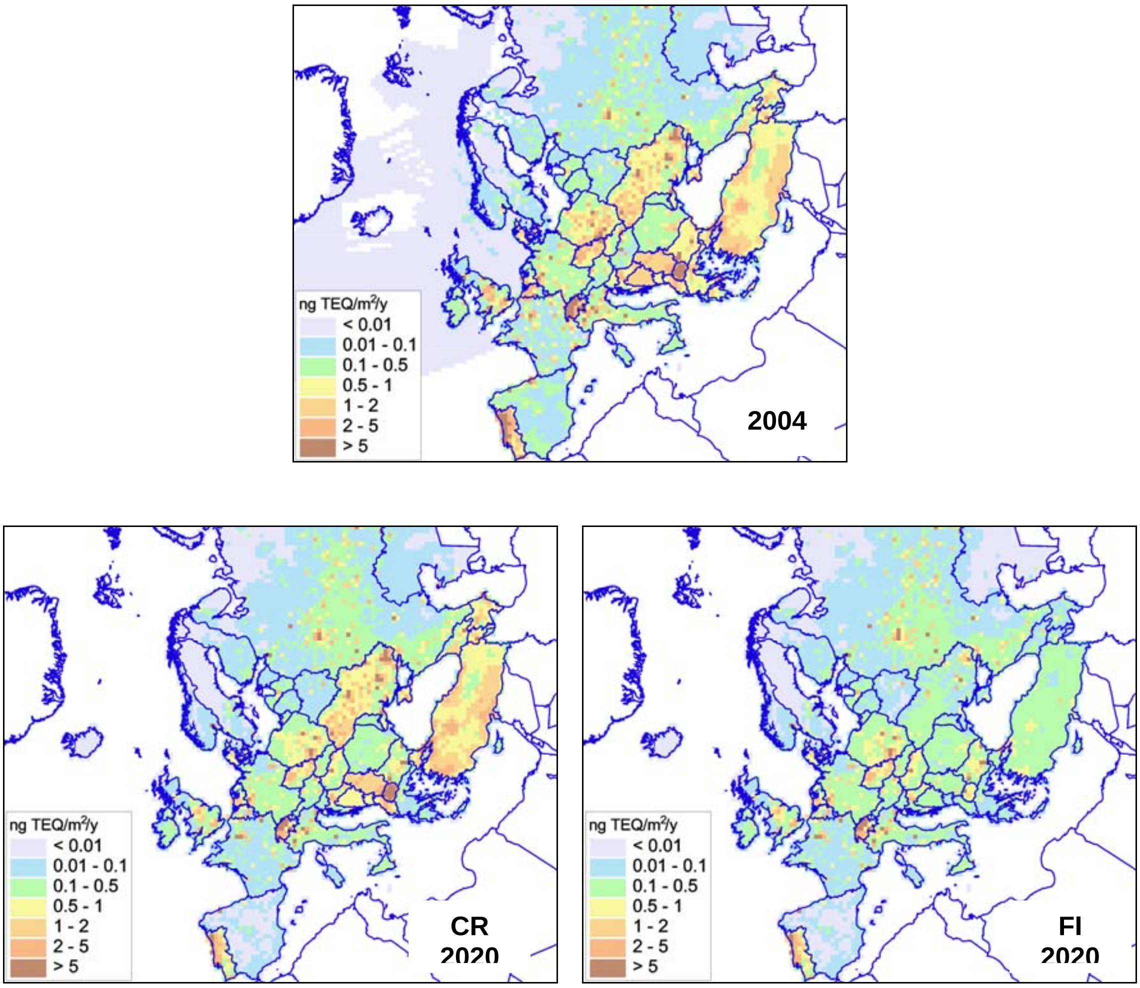
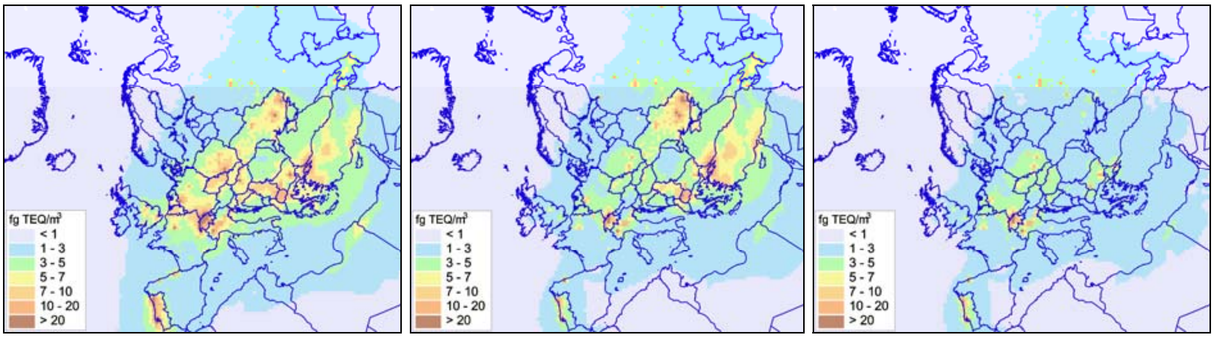


Fig. 4.17. *Spatial distribution of the emissions of PCDD/Fs in the EMEP region in 2004 and 2020 for both scenarios, ng TEQ/m^2/y*

More detailed description of the above emission scenarios can be found in [*Gusev et al.*, 2007].

As a result of the above calculations spatial distribution of contamination 2020 according to the two above scenarios are obtained and compared with that for 2004. These spatial distributions were refined by means of regional model calculations using initial and boundary data obtained in the course of hemispheric model runs. The comparison of spatial distributions of air concentrations obtained for 2020 under CR and FI scenarios with that for 2004 is displayed in Fig. 4.18.



a b c

Fig. 4.18. *Comparison of spatial distribution of air concentrations in 2020 calculated with CR (b) and FI (c) emission scenarios with that in 2004 (a), fg TEQ/m*^{3}

For CR scenario, main reduction of air contamination takes place in Central European countries whereas at southeast of Europe even some increase of air concentrations take place. For FI scenario, in addition to decrease of air concentration levels in Central Europe essential reduction of contamination levels in eastern and southeastern parts of Europe takes place.

On the basis of calculated spatial distribution of contamination, reductions of average air and soil concentrations in European countries were estimated.

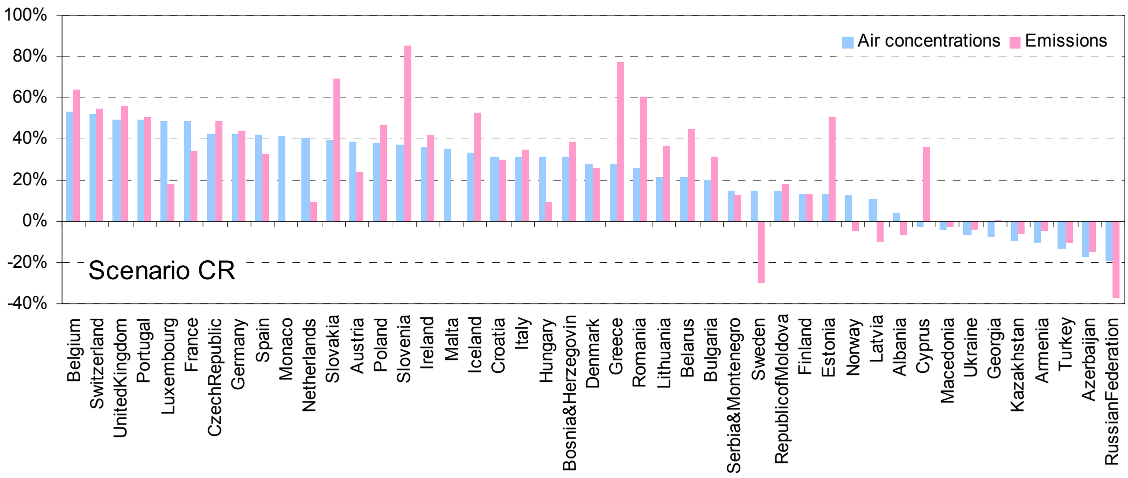


Fig. 4.19. *Reduction of average air concentrations in European countries from 2004 to 2020 according to CR emission scenario in comparison with emission reductions, %*

The comparison of emission reduction in European countries under CR scenario with the reduction of air concentrations from 2004 to 2020 is presented in Fig. 4.19. For convenience, the countries are ordered by average air concentrations in 2020. It is seen that emission reductions do not correlate in general with the reduction of air concentrations. As it was shown before, this is due to the fact that air concentrations are strongly affected not only by the reductions of national emissions of the current year but also by transboundary transport and re-emission process. The latter depends on accumulations of the pollutant in previous years and on meteorological and geophysical conditions (temperature, soil properties, etc.).

The plot also shows a number of countries with possible increase of air concentration levels according to the considered scenario. These are mostly countries located in eastern and southern parts of Europe.

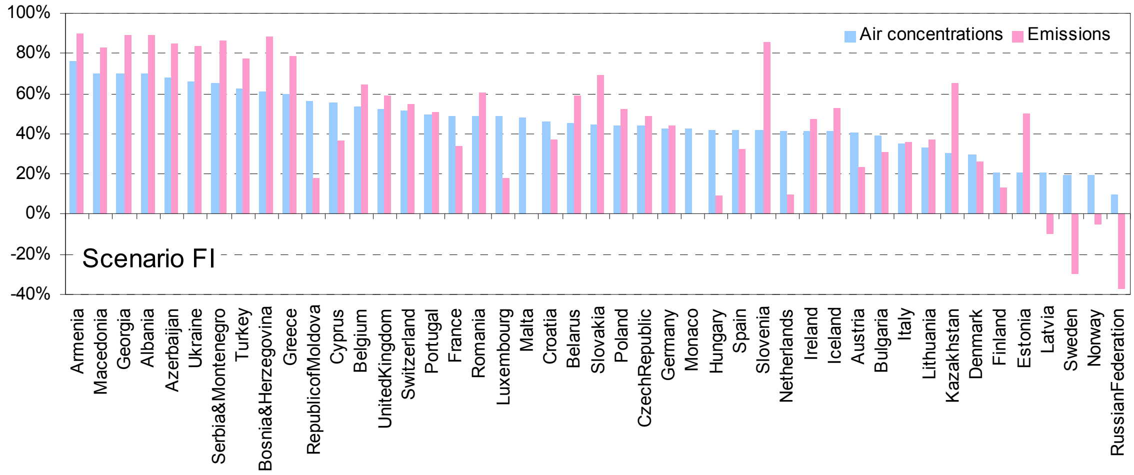


Fig. 4.20. *Reduction of average air and soil concentrations in European countries from 2004 to 2020 according to FI emission scenario in comparison with emission reductions, %*

The plot of air concentration reductions in European countries in comparison with emission reductions for FI scenario is displayed in Fig. 4.20. Here emissions are reduced in the majority of European countries. Air concentrations are reduced in all European countries even if national emissions are increased. This is conditioned by the decrease of transboundary contributions to air contamination and the reduction of re-emission fluxes over Europe.

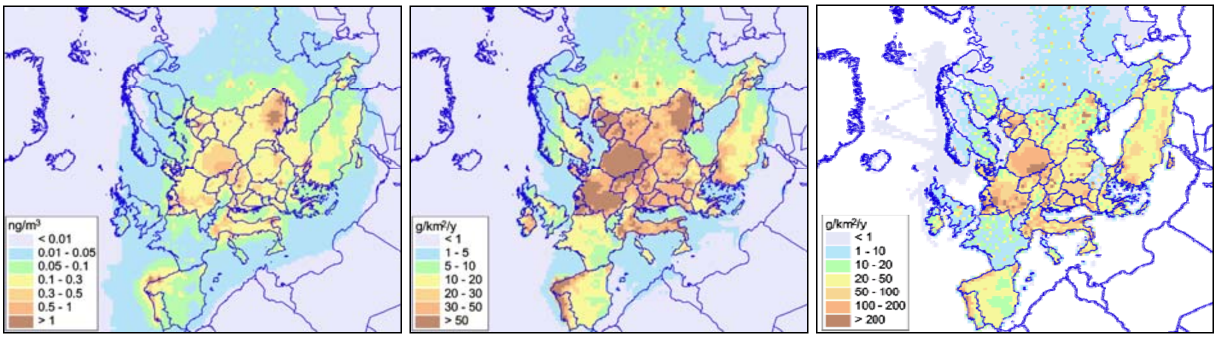
4.1.2. Polyaromatic hydrocarbons (PAHs)

Pollution levels in the EMEP region

Calculations of pollution levels of the four indicator PAH congeners (B[a]P, B[b]F, B[k]F and I_P) in the EMEP region were performed with the help of regional model with resolution 50x50 km^2 for 2005. For evaluation of atmospheric pollution levels (air concentrations and depositions) calculations were done for one-year period. The emission data used in the calculations are based on official data and include unofficial data when official information is not available (Chapter 2).

Benzo[a]pyrene (B[a]P). The maps of spatial distributions of B[a]P concentrations in surface atmospheric layer and depositions in comparison with emissions are shown in Fig. 4.21.

Atmospheric concentration levels in some European regions (Poland, the Ukraine, parts of Czech Republic and Slovakia) are close to or even higher than the level of 1 ng/m^3 accepted in some countries as the limit value of atmospheric concentrations. Comparatively high levels of B[a]P air concentrations (0.1 – 0.3 ng/m^3) are characteristic for the whole Central Europe.



a b c

Fig. 4.21. *Calculated air concentrations, ng/m^3 (a) and deposition fluxes, g/km^2/y (b) of B[a]P in 2005 in comparison with emissions, g/km^2/y (c)*

In comparison with calculations for 2004 carried out in the previous year, pollution levels in Europe became slightly higher. In particular, total B[a]P depositions to the EMEP region as a whole increased by 3.3%. The reason for such an increase is that total emissions of B[a]P in the EMEP region increased by 4.7% (from 471 t in 2004 to 493 t in 2005). This increase is explained by changes of emission data compared to that used in the previous year. Most essential increase of reported official emission data took place in Germany, Italy and Romania.

Transboundary transport of B[a]P

Here the calculated source-receptor relationships in the EMEP region for PAHs in 2005 are exemplified by B[a]P. In calculations the above-described emission data were used. Similar to the case of PCDD/Fs, source-receptor matrices for B[a]P in 2005 were calculated both for deposition and for air concentrations. Below we illustrate source-receptor relationships by the example of deposition matrix.

Spatial distribution of B[a]P annual depositions originated from national emission sources of Switzerland, Denmark and Croatia is presented in Fig. 4.22.

Denmark *Switzerland* *Croatia*

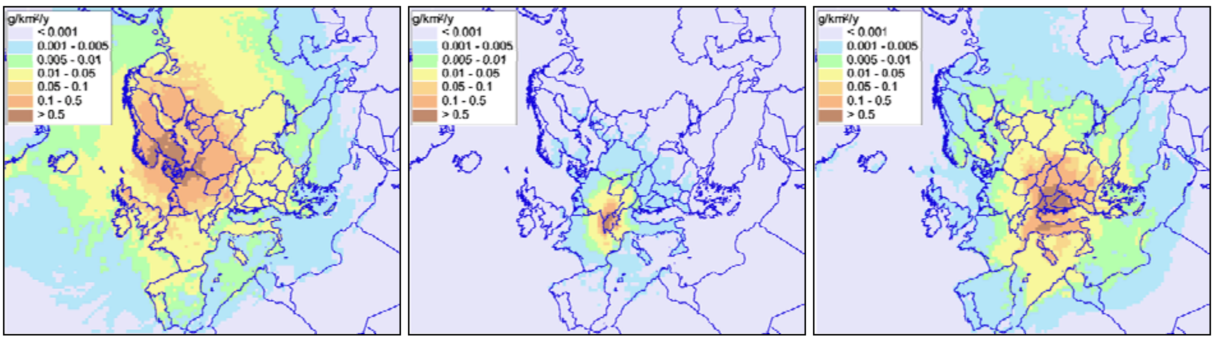


Fig. 4.22. *Annual total depositions of B[a]P originated from national emissions of Denmark, Switzerland and Croatia, g/km^2/y*

On the basis of spatial distribution of depositions caused by each source region source-receptor relationships (export and import) in the EMEP region was evaluated.

Export. The splitting of total depositions to EMEP region due to national anthropogenic sources of a country to deposition to the territory of the country and deposition to the rest EMEP territory in 2005 is shown in Fig. 4.23.

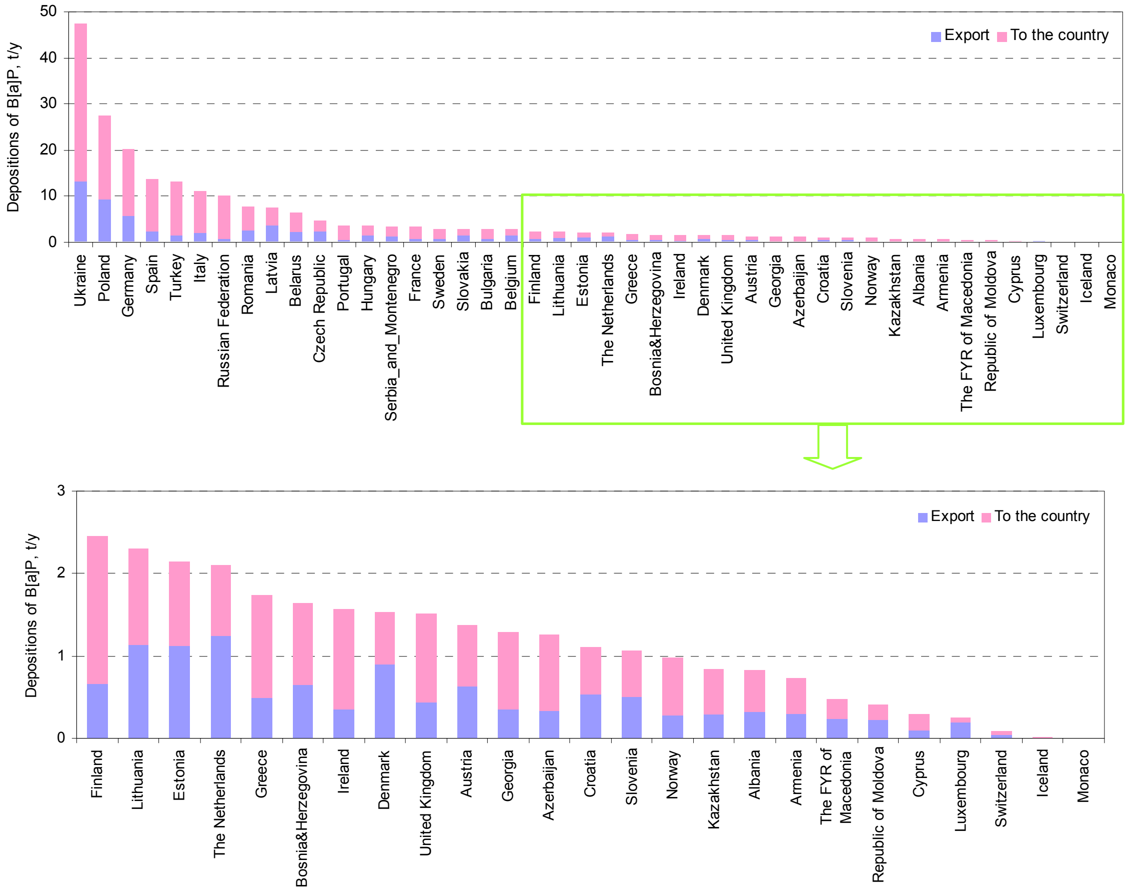


Fig. 4.23. Depositions of B[a]P to the own territory and depositions to the rest EMEP territory (export) due to national emissions of European countries, t/y

The plot of the fraction of depositions to the entire EMEP region due to emissions of the given country deposited to the territory of all the rest countries (export fraction) is displayed in Fig. 4.24. Typically, about 20 – 50% of depositions caused by national emission sources of a country are deposited outside this country.

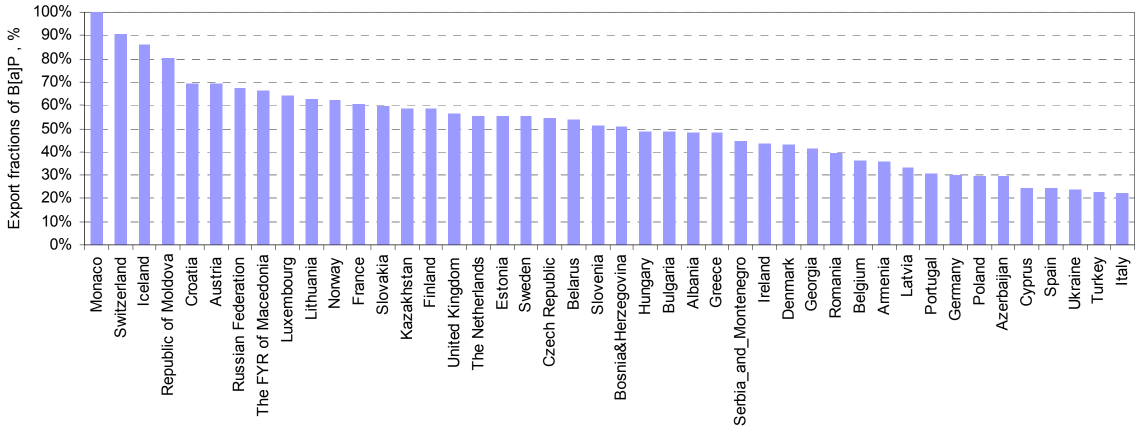


Fig. 4.24. Export fractions of B[a]P for European countries, %

Further specification of export of European countries is exemplified by Denmark, Switzerland and Croatia in Fig. 4.25.

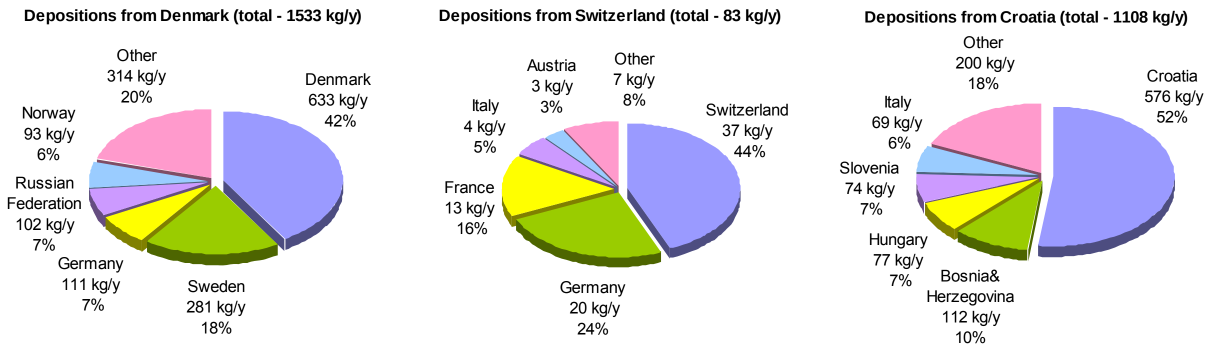


Fig. 4.25*. Transboundary transport from some countries, % of depositions*

In particular, in Denmark and Switzerland export fractions amount to more than 50%. This means that for these countries more than a half of depositions to the EMEP domain caused by their national emissions fall at the territory of other European countries.

Import. The calculated values of total depositions of B[a]P to the territories of European countries in 2005 together with their splitting to depositions due to own sources and due to sources of other countries (import) are displayed in Fig. 4.26.

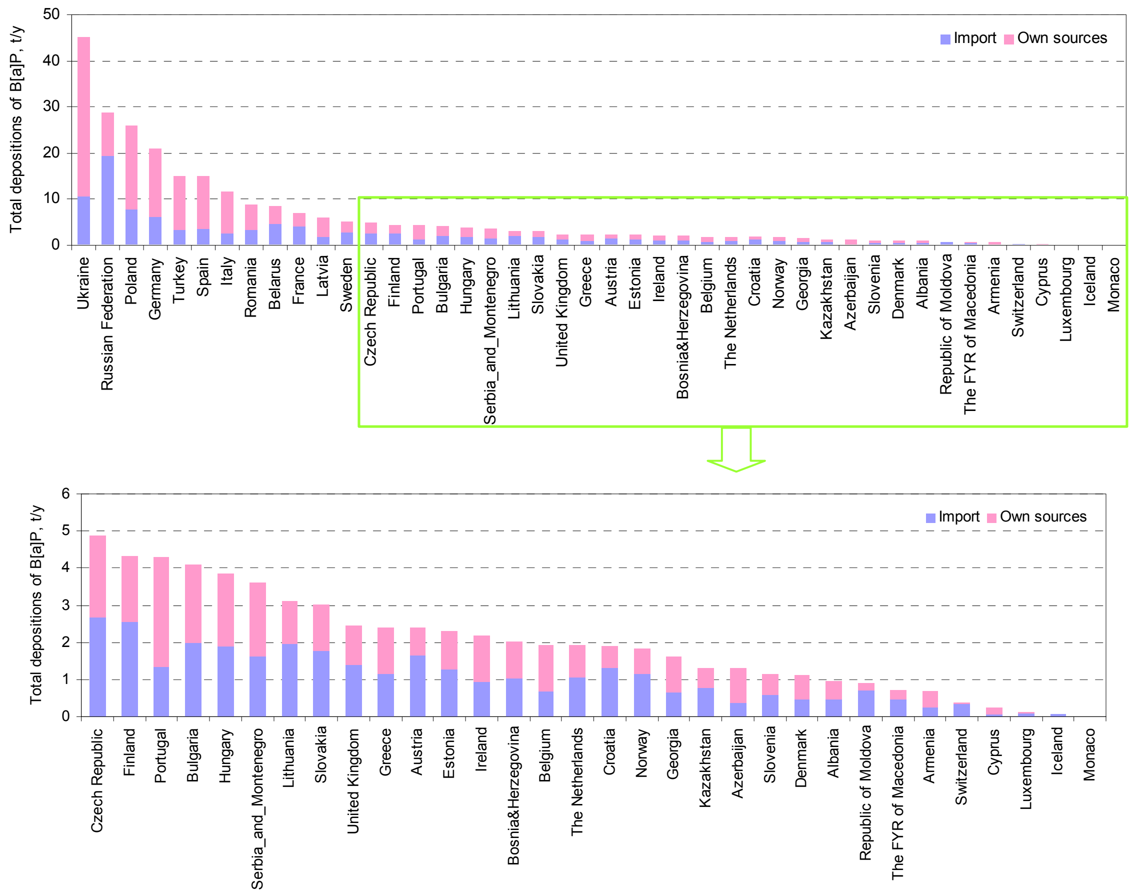


Fig. 4.26. *Total depositions of B[a]P to the territories of European countries, t/y*

The contributions of transboundary transport to depositions to European countries are shown in the plot in Fig. 4.27.

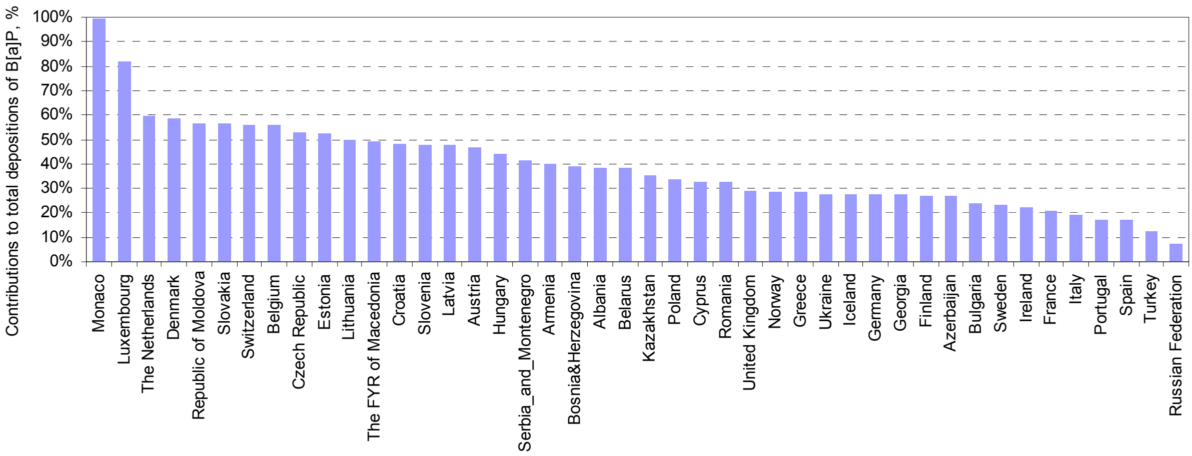


Fig. 4.27. *Contributions of transboundary transport to total annual depositions of B[a]P from European emission sources for each European country, %*

Typically contributions of other European countries to the deposition levels of a particular country vary from 30% to 70%.

The information of contributions of various European countries to deposition levels of a particular country due to atmospheric transport is presented in Fig. 4.28 for Switzerland, Denmark and Croatia.

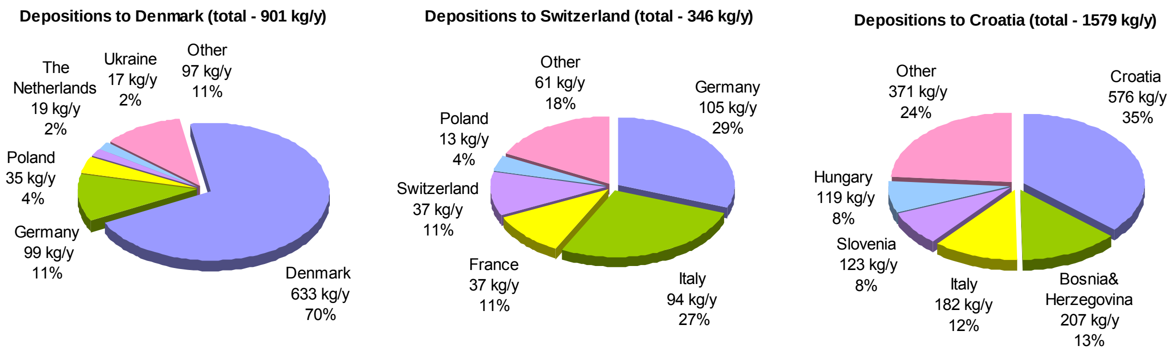


Fig. 4.28. *Import of B[a]P depositions to Denmark, Switzerland and Croatia originated from atmospheric transport of other EMEP countries, %*

For Switzerland the contribution of atmospheric transboundary transport to total depositions (346 kg) is significant (about 89%) while national emissions contribute 11%. In case of Denmark the contribution of transboundary transport from other European countries is only 30%.

Peculiarities of spatial distribution of total annual B[a]P depositions and contributions of transboundary transport for a particular European country are exemplified in Fig. 4.29. Distribution of total annual depositions over Denmark together with distribution of deposition fractions due to transboundary transport is presented. Along with that spatial distribution of B[a]P emissions of Denmark in 2005 are shown in the figure.

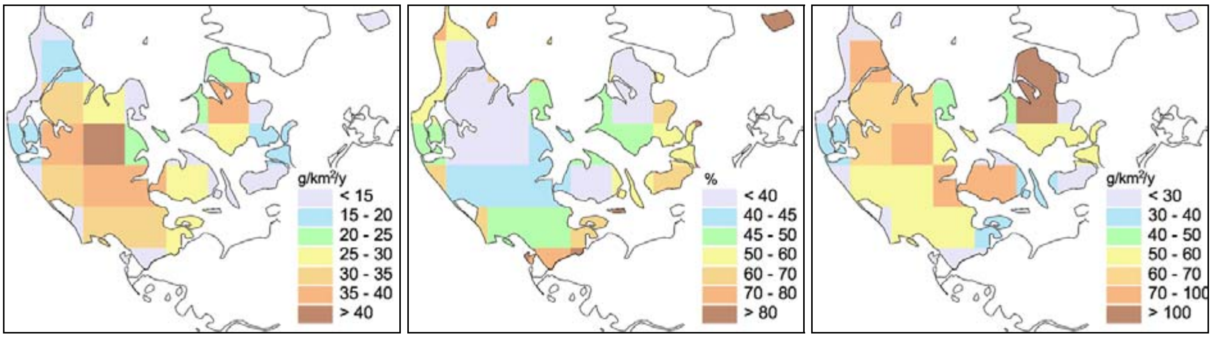


Fig. 4.29*. Spatial distribution of annual total depositions of B[a]P to Denmark, g/km^2/y, (a); contribution of transboundary transport to depositions over Denmark, %, (b); annual emission of B[a]P in Denmark, g/km^2/y, (c)*

On the average, the joint contribution of transboundary transport for Denmark is about 30%. However, for different locations inside the country this contribution can be quite different reaching 50% and higher. Highest contribution of transboundary transport is characteristic of regions with low levels of national emissions and for regions located close to the country borders.

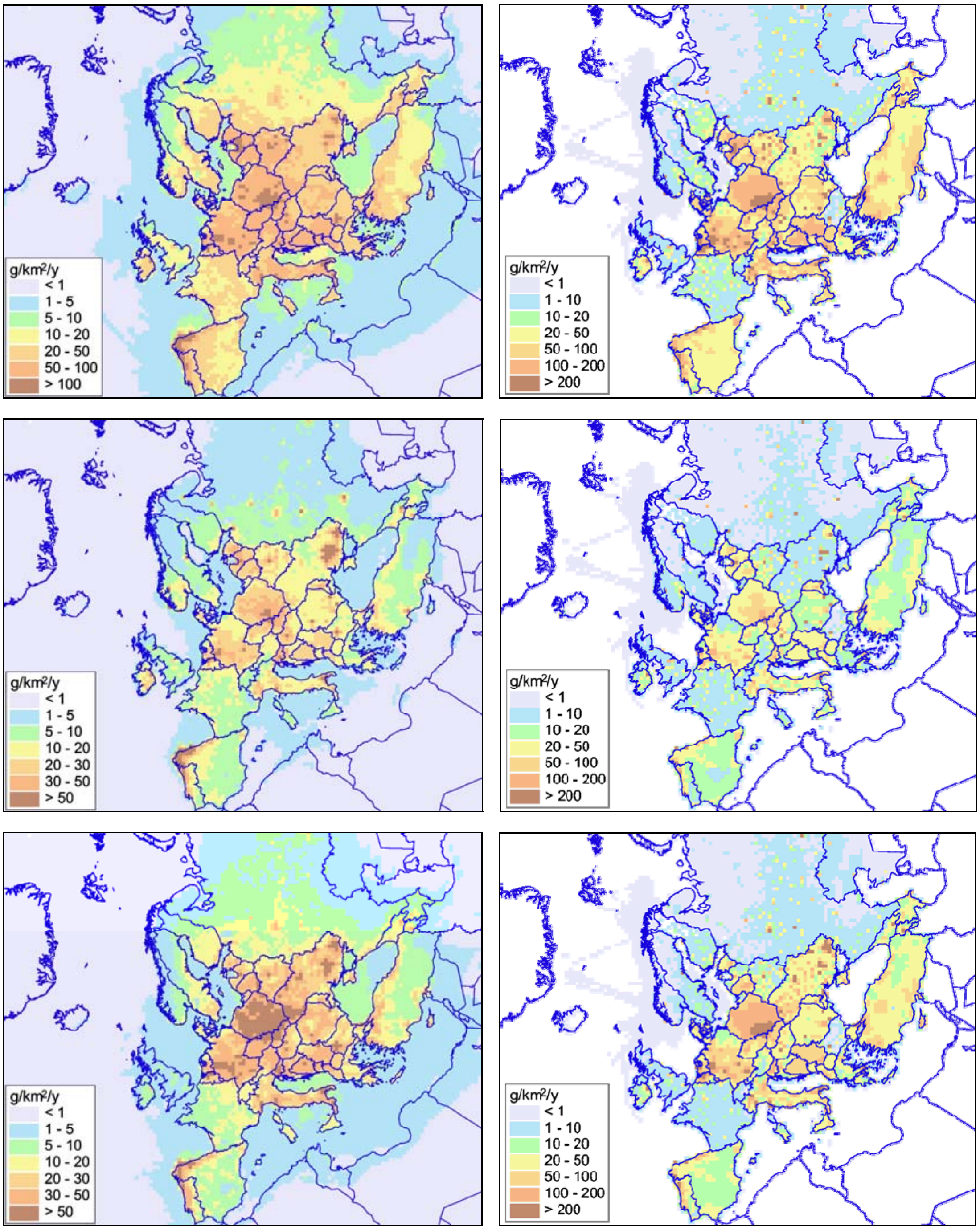
Detailed information on source-receptor relationships for B[a]P depositions can be found in the Annex B.

The rest indicator congeners. For the rest three indicator congeners (B[b]F, B[k]F and I_P) evaluation of pollution levels was carried out. The maps of spatial distributions of depositions in comparison with their emissions are shown in Fig. 4.30 a, b and c, respectively.

Deposition fluxes of B[b]F and I_P in Europe vary from low (5 – 10 g/km^2/y) in northern Europe to rather high (up to 50 g/km^2/y and higher) in central Europe. In general, spatial pattern of depositions for these compounds is close to that for B[a]P. Higher emission densities in the northern part of Spain lead to increase of deposition levels in northern Spain and southern France compared with B[a]P.

Deposition fluxes of B[k]F in Europe are lower (from 1 – 5 g/km^2/y in northern Europe up to 30 g/km^2/y in central Europe). Absolute values of deposition fluxes are smaller than for the two above considered pollutants since emission levels for B[k]F are considerably lower according to emission data used in modelling. Spatial pattern of air contamination for B[k]F is similar to that for B[a]P, B[b]F and I_P.

In view of similarities between spatial patterns of emissions and atmospheric contamination evaluating of source-receptor relationships for PAHs at present stage of investigation is performed for B[a]P only. This choice is conditioned by larger amount of measurement data and more reliable emission inventories for B[a]P. In future, for more detailed evaluation of source-receptor relationships for the rest three PAHs more information on substance-specific emissions is needed.



a

b

c

Fig. 4.30. *Calculated deposition fluxes (on the left) and emissions (on the right) of B[b]F (a), B[k]F (b) and I_P (c) in 2005, g/km^2/y*

4.1.3. Comparison with measurements

This subsection is devoted to model validation by comparison of calculated air concentrations, concentrations in precipitation and deposition fluxes of PAHs with measurements obtained within the EMEP monitoring network.

For B[a]P, measurement data on air concentrations are available at 6 EMEP monitoring sites: SE12, SE14, FI96, CZ3, NO42 and GB14. The comparison of measured and calculated annual means of B[a]P air concentrations at these sites is displayed in Fig. 4.31. For all sites but CZ3 the discrepancy between measured and calculated values is in the range 20% − 50%.

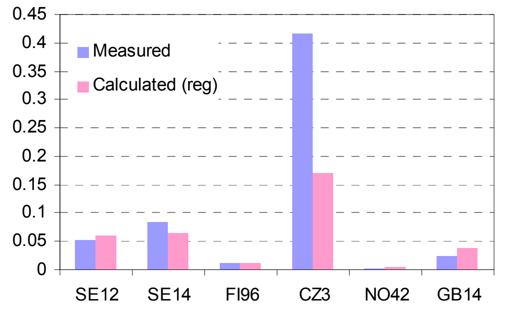


Fig. 4.31. *Comparison of calculated and measured annual means of B[a]P* ***air concentrations*** *at EMEP monitoring sites, ng/m*^{3}

The comparison of monthly means of air concentrations (Fig. 4.32) is presented at all above sites except for GB14 where only quarterly means are available. At SE12, SE14 and FI96 the model reasonably represents seasonal variations of B[a]P air pollution. Outstanding measurement values at SE14 in February and at FI96 in January can be explained by episodic contamination which is not taken into account by the model. The plot of monthly averages at CZ3 gives rise to the supposition that seasonal variations of emissions in Central Europe are stronger than it is assumed by the model. The refinement of emission seasonal variations could improve the agreement between calculations and measurements.

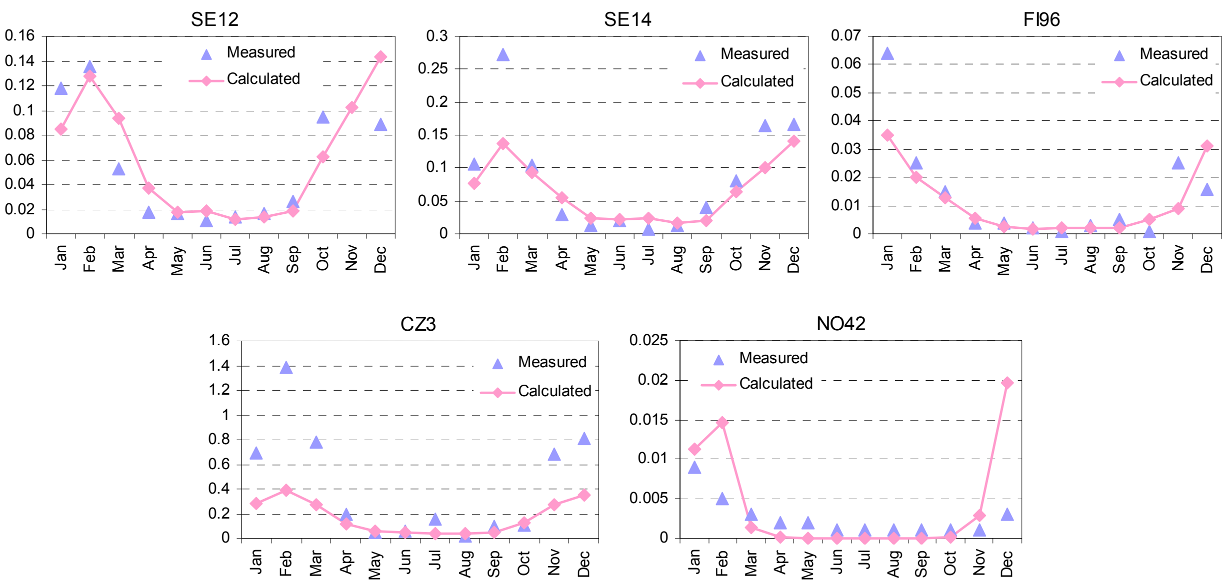


Fig. 4.32. *Comparison of calculated and measured monthly means of B[a]P* ***air concentrations*** *at EMEP monitoring sites, ng/m*^{3}

Measurements of B[a]P concentrations in precipitation in 2005 are available at sites DE1 and DE9. The comparison of annual and monthly means of concentrations in precipitation is shown in Fig. 4.33. There is a good agreement between calculated and measured annual means but there is some difference between monthly means of concentrations in precipitation on the sites. The difference concerns mainly the beginning of the year. In general the model reasonably describes concentrations in precipitation.

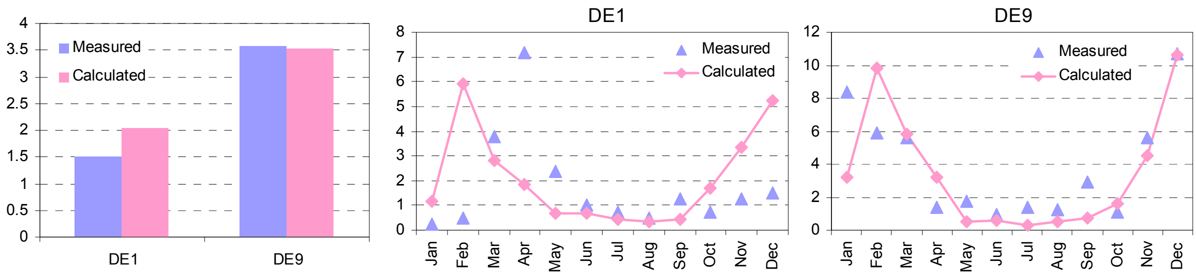


Fig. 4.33. *Comparison of calculated and measured annual and monthly means of B[a]P* ***concentrations in precipitation*** *at EMEP monitoring sites, ng/L*

Measurements of B[a]P deposition fluxes in 2005 are available at sites FI96, SE12 and SE14. The comparison of annual depositions at these sites is given in Fig. 4.34. Only wet deposition flux is taken into account in the comparison. However, it should be taken into account that measured values of deposition flux include also an unknown part of dry deposition. The methodology of comparison of calculated and measured POP fluxes should be a topic for discussion between MSC-E, CCC and national experts.

For the rest three PAH species included in the POP Protocol (B[b]F, B[k]F and I[123-cd]P), measurement data are rather limited. Here we present the comparison of annual means of air concentrations only. These data are available at two monitoring sites (SE14 and FI96) for B[b]F and B[k]F and at four sites (SE12, SE14, FI96 and GB14) for IP. The comparison of measured and calculated annual means of air concentrations at these sites for the mentioned three PAHs is displayed in Fig. 4.35. The discrepancy between measured and calculated values mostly is less than 50%.

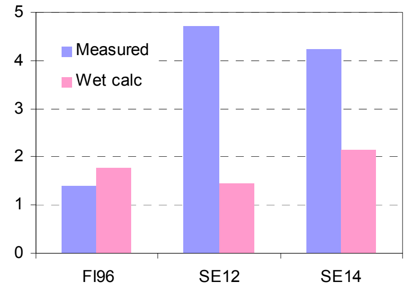


Fig. 4.34. *Comparison of calculated and measured annual* ***deposition fluxes*** *of B[a]P at EMEP monitoring sites, g/km^2/y*

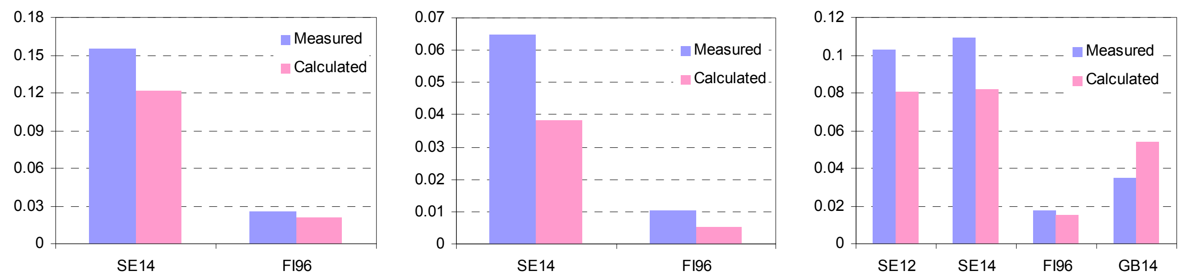


Fig. 4.35. *Comparison of calculated and measured annual means of B[b]F, B[k]F and IP* ***air concentrations*** *at EMEP monitoring sites, ng/m^3*

To improve the agreement between calculation and measurements for all four PAH compounds from POP Protocol more data on congener composition of PAH emission from countries are needed.

4.2. Hemispheric transport of POPs

Development of hemispheric POP modelling approach of MSC-E during this year was focused on several tasks. First of all, it was the continuation of development of hemispheric/regional POP modelling approach based on the nesting of hemispheric and regional MSCE-POP model simulations. Hemispheric MSCE-POP model was further developed for providing necessary information on concentrations at lateral boundaries of EMEP domain and the content of POPs in the atmosphere and other environmental compartments as initial conditions for regional scale modelling. Developed approach was applied to the investigation of PCDD/F long-range transport on regional scale taking into account the contribution of intercontinental transport from the emission sources outside the EMEP region. The description of this work and the results are presented in the section 4.1 of this report.

Investigation of PCBs, γ-HCH, and HCB pollution levels on hemispheric scale and of their intercontinental transport was continued. Using available emission data the distribution of pollution for 2005 from the selected groups of emission sources within the northern hemisphere was evaluated. In addition, the contributions of these source groups to the pollution of the Arctic regions and selected Central Asia countries were estimated. Preliminary comparison of obtained modelling results was carried out using available measurements made at EMEP monitoring sites in 2005. At further stage of the work it is planned to perform nested hemispheric/regional modelling for these POPs and to provide estimates of pollution levels for the EMEP region with finer resolution 50x50 km along with the detailed comparison of model results with measurements.

In this section the description of results of the evaluation of PCBs, γ-HCH, and HCB pollution levels within the northern hemisphere, their comparison with measurements and evaluation of intercontinental transport for 2005 is presented.

4.2.1. Polychlorinated biphenyls (PCBs)

Evaluation of PCB long-range transport for 2005 was carried out for three PCB congeners PCB-28, PCB-118, and PCB-153 using hemispheric MSCE-POP model. Selected three PCB congeners represent different physical-chemical properties of light and heavy PCB congeners. PCB-118 was selected as one of co-planar PCB congeners for which toxic equivalents are assigned.

Modelling was performed for the period 1970-2005 on the basis of the updated global emission inventory of PCBs [*Breivik et al.*, 2007]. This inventory provides refined set of emission data for the period 1930-2000 and continued estimates of emission for the subsequent period of time 2000-2100. It includes three different scenarios of global PCB emissions, namely, minimum scenario, default scenario, and maximum scenario. At this stage of investigations of PCB pollution levels at the hemispheric scale the modelling was performed using the maximum scenario representing maximum levels of pollution. At further stages it is planned to include also other two scenarios and to provide modelling results for the default and minimum estimates of pollution levels.

Several groups of emission sources were considered, namely: Europe, Russia, Southeast Asia, Americas, and Africa and Central Asia (section 2.4).

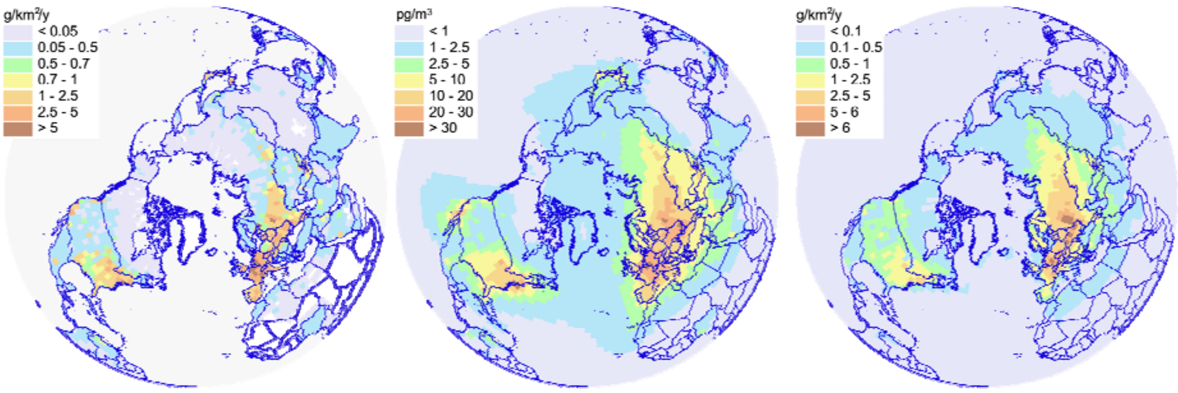
For the evaluation of PCB intercontinental transport separate model runs were made for each of the selected groups of emission sources. On the basis of obtained modelling results distribution of PCB congener's depositions between the selected receptor regions (Fig. 4.36) was estimated. To evaluate contributions to the pollution of Central Asia countries, in particular, Kazakhstan, Kirgizstan, Tajikistan, Turkmenistan, and Uzbekistan, their territory was distinguished as an additional receptor. Pollution of remote regions was exemplified by the analysis of contributions of selected groups of emission sources to PCB depositions to the Arctic.

***Fig. 4.36**. Selected receptor regions*

Intercontinental transport

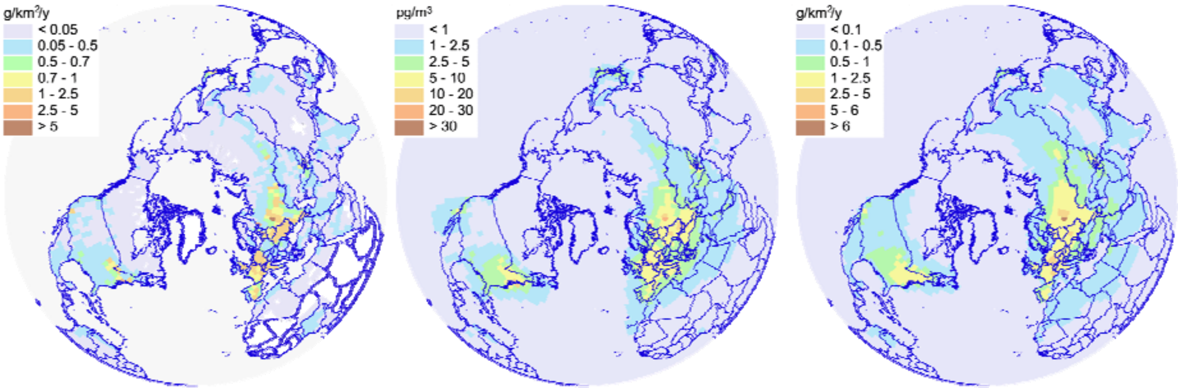
The computations of long-range transport of selected PCB congeners carried out for 2005 permitted to evaluate the distribution of pollution from various regions of the northern hemisphere. Spatial distribution of PCB-28, PCB-118, and PCB-153 annual emission for 2005 is presented in Figs. 4.37 – 4.39. Following the inventory of *Breivik et al.* [2007] total annual emission of lighter congener PCB-28 in 2005 within the northern hemisphere accounted for 35 tonnes while annual emissions of PCB-118 and PCB-153 were about 14 and 11 tonnes, respectively. The updated inventory provided somewhat different total emissions in comparison with the data used in computations for 2004 presented in previous Status Report [*Gusev et al.*, 2006]. In particular, emissions of PCB-28 and PCB-118 for 2005 are 33% and 22% lower than emissions for 2004, respectively. Total annual emission of PCB-153 within the northern hemisphere used in computations for this and the previous Status Report is nearly the same.

Spatial distribution of annual mean air concentrations and total annual deposition fluxes of selected PCBs for 2005 resulting from all considered emission sources is shown in Figs. 4.37 – 4.39 b and c.



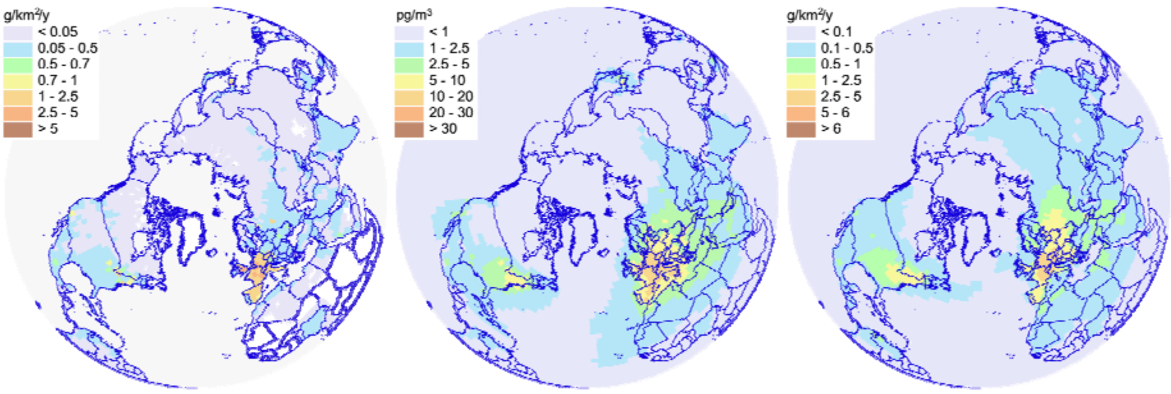
a b c

***Fig. 4.37.** Spatial distribution of PCB-28 annual emissions, g/km^2/y (a), annual mean air concentrations, pg/m^3 (b), and total depositions, g/km^2/y (c) for 2005*



a b c

Fig. 4.38. *Spatial distribution of PCB-118 annual emissions, g/km^2/y (a), annual mean air concentrations, pg/m^3 (b), and total depositions, g/km^2/y (c) for 2005*



a b c

Fig. 4.39. *Spatial distribution of PCB-153 annual emissions, g/km^2/y (a), annual mean air concentrations, pg/m^3 (b), and total depositions, g/km^2/y (c) for 2005*

Significant levels of calculated PCB-28 air concentrations (about 20 pg/m^3) and total annual depositions (5-10 g/km^2/y) in Europe can be noted for Germany and European part of Russia. Relatively lower levels of pollution of European countries are obtained for PCB-118. In case of PCB-153, due to different character of the spatial distribution of emissions, higher levels of air concentrations (about 15 pg/m^3 and higher) and total annual depositions (about 10 g/km^2/y) are obtained for France, Belgium, the Netherlands, and Germany.

To characterize the contribution of the intercontinental transport to the pollution levels within the northern hemisphere total depositions to land territories were considered. Intercontinental transport of selected PCB congeners was estimated for the following groups of emission sources: Europe, Americas, Russia, Southeast Asia, and Africa and Central Asia (Fig. 2.8). Depositions over marine regions were not taken into account in calculation of contributions of intercontinental transport.

The distribution of depositions of PCB-28, PCB-118, and PCB-153 over selected receptors originated from emission sources of Europe and Southeast Asia is shown in Figs. 4.40 – 4.41. More volatile PCB congeners have higher contributions of intercontinental transport to the depositions. In particular, emissions of PCB-28, PCB-118, and PCB-153 originated from Europe contribute 22%, 15%, and 8%

to depositions over Russia, respectively (Fig. 4.40). The contribution of Southeast Asian emission sources to the depositions of PCB-28, PCB-118, and PCB-153 over America accounts for 26%, 12%, and 9%, respectively (Fig. 4.41).

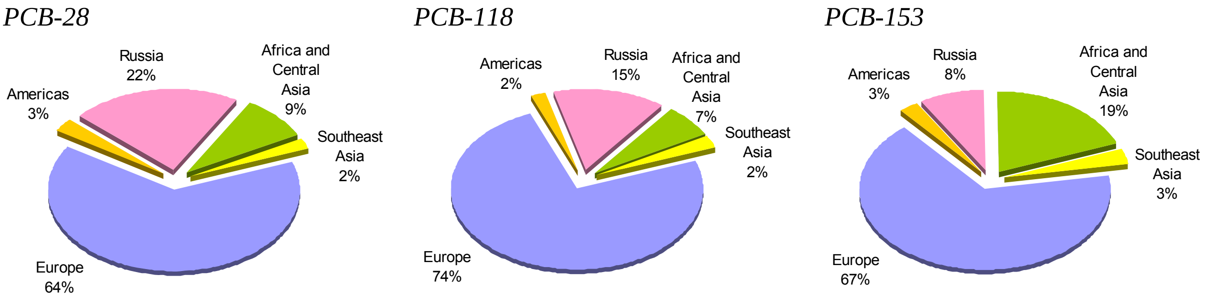


Fig. 4.40. *Distribution of three PCB congeners (PCB-28, PCB-118, PCB-153) depositions, originated from emission sources of Europe, over land territories of selected receptor regions of the northern hemisphere for 2005*

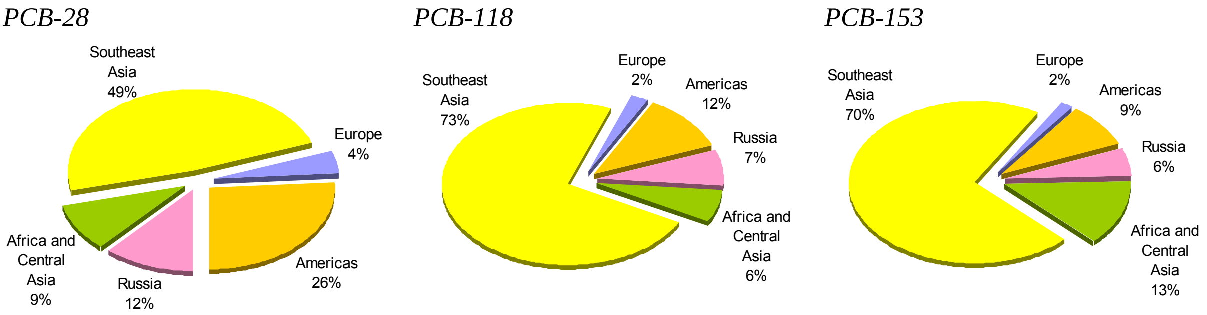


Fig. 4.41. *Distribution of three PCB congeners (PCB-28, PCB-118, PCB-153) depositions, originated from emission sources of Southeast Asia, over land territories of selected receptor regions of the northern hemisphere for 2005*

Pollution of remote regions

The contribution of intercontinental transport to the contamination of remote regions is exemplified by the Arctic. In Fig. 4.42 the contributions of selected groups of emission sources to annual total depositions of three PCB congeners over the Arctic region for 2005 are presented.

In case of PCB-28 the most significant contribution to the depositions belongs to Europe (41%) followed by Russia (34%), and America (17%). For PCB-118 40% of depositions to the Arctic is originated from the emission sources of Russia, 32% from European emission sources, and 15% from American emission sources. Different pattern of contributions to deposition over the Arctic is obtained for PCB-153 which is explained by the difference in spatial distribution of PCB-153 emission compared to the emissions of other two congeners. In particular, contributions of Europe, America, and Russia are accounted for 57%, 17%, and 14%, respectively.

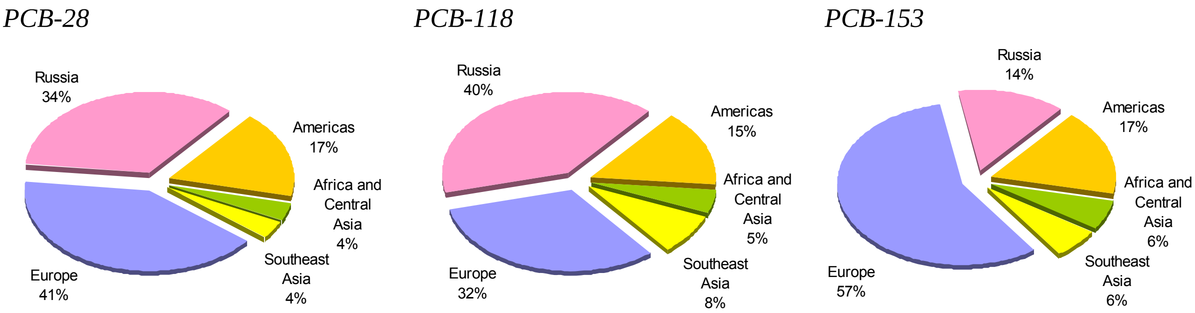


Fig. 4.42. *Contributions of selected groups of emission sources of PCB-28, PCB-118, and PCB-153 to depositions over the Arctic region in 2005*

Pollution of Central Asia countries

Preliminary estimates of the pollution of Central Asia countries by PCBs for 2005 were made for Kazakhstan, Kirgizstan, Tajikistan, Turkmenistan, and Uzbekistan. In Fig. 4.43 the contributions of selected groups of emission sources to annual total depositions of three PCB congeners over the whole territory of five Central Asia countries in 2005 are presented.

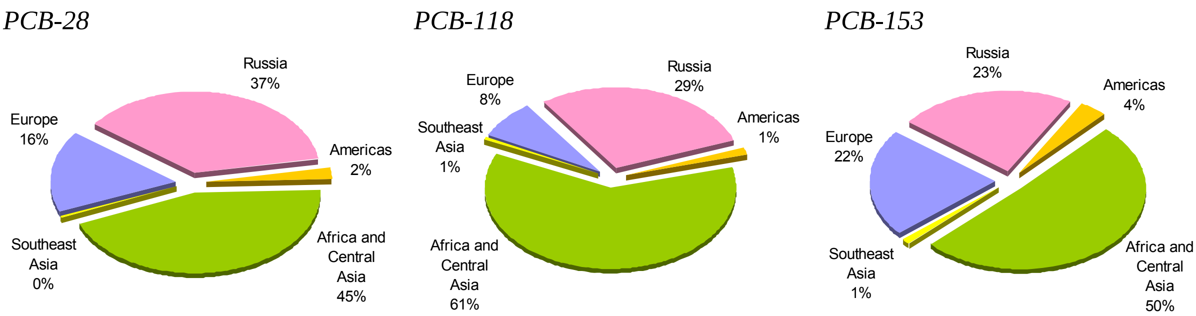


Fig. 4.43. *Contributions of selected groups of emission sources of PCB-28, PCB-118, and PCB-153 to depositions over the five Central Asia countries (Kazakhstan, Kirgizstan, Tajikistan, Turkmenistan, and Uzbekistan) in 2005*

Major contribution to the depositions of PCB-28 to the selected five Central Asia countries belongs to emission sources of Africa and Central Asia (45%). Significant contributions belong also to Russia (37%), and Europe (16%). Total depositions of PCB-118 mostly originated from Africa and Central Asia which contribute more than 60%. Other two significant contributors to PCB-118 depositions are Russia (29%) and Europe (8%). In case of PCB-153 the contributions of these three groups of emission sources are accounted for 50%, 23%, and 22%, respectively. Differences in patterns of contributions are connected with the differences in physical-chemical properties of selected PCB congeners and in spatial distribution of their emissions.

Comparison of modeling results with measurements of PCBs

For the verification of obtained modelling results preliminary comparison of computed mean annual concentrations of selected three PCB congeners in air and in precipitation with measurements of EMEP monitoring sites was performed.

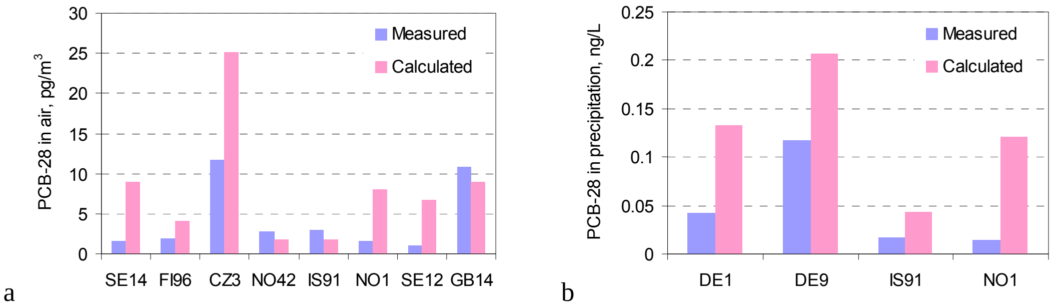


Fig. 4.44. *Comparison of computed annual mean air concentrations of PCB-28 in air (a) and in precipitation (b) with measurements of EMEP monitoring sites for 2005*

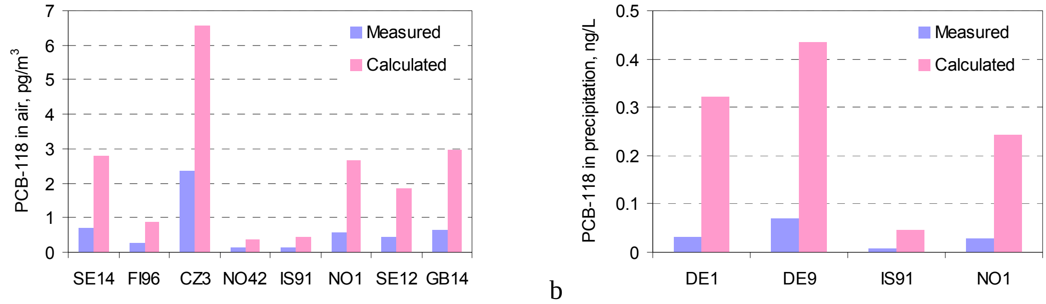


Fig. 4.45. *Comparison of computed annual mean air concentrations of PCB-118 in air (a) and in precipitation (b) with measurements of EMEP monitoring sites for 2005*

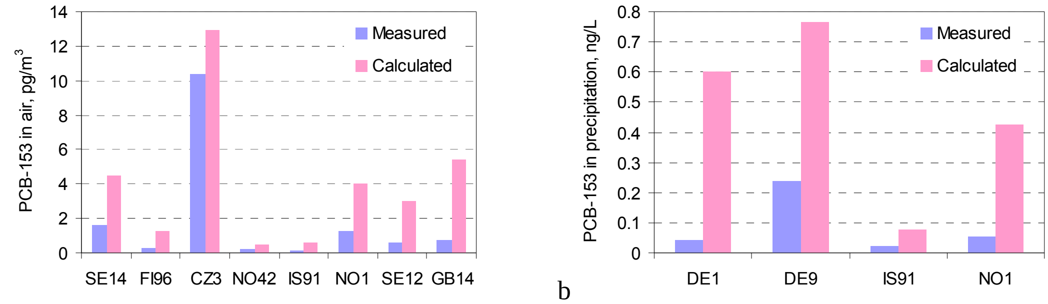


Fig. 4.46. *Comparison of computed annual mean air concentrations of PCB-153 in air (a) and in precipitation (b) with measurements of EMEP monitoring sites for 2005*

Results of the comparison of mean annual concentrations are presented in Fig. 4.44 – 4.46. This comparison has a preliminary character since the hemispheric MSCE-POP model uses rather rough spatial resolution 2.5x2.5 degrees and therefore it is difficult to expect good agreement with measurements of sites within the Europe. For the majority of sites computed values of concentrations both in air and precipitation overestimate measured values. On average, the overestimation is in the range of a factor of 2 – 5.

The overestimation is most likely connected with the usage of maximum estimates of PCB emission provided by the inventory of [*Breivik et al.*, 2007]. This inventory includes three different scenarios of global PCB emissions, namely, minimum scenario, default scenario, and maximum scenario. Currently, investigations of PCB pollution levels at the hemispheric scale were carried out using the maximum scenario of emission representing maximum levels of pollution. At further stage of the work it is planned to include also other two scenarios and to provide modelling results for the default and minimum estimates of pollution. It is believed that relative contributions of the selected groups of emission sources presented in this section for PCBs will not change significantly as a result of using the default and minimum PCB emission scenarios.

4.2.2. Lindane (γ-HCH)

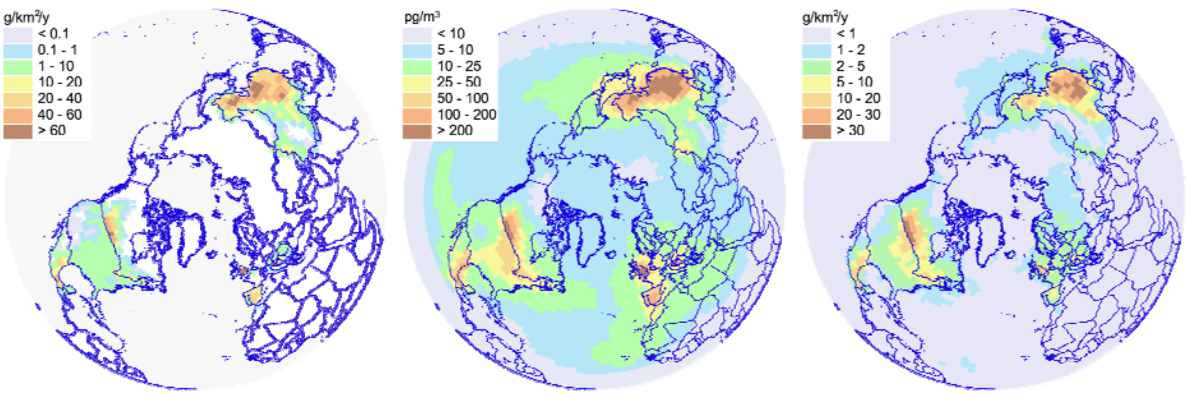
During the recent decade the usage of lindane (γ-HCH) in the majority of European countries is banned or severely restricted. Only several countries reported information on its emission for 2005. According to the measurements made at the EMEP monitoring sites the atmospheric concentrations of γ-HCH are significantly decreased in period 1990-2005.

Evaluation of intercontinental transport of γ-HCH within the northern hemisphere was carried out using the hemispheric version of the MSCE-POP model. Annual emissions of γ-HCH for the period 1990-2005 and their spatial distribution used for computations are described in section 2.5 of this report. It should be noted that currently the complete global emission inventory for γ-HCH is not available. Data on emissions of γ-HCH or its usage were compiled from several available sources and cover only part of the northern hemisphere. However, this information permits to carry out preliminary estimates of the intercontinental transport of γ-HCH from European, North American, and Chinese emission sources.

Intercontinental transport

Modelling of γ-HCH intercontinental transport was performed on the basis of emission scenario described in the section 2.5 of this report. Three groups of emission sources within the northern hemisphere were distinguished: Europe, North America, and China. Separate model runs were made for each of these groups. Obtained modelling results were used to obtain the distribution of γ-HCH depositions to the selected receptor regions shown in Fig. 4.36. In addition, the contributions of emissions from Europe, North America, and China to depositions over the Arctic region and selected Central Asia countries were evaluated.

Spatial distribution of annual emissions, mean air concentrations, and total deposition fluxes of γ-HCH for 2005 is presented in Fig. 4.47. Considering obtained modelling results it can be noted that γ-HCH emissions of North America and Europe can essentially contribute to the pollution Northern Atlantic and the Arctic region. Emission sources of China and possibly other countries of Southeast Asia can be important for Pacific Ocean and under favourable meteorological conditions for the North America.



a b c

Fig. 4.47. *Spatial distribution of γ-HCH annual emissions, g/km^2/y (a), annual mean air concentrations, pg/m^3 (b), and total depositions, g/km^2/y (c) for 2005*

The distribution of γ-HCH depositions over land territories originated from three selected groups of emission sources, in particular, Europe, North America, and China, is presented in Fig. 4.48. More than 60% of deposited γ-HCH over land emitted from European annual emission is accounted for Europe, 17% for Russia, 10% for Africa and Central Asia. Other 8% are counted for Americas and Southeast Asia receptors. In case of Chinese sources major part of deposited γ-HCH over land belongs to its own territory (77%). Depositions for other receptors are accounted for 9% for Americas, 8% for Russia, 4% for Africa and Central Asia, and 2% for Europe. About 90% of γ-HCH depositions from emission sources of North America pertain to Americas receptor.

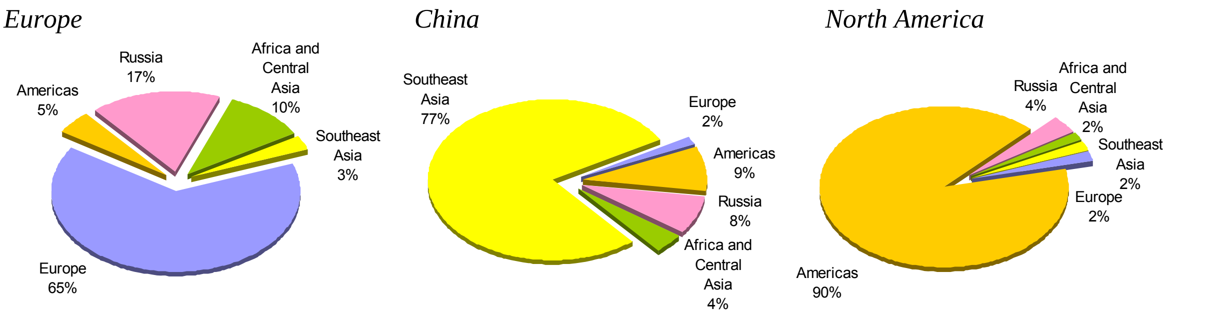


Fig. 4.48. *Distribution of γ-HCH depositions originated from emission sources of Europe, China, and North America over land territories of selected receptor regions within the northern hemisphere in 2005*

Pollution of remote regions

The contributions to total annual depositions of γ-HCH over the Arctic region emitted by selected groups of emission sources for 2005 are presented in Fig. 4.49. In comparison to the pattern of contributions presented in the previous Status Report [*Gusev et al.*, 2006] more significant contribution is obtained for Chinese emission sources (59%) while contribution of Europe is decreased to 19%. Contribution of North America accounts for 22% of total annual depositions over the Arctic. These changes in contributions of Chinese and European sources can be connected with the differences in meteorological conditions in 2004 and 2005.

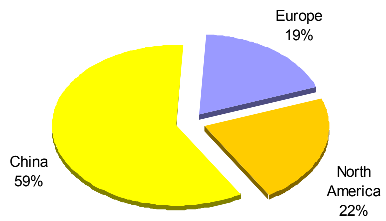


Fig. 4.49. *Contributions of selected groups of emission sources of γ-HCH to depositions over the Arctic region in 2005*

Pollution of Central Asia countries

Preliminary estimates of contributions to the pollution of several Central Asia countries by γ-HCH were made for Kazakhstan, Kirgizstan, Tajikistan, Turkmenistan, and Uzbekistan. The contributions of three selected groups of emission sources (Europe, North America, and China) to annual total depositions of γ-HCH over the whole territory of five Central Asia countries in 2005 are presented In Fig. 4.50.

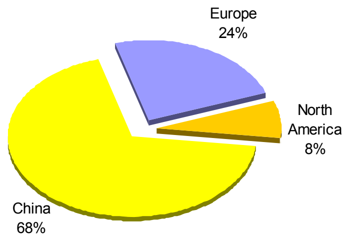


Fig. 4.50. *Contributions of selected groups of emission sources of γ-HCH to depositions over the five Central Asia countries (Kazakhstan, Kirgizstan, Tajikistan, Turkmenistan, and Uzbekistan) in 2005*

The most significant contribution to γ-HCH depositions over the five Central Asia countries belongs to emission sources of China (68%) followed by Europe (33%) and North America (23%).

Comparison of modeling results with measurements of γ-HCH

For the verification of obtained modelling results for γ-HCH preliminary comparison of computed mean annual concentrations in air and in precipitation with measurements of EMEP monitoring sites was carried out. Results of the comparison of measured and computed concentrations are given in Fig. 4.51.

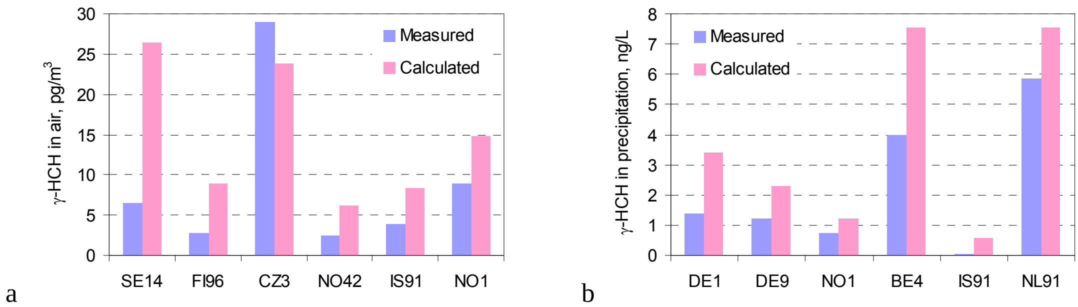


Fig. 4.51. *Comparison of computed annual mean air concentrations of γ-HCH in air (a) and in precipitation (b) with measurements of EMEP monitoring sites for 2005*

In general, it can be seen that model results have a tendency to overestimate measured levels of concentrations both in air and precipitation. The most significant differences in air concentrations accounting for more than a factor of two are encountered for the sites Rao (SE14) and Pallas (FI96). In case of concentrations in precipitation the most significant overestimation of measured levels by the model is obtained for Westerland (DE1) and Storhofdi (IS91). For other sites computed concentrations agree with measurements within a factor of two.

The overestimation is possibly connected with the uncertainties of officially reported data and available unofficial estimates of emission used for modelling. Other possible reason can be connected with the rough spatial resolution of the hemispheric MSCE-POP model which is currently 2.5x2.5 degrees. For accurate evaluation of γ-HCH pollution levels over the Europe it is more reasonable to use modelling with finer resolution. Therefore it is planned at further stage of the work to perform evaluation of γ-HCH pollution levels for the EMEP region using hemispheric/regional modelling approach based on the nesting of hemispheric and regional MSCE-POP model simulations.

4.2.3. Hexachlorobenzene (HCB)

Evaluation of HCB intercontinental transport within the northern hemisphere for 2005 was performed using the hemispheric version of MSCE-POP model. The model was run for the period 1990-2005 to take into account accumulation of HCB in the environmental media. The aim of this study was further investigation of HCB pollution levels on the hemispheric scale, evaluation of intercontinental transport and preliminary comparison with available measurements.

The emission scenario used in computations for this period is described in section 2.3 of this report. Several groups of emission sources were considered, namely: Europe, Russia, Central Asia, Southeast Asia, and Northern America. The information on HCB emission within the northern hemisphere was compiled from different sources. Official data on HCB emissions submitted by European countries were complemented by the available unofficial emission data. It should be noted that most of included official emissions were essentially lower than unofficial data on HCB emissions [*Pacyna et al.*, 1999; *Bailey*, 2001] used in calculations made in the previous years. Therefore the HCB emission in a number of European countries is most likely underestimated and requires further refinement.

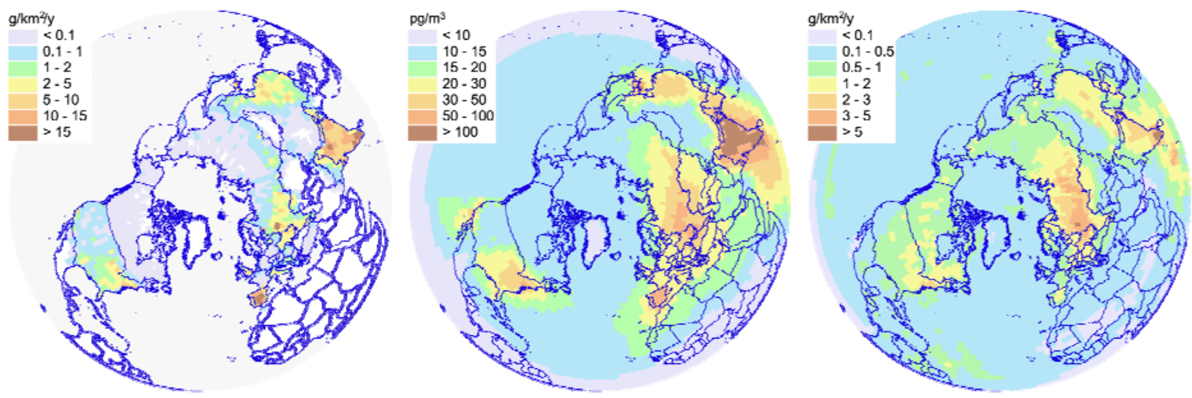
In comparison with the emission scenario presented in previous Status Report [*Gusev et al.*, 2006] current set of emission data uses unofficial data on HCB emissions for USA. Since the official emission data of the USA for 2005 and previous years were not reported the emission was prepared using available estimates of [*Bailey*, 2001].

Taking into account gaps and significant uncertainties in estimates of HCB emission within the northern hemisphere the modelling results on HCB intercontinental transport and pollution levels currently are of a preliminary character.

Pollution levels within the northern hemisphere

On the basis of model calculations performed for 2005 the pathways of HCB atmospheric transport were evaluated and contributions of selected emission sources to depositions over the receptor regions were obtained. The following groups of emission sources within the northern hemisphere were distinguished: Europe, Russia, Central Asia, Southeast Asia, and North America (section 2.4).

Spatial distribution of annual emissions, annual mean air concentrations and total annual deposition fluxes of HCB for 2005 is shown in Fig. 4.52. Elevated levels of HCB air concentrations for 2005 (about 30-60 pg/m^3 and higher) are obtained for countries of Southeast Asia, European part of Russia, Spain, and Portugal. Significant level of HCB air concentrations (higher than 100 pg/m^3) is characteristic of India. In comparison to the results for 2004 presented in the previous Status report [*Gusev et al.*, 2006] somewhat higher values of air concentrations are obtained for North America. This can be explained by the differences in emissions used for computations performed for 2004 and 2005. In particular, modelling results for 2005 were obtained on the basis of unofficial data on HCB emission for USA [*Bailey*, 2001] which were essentially higher than previously reported official emission data.



a b c

Fig. 4.52. *Spatial distribution of HCB annual emissions, g/km^2/y (a), annual mean air concentrations, pg/m^3 (b), and total depositions, g/km^2/y (c) for 2005*

Elevated levels of total deposition fluxes can be noted over the territory of Russia, countries of Eastern Europe and Southeast Asia (2.5 - 5 g/km^2/y). Lower values of total depositions (0.5 – 1 g/km^2/y) were obtained for Europe, eastern part of Russia and North America.

The distribution of total HCB depositions over the land territories of selected receptors (Fig. 4.36) originated from the emission sources of Europe, Southeast Asia and North America for 2005 is presented in Fig. 4.53. More than a half of HCB depositions originated from European emission sources fell out over Russia (53%), 17% over Europe itself, and 16% over Africa and Central Asia. In case of emission sources of Southeast Asia 47% are deposited over its territory, 24% over Americas, and 16% over Russia. Major part of total HCB depositions over land originated from North American emission sources (66%) belongs to Americas continent, followed by Russia (15%) and Africa and Central Asia (8%).

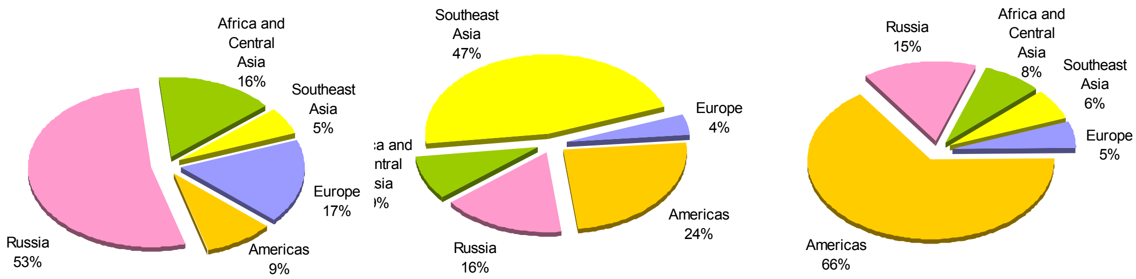


Fig. 4.53. *Distribution of HCB depositions originated from emission sources of Europe, Southeast Asia, and North America over land territories of selected receptor regions within the northern hemisphere in 2005*

Pollution of remote regions

The contributions to total annual depositions over the Arctic region of HCB emitted by selected groups of emission sources for 2005 are presented in Fig. 4.54. In comparison to the pattern of contributions presented in the previous Status Report [*Gusev et al.*, 2006] more significant contribution is obtained for HCB emission sources of North America (14%). This increase of contribution of North America is connected with the usage of the unofficial data of HCB emission for USA emission sources which are essentially higher than previously reported official emission data for HCB. Contributions of other groups of emission sources do not changed noticeably except for Southeast Asia. In particular, contributions of emission sources of Europe, Russia, Central Asia, and Southeast Asia to depositions over the Arctic in 2005 amounted to 35%, 26%, 13%, and 12%, respectively.

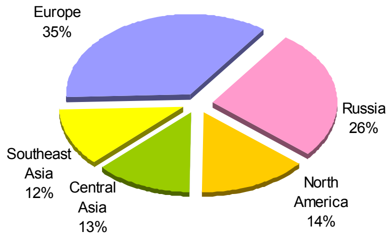


Fig. 4.54. *Contributions of selected groups of emission sources of HCB to depositions over the Arctic region in 2005*

Pollution of Central Asia countries

Preliminary estimates of contributions to the pollution of several ECCA countries by HCB were made for Kazakhstan, Kirgizstan, Tajikistan, Turkmenistan, and Uzbekistan. In Fig. 4.55 the contributions of selected groups of emission sources to annual total depositions of HCB over the whole territory of five Central Asia countries in 2005 are presented.

The most significant contribution to HCB depositions over the five Central Asia countries belongs to emission sources of Europe (52%) and Russia (33%). Contributions of other emission sources are less significant, in particular, Central Asia, North America, and Southeast Asia contribute 6%, 5%, and 4%, respectively. In comparison to the results obtained for PCBs the pattern of contributions for HCB is different. It can be noted that the contribution of European emission sources is more significant. HCB is more volatile comparing to PCB-153 and PCB-118. Therefore the role of European emission sources in the pollution of ECCA countries by HCB becomes more important.

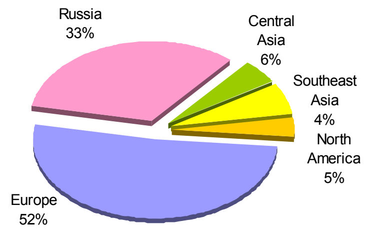


Fig. 4.55. *Contributions of selected groups of emission sources of HCB to depositions over the five Central Asia countries (Kazakhstan, Kirgizstan, Tajikistan, Turkmenistan, and Uzbekistan) in 2005*

Comparison of modeling results with measurements of HCB

Preliminary comparison of obtained modelling results for HCB with measured levels of concentrations in air and in precipitation at EMEP monitoring sites was performed. Summarized results of the comparison are presented in Fig. 4.56.

HCB concentrations in air were measured at three EMEP sites NO1, IS91, and NO42. It can be seen that the model underestimates observed levels of HCB in air at sites NO1 and NO42. Concentrations in precipitation for HCB were obtained at four sites DE1, DE9, NO1, and IS91. In this case the model also tends to underestimate measured concentrations in precipitation for sites DE1, DE9, and NO.

Contrary to other sites computed concentrations for IS91 overestimates measured levels both in air and precipitation. The disagreement can be connected with the uncertainties in available information on HCB emissions for European countries and North America. Besides the significant difference between HCB air concentrations measured at IS91 and other two sites (NO42 and NO1), accounted for more than 20 times can be noted which requires further investigations.

Results of this preliminary comparison indicate that the levels of HCB emission in Europe are likely more significant than currently available emission data. Therefore further work on the refinement of HCB emission data is required.

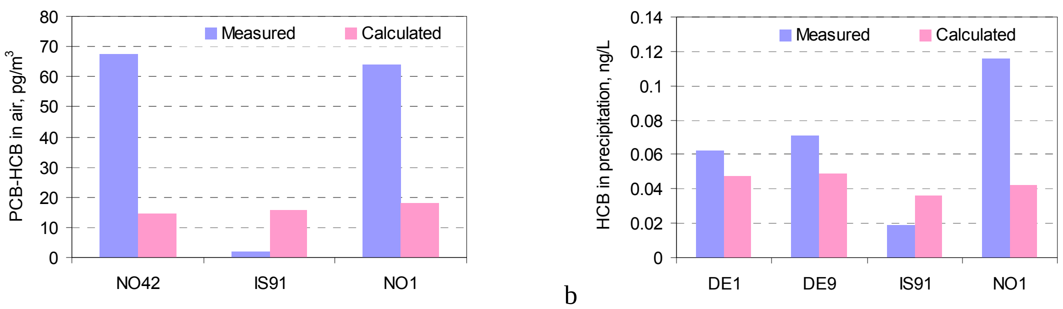


Fig. 4.56. *Comparison of computed annual mean air concentrations of HCB in air (a) and in precipitation (b) with measurements of EMEP monitoring sites for 2005*

5. CO-OPERATION

During this year the EMEP Centres continued to work in close co-operation with the subsidiary bodies to the Convention, international organizations and programmes as well as with national experts.

According to the EMEP work-plan for 2007 MSC-E continued the work on further improvement of the MSCE-POP model in accordance with the recommendations of the model review performed by the EMEP Task Force on Measurements and Modelling. In 2007 MSC-E contributed to the work of the Task Force on POPs on evaluation of new substances proposed to be added to the Protocol on POPs. This year MSC-E in close collaboration with national experts completed the final (third) stage of EMEP POP model intercomparison study and took part in the model intercomparison of the EMEP Task Force on Hemispheric Transport of Air Pollution. Experts of MSC-E participated in the 3rd Summer School of Environmental Chemistry and Ecotoxicology organized by Research Centre of Excellence for Environmental Chemistry and Ecotoxicology (RECETOX) and took part in the 17th SETAC Europe Annual Meeting.

5.1. Task Force on Measurements and Modelling

MSC-E took part in the 8th meeting of the Task Force on Measurements and Modelling held in Dessau in April 2007. TFMM participants were informed about the outcome of the joint MSC-E and MSC-W technical meeting (Moscow, February 2007) held in accordance with the recommendation of the Bureau of the EMEP Steering Body. One of the main aims of the meeting was streamlining the work of MSC-E and MSC-W in relation to the development of hemispheric/global modeling. Centres recognized that especially for ozone, mercury and some POPs there was a clear need to consider their transport at the global scale rather than at hemispheric one. A detailed work-plan for the elaboration of a common modular system for modeling of different pollutants on global level was presented. A step-wise approach was suggested for the development of a global Unified EMEP model, beginning with the unification of model geometry, input data, meteorological drivers and driving meteorological input, and harmonization of physical/chemical modules and numerical techniques. The work had been already started in 2007 (selection of meteorological preprocessors, downloading meteorological driving input data, compilation of geophysical information and harmonization of dust re-suspension parameterizations) and it is planned to be completed in 2010-2012.

The other important topic of the joint meeting was consideration of the requirements on the extension of the EMEP grid in order to include EECCA countries in the routine model calculations of EMEP. Centres proposed a two-step approach. As interim decision (step1) it was suggested to extend current EMEP 50x50 km. grid eastward to cover Central Asian countries.

Final version of an extended EMEP grid (step 2) was planned to be based on the application of a new Unified EMEP global model. (Minutes of the joint MSC-W and MSC-E technical meeting are given in the Annex C).

5.2. Task Force on POPs

In 2007 MSC-E attended the sixth meeting of the Task Force on POPs held in Vienna in June, 2007 and continued to contribute to the work on evaluation of new substances proposed for the inclusion into the Protocol on POPs. As additional information for the evaluation of short chain chlorinated paraffins (SCCPs) has been obtained with the help of MSCE-POP model with regard to the following criteria: potential for long-range transboundary atmospheric transport (LRTP) and overall persistence (Pov).

Three SCCP isomers ($C_{10}H_{17}Cl_5$, $C_{12}H_{20}Cl_6$ and $C_{13}H_{21}Cl_7$) are evaluated. The choice of these isomers for model assessment is conditioned by the fact that they are present both in technical mixtures of SCCP and in the atmosphere. Their formulas and abbreviations are given in Table 5.1.

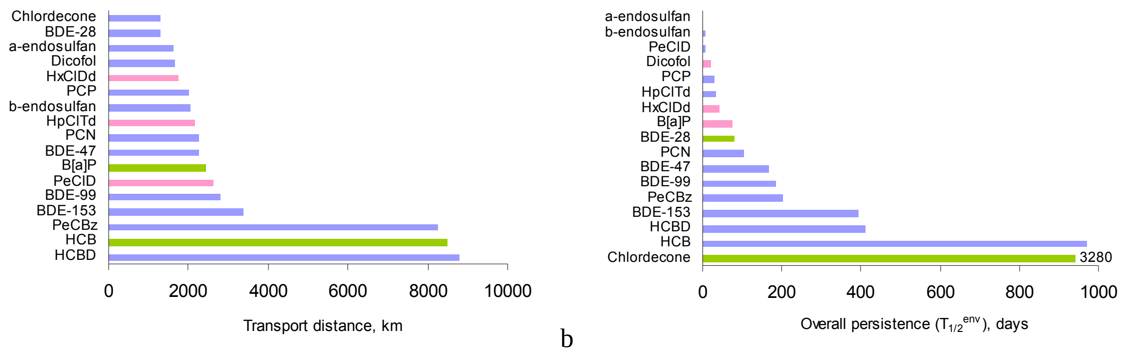
Table 5.1. *Chemical formulas and abbreviations for three SCCP isomers chosen for modelling*

Chemical formula	Chemical name	Abbreviation
$C_{10}H_{17}Cl_5$	Pentachloro-n-decan	PeClD
$C_{12}H_{20}Cl_6$	Hexachloro-n-dodecan	HxClDd
$C_{13}H_{21}Cl_7$	Heptachloro-n-tridecan	HpClTd

The results of model evaluation of the above mentioned SCCP isomers in detail are presented in MSCE Information Note 5/2007.

To characterize the LRTP, model estimates of half-life of the considered three SCCP isomers in the atmosphere ($T_{1/2}^{air}$, days) are used. LRTP is also illustrated by the Transport Distance (*TD*, km), that is the distance from the source at which annual mean atmospheric concentration of a chemical in question drops 1000 times compared with the concentration near the point source. Overall persistence is enumerated by half-life in the environment ($T_{1/2}^{env}$, days) estimated for the considered substances on the basis of the model calculations of their atmospheric transport taking into account deposition processes, degradation and exchange of a pollutant between main environmental media.

The results of calculations for the three SCCP isomers in comparison with that for substances earlier evaluated by the MSCE-POP model [*Vulykh et al*, 2005 a, b, c, d, 2006] (HCBD, PeCBz, BDE-28, 47, 99 and 153, PCN-47, dicofol, PCP and α- and β- isomers of endosulfan) are illustrated by the plots in Fig. 5.1. The results for benzo(a)pyrene (B[a]P) and hexachlorobenzene (HCB) as benchmark substances of regional and global concern, respectively, are shown in the same plots.



a b

Fig. 5.1. *Transport distance (a) and overall persistence (b) for selected substances*

Calculation results show that TD values for all three considered SCCP isomers are very close to that for B[a]P. The estimated values of $T_{1/2}^{env}$ for HxClDd and HpClTd are about two times lower than for B[a]P. Taking into account these results and uncertainties in the model parameterization of the isomers, SCCPs can be considered as pollutants of regional concern.

In addition to the calculations of *TD* and $T_{1/2}^{env}$, model simulations allow evaluating spatial distributions of the pollution by new substances originated from a conventional emission point source. As an example, Fig. 5.2 shows the maps of air concentrations of PeClD (a), HxClDd (b) and HpClTd (c) originated from the conventional point source of identical power (1 t/y) located in Europe (France). For convenience, air concentrations are presented in the relative units, i.e. as ratios of the concentration calculated in the particular point to the concentration near a source (basic value).

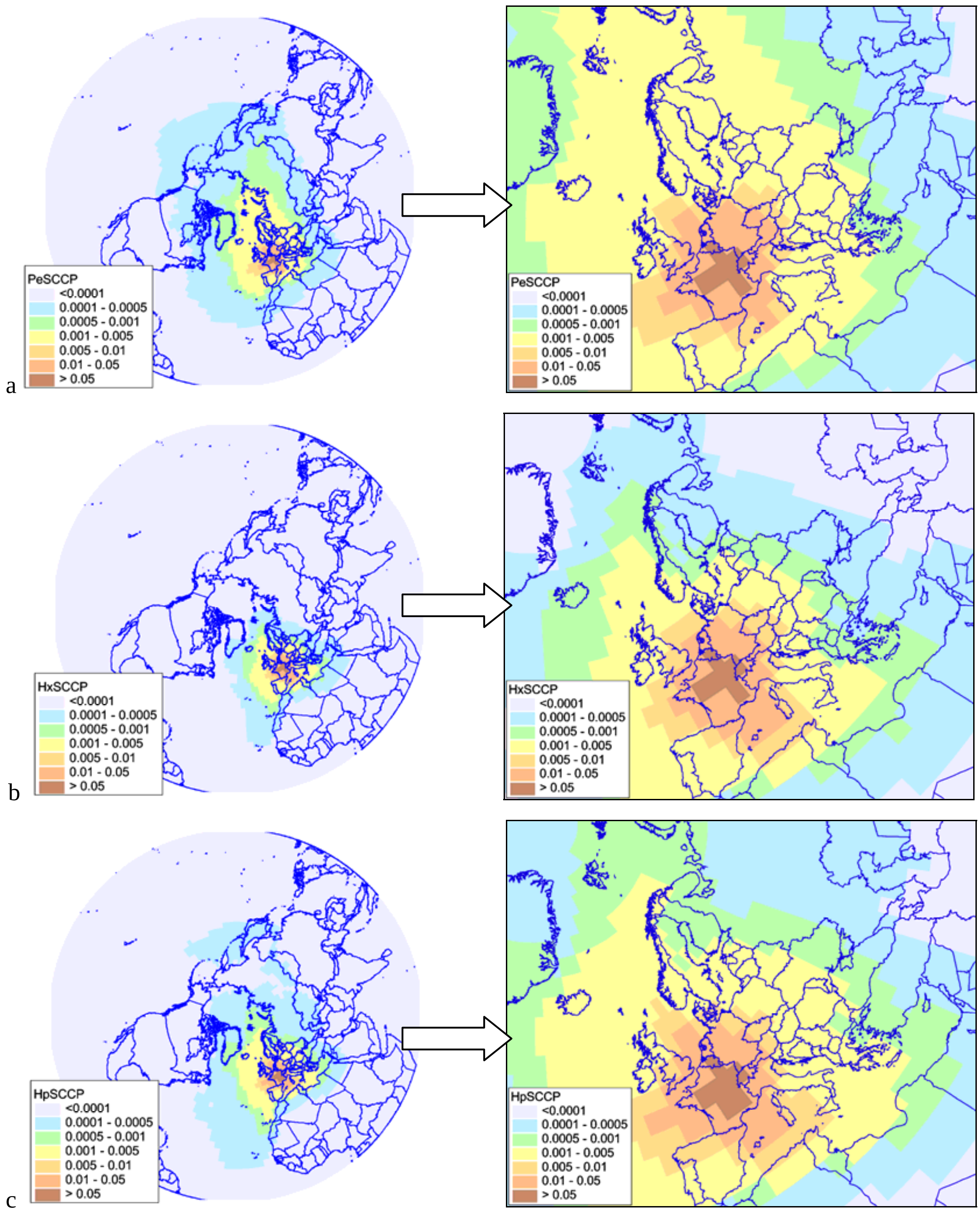


Fig. 5.2. *The spatial distribution of air pollution by PeClD (a), HxClDd (b) and HpClTd (c) in the Norhern Hemisphere and in the EMEP domain from the source (1 t/y) located in Europe (France)*

According to the calculation results, HxClDd is characterized by the least noticeable long-range atmospheric transport from European region (Fig. 5.2 b) among other three SCCPs. However, the areas with concentrations equal to 0.001 of the basic value cover an essential part of the EMEP region. Areas with high air concentrations (> 0.05 of the basic value) are located near the source. Concentrations from 0.01 to 0.05 cover neighboring regions (northern Italy, Germany, France and part of the Mediterranean Sea). Relatively low contamination levels (0.001 – 0.005 of the basic value) are calculated for in central and southern parts of Italy, Spain, the UK, Poland, Scandinavian countries.

Higher ability to long-range atmospheric transport is characteristic of PeClD (Fig. 5.2 a) and HpClTd (Fig. 5.2 c). European source can cause relatively high contamination levels over longer distances. For these isomers concentrations lower than 1000 times than basic value almost reach the Greenland coast. Within the EMEP region an area with concentrations 100 times less than basic one is much wider than for HxClDd and covers southern part of the UK, northern Italy, Germany and considerable parts of the Mediterranean and the North Seas.

5.3. Task Force on Hemispheric Transport of Air Pollution

In framework of co-operation with the EMEP Task Force on Hemispheric Transport of Air Pollution (TF HTAP) MSC-E is taking part in the coordinated multi-model intercomparison and evaluation studies of hemispheric transport and is a task leader with respect to modelling of POPs. The aim of this activity is to support the developing of better understanding of the intercontinental transport of air pollutants, its frequency and magnitude in the northern hemisphere.

The TF HTAP multi-model intercomparison started from the source-receptor experiments. The main objective of these experiments is to evaluate importance and uncertainties of hemispheric transport processes of selected POPs. It is proposed to conduct several model calculations on the basis of global emission inventories of PCB-153 and α-HCH for 2001. The four regions of the globe selected for evaluation of source-receptor relationship are Europe (EU), North America (NA), East Asia (EA), and South Asia (SA). The computations comprise base case simulation for 2001 with all emission sources and four additional model runs with emissions reduced by 20% for each selected region. For the evaluation of PCB intercontinental transport the global inventory of PCB usage and emission in the period 1930 − 2000 developed by [*Breivik et al*., 2002b] is selected. Evaluation of long-range transport of α-HCH is based on global emission inventory compiled by [*Li et al*., 2000]. On the basis of these inventories preliminary modelling results using MSCE-POP model were obtained and submitted for the analysis within the TF HTAP model intercomparison. The results can be used to characterize the significance of intercontinental transport of selected POPs. Several examples of the information obtained in source-receptor experiment using MSCE-POP model are given below. More detailed results are presented in the MSC-E Technical Report 1/2007 [*Gusev et al.*, 2007].

Spatial distribution of annual mean air concentrations of PCB-153 for 2001 obtained in the base case model run is presented in Fig. 5.3 along with the changes of PCB-153 mean annual concentrations due to 20% reduction of emissions in European region (EU) on levels of PCB-153 annual mean air concentrations. Similar information for α-HCH is shown in Fig. 5.4.

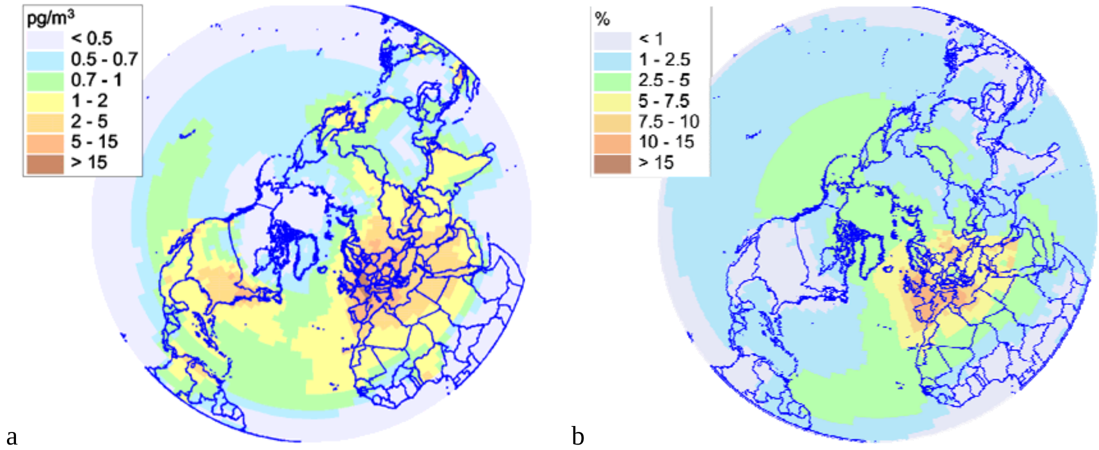


Fig. 5.3. *Spatial distribution of PCB-153 annual mean air concentrations, pg/m^3 (a), and the effect of 20% reduction of PCB-153 annual emissions in EU region on annual mean air concentrations, % (b)*

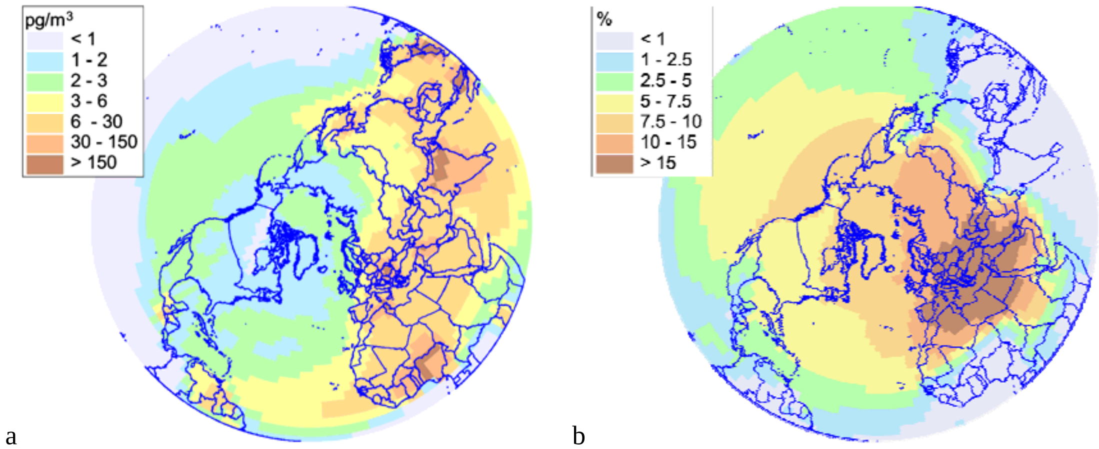


Fig. 5.4. *Spatial distribution of α-HCH annual mean air concentrations, pg/m^3 (a), and the effect of 20% reduction of α-HCH annual emissions in EU region on annual mean air concentrations, % (b)*

Levels of PCB-153 annual mean air concentrations in western and southern parts of Europe are 10-15% lower than in the base case model run. Essential influence can be noted for air concentrations in the Arctic region, and northern Atlantic. Changes in air concentrations of α-HCH due to the decrease of European emission are even more significant. This can be explained by significant contribution of European emissions to the total emission of considered pollutants within the northern hemisphere.

Changes in PCB-153 and α-HCH deposition levels in the selected receptor regions expressed in percents relative to the level obtained in the base case model run are presented in the Tables 5.2 and 5.3, respectively. The tables include also the information on the relative changes in total annual depositions of selected pollutants over the Arctic region.

It can be seen that the most significant influence on levels of PCB-153 depositions among the four selected regions belongs to the European region. Following the model simulations, 20% reduction of PCB-153 emission in European region leads to the decrease of depositions (about 2%) in East and South Asia. More essential decrease (3.5%) is obtained for the Arctic region. Influence of other selected regions is less significant due to comparatively lower contributions to the total PCB-153 emission within the northern hemisphere.

Among the four selected regions the most significant influence on levels of α-HCH depositions within the northern hemisphere also belongs to the European region. 20% reduction of emission in this region resulted in almost 18% reduction of α-HCH depositions. Essential influence can be also seen in North America region (6%) and in the Arctic region (9%). Influence of other selected regions is less significant.

Table 5.2. *Changes in annual depositions of PCB-153 to the selected regions due to 20% reduction of annual emissions, %*

Source	EA	EU	NA	SA	Arctic
EA	2.8	< 0.1	0.1	0.1	*0.2*
EU	2.1	7.6	0.4	1.9	*3.5*
NA	0.3	0.1	4.4	0.2	*0.5*
SA	0.5	< 0.1	< 0.1	4.3	*< 0.1*

Table 5.3. *Changes in annual depositions of α-HCH to the selected regions due to 20% reduction of annual emissions, %*

Source	EA	EU	NA	SA	Arctic
EA	10.5	0.2	3	0.4	2.9
EU	2.1	17.8	5.8	1	9.2
NA	< 0.1	< 0.1	1.5	< 0.1	< 0.1
SA	4	0.2	2.1	17.4	1.3

Preliminary results obtained with MSCE-POP model indicate that intercontinental transport of selected POPs (PCB-153 and α-HCH) is essential and should be taken into account in evaluation of pollution of different regions of the northern hemisphere. In particular, influence of emission sources of Europe and East Asia on the pollution levels in the northern hemisphere can be substantial.

Further experiments aimed at the investigation of POP intercontinental transport can address specific features of POPs such as dynamic exchange with underlying surface and subsequent re-emission and can be possibly made for new chemicals candidates to POPs. It is of importance also to include the comparison with available routine measurements and results of specific campaigns, e.g. passive sampling measurements of POPs.

5.4. UNEP Chemicals

At the request of European Commission MSC-E performed the model assessment of long-range transport potential and persistence in the environment of chlordecone proposed to be added to the priority list of the Stockholm Convention. The results are presented in the EMEP MSC-E Information Note 8/2006 [*Vulykh et al*., 2006].

5.5. Co-operation with Helsinki Commission

In framework of co-operation of EMEP Centres and Helsinki Commission MSC-E prepared contribution to the joint annual report for HELCOM devoted to the evaluation of airborne pollution load to the Baltic Sea in 2004 [*Bartnicki et al*., 2006]. Evaluation of atmospheric transport and depositions of PCDD/Fs to the Baltic Sea as well as contributions to depositions of particular HELCOM countries was carried out. Modelling was performed on the basis of EMEP officially submitted emission data. In addition MSC-E has prepared the environmental indicator report with regard to temporal variations of PCDD/F emissions to the atmosphere and their depositions over the Baltic Sea in period from 1990 to 2004. This indicator report can be found in the Internet at the web site of Helsinki Commission [*www.helcom.fi*].

According to official data the annual emissions of dioxins and furans from HELCOM countries have decreased in most of the HELCOM countries. The most significant drop of PCDD/F emissions can be noted for Sweden (39%), Estonia (34%) and Russia (34%). Some decrease of emissions can also be noted for Denmark (16%) and Poland (9%). For some of the HELCOM countries, in particular, for Finland, Latvia, Lithuania, and Germany, the level of PCDD/F emissions in 2004 is higher than emission of 1990.

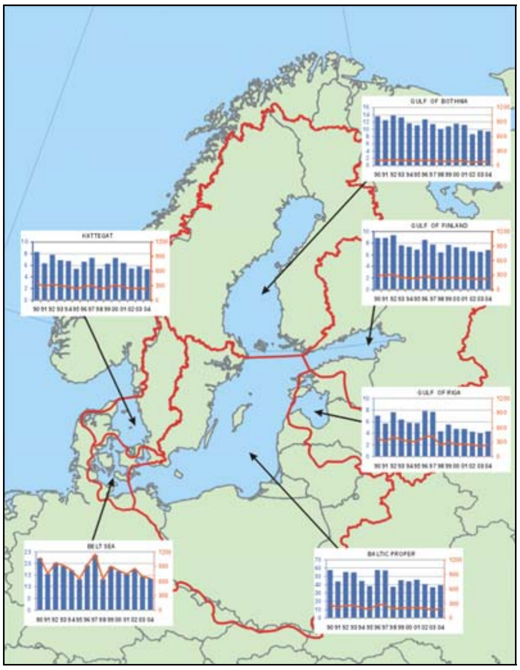


Fig. 5.9. *Time-series of computed total annual atmospheric deposition of PCDD/Fs to six sub-basins of the Baltic Sea for the period 1990-2004 in t/y as bars (left axis) and total deposition fluxes in μg TEQ/km^2/y as lines (right axis)*

Despite substantially increased dioxin and furan emissions from HELCOM countries as a whole, their total annual atmospheric depositions to the surface of the Baltic Sea have decreased in the period 1990 − 2004 by 33%. Time-series of computed annual atmospheric depositions of PCDD/Fs to the six sub-basins of the Baltic Sea for this period are shown in Fig. 5.9. On the level of individual sub-basins the most significant drop in PCDD/F depositions can be noted for the Belt Sea (40%) and the Gulf of Riga (39%). In spatial distribution of PCDD/Fs depositions on the Baltic Sea the highest levels can be noted for the southern-western part of the Baltic Sea (the Belt Sea). Significant levels of depositions can also be noted for the Kattegat and the Gulf of Riga. Lowest level of depositions can be noted for the Gulf of Bothnia. Among the HELCOM countries the most significant contributions to PCDD/F depositions over the Baltic Sea belong to Germany, Poland, and Russia.

5.6. Co-operation with national experts

In 2007 MSC-E in co-operation with national experts continued the work on the intercomparison of POP models. The fifth EMEP expert meeting on intercomparison of POP models was held in Moscow in February, 2007. The meeting was attended by 15 experts from the Czech Republic, Germany, Japan, the Netherlands, Norway, Switzerland, the UK and MSC-E.

This year a scientific paper devoted to the main output of Stages I and II and analysis of agreement and discrepancies between model simulations of these stages is under preparation. Within Stage III evaluation of overall persistence and long-range transport potential for 14 reference chemicals was performed and relative order in their ranking was compared. It was found that there was a reasonable agreement between results of six different models on relative order in ranking a number of reference chemicals with respect to LRTP and Pov. A group of 14 considered pollutants was nearly divided by all of the models on chemicals with high, medium and low LRTP and Pov. For some pollutants notable differences in ranking took place. Better agreement between the models for ranking with respect to Pov than to LRTP was found.

The work on the comparison of calculation results with monitoring data [*Gusev et al.*, 2007] was carried out in the collaboration with national experts in monitoring - Dr. A. Sweetman (UK) and Prof. I Holoubek (Czech Republic).

MSC-East took part in the third annual Summer School on Environmental Chemistry and Ecotoxicology organized by EU-DG Research Centre of Excellence for Environmental Chemistry and Ecotoxicology (RECETOX). The representatives of MSC-E participated in the work of the School as invited lecturers on modelling POP fate in the environment.

This year MSC-E participated in the 17th Annual Meeting of SETAC Europe (Society of Environmental Toxicology and Chemistry) held in Porto in May 2007. The meeting was focused on "The multiple stressors for the environment - present and future challenges and perspectives". The main aims of the meeting were to address and foster presentations about the challenges posed by the presence of multiple stressors in the environment, including man, being it of a human nature (i.e. pharmaceuticals, industrial chemicals) or natural, as a result of global climate change (i.e. increased temperature, UV radiation), as well as to bridge the gaps between science and policy. In the framework of the session 'Fate and exposure modelling' MSC-E representatives made a presentation "POP fate modeling under EMEP: recent developments'. The talk presented recent findings in the development of MSCE-POP model and in the application of spatially resolved model to the evaluation of new possible POPs. The latter can be also useful for environment-protection activities within the LRTAP Convention, Stockholm Convention, REACH, etc. In the framework of the meeting a special topic devoted to REACH (Registration, Evaluation, Authorization and Restriction of CHemicals – new EU regulation on chemicals) one of the most important aims of which is to improve protection of human health and the environment from the risks of chemicals pollution was discussed.

6. FUTURE ACTIVITIES

In order to further improve the quality of estimates of the POP pollution levels in the EMEP region, the following activities are proposed for 2008:

1. Model development

    1.1. Improve the information on physical-chemical properties of PAHs, PCDD/Fs, PCBs, γ-HCH and HCB for the use in model simulations.

    1.2. Start the development of global POP multicompartment transport model.

    1.3. Participate in the POP model intercomparison study, evaluation exercise and in the development of intercomparison tools begun at the Workshop on Intercontinental Transport Modelling Intercomparison held in January 2006.

    1.4. Investigate possible approaches to the evaluation of the influence of climate change on the fate and behavior of POPs.

    1.5. Continue development of the model parameterization for POP re-suspension.

2. Input data preparation

    2.1. Prepare spatial distributions of anthropogenic emission for modelling based both on official and unofficial data.

    2.2. Refine spatial and temporal aerosol distribution in the atmosphere for more precise description of POP gas/particle partitioning and particulate degradation.

    2.3. Refine spatial and temporal distribution of OH-radical in the atmosphere for more precise description of POP degradation in gaseous form.

    2.4. Continue preparation of meteorological and geophysical data for hemispherical/global modelling.

    2.5. Start preparation of input data for global modelling (land cover, sources, global data on soil properties, etc).

    2.6. Employ ECMWF reanalysis for data processing

3. Evaluation of pollution

    3.1. Prepare information on polycyclic aromatic hydrocarbons (PAHs) and toxic congeners of dioxins/furans (PCDD/Fs) for 2006: air concentrations and depositions over Europe and country-to-country matrices.

    3.2. Evaluate ecosystem-dependent depositions of POPs in co-operation with effect community.

    3.3. Evaluate dispersion of PCBs, HCB and γ-HCH at the hemispheric scale; evaluate European pollution in 2006 by regional calculations with the use of boundary and initial conditions obtained by hemispheric modeling.

3.4. Complement EMEP monitoring data with quality-checked data from other international programmes and make a comprehensive comparison of observations with model results. Compare modelling results (concentration in air and precipitation, deposition fluxes) with available monitoring data.

3.5. Continue the work on the evaluation of possible new POPs to support TF on POPs.

3.6. Continue to co-operate with EU, HELCOM, UNEP, etc.

CONCLUSIONS

In this Status Report the progress in the evaluation of POP pollution levels and source-receptor relationships within the European region and at the hemispheric scale is discussed.

The main conclusions of the work carried out are summarized below.

Monitoring of POPs

- In 2005 it was 14 measurement sites measuring POPs in air and/or precipitation. The spatial distribution in Europe is still unsatisfactory; there are no sites in east of Europe. Hopefully, the new EU directive on heavy metals and PAH will have a positive effect on the number of EMEP measurement stations as well.
- In 2006 EMEP/CCC arranged a passive sampling campaign covering whole of Europe as well as central Asia to evaluate the spatial patterns of POPs in air. The results of this campaign will be available and discussed next year.
- PCB concentrations in the Czech Republic and the UK are much higher than those observed in the Nordic countries. It is explained by the high historical usage of PCBs in central Europe. With the exception of the UK, the PCB28/PCB180 ratio tends to increase from south to north. This confirms that there are marked differences in the long-range transport potential (LRTP) within the group of PCBs.
- The presence of HCH in environments far away from the sources is due to long-range atmospheric transport. The relatively high concentrations of α-HCH measured at higher latitudes have also been observed in seawater.

Emission data

- The official data on POP emissions (PAHs, PCDD/Fs, HCB, PCBs and HCH) for the period from 1990 to 2005 (at least for one year) were submitted by 35 Parties to the Convention. It should be pointed out that the number of countries that submit official information on spatial distribution of emissions and gridded sector data is gradually increasing. Nevertheless, to estimate total emission of POPs and their spatial distribution over the European region unofficial emission data still have to be used.
- According to the official and unofficial data, emissions of all the pollutants of concern tend to decrease from 1990 to 2005. In particular, emissions in the European region of four indicator PAHs (benzo[a]pyrene (B[a]P), benzo[b]fluoranthene (B[b]F), benzo[k]fluoranthene (B[k]F), indeno[1,2,3-cd]pyrene (I_P)) have decreased by 23 - 28% depending on particular PAH, European emissions of PCDD/Fs by 50%, of HCB by 22% and of γ-HCH by 98%.

Model development

- This year further model development is performed in accordance with the recommendations of model review.
- The number of land-use types involved into the model was enlarged. This allowed obtaining information on deposition to various ecosystems and refining model descriptions of particulate dry deposition to various types of underlying surface.

- The influence of re-suspension process to contamination of the European region was evaluated. The investigations show that under specific conditions re-suspension process can essentially contribute to the contamination levels. In particular, the decrease of net deposition flux in the UK due to re-suspension reaches about 20 – 30%.
- The input data for modelling on atmospheric aerosol and OH-radical concentrations in 2000 were prepared by CMAQ model. These data have spatial resolution of the model and temporal resolution up to 6 hours. These modifications have led to essential improvement of the agreement of calculated and measured contamination levels at EMEP monitoring sites.

Model assessment of POP pollution levels

- Model evaluation of the environmental pollution levels within the European region was carried out for the four indicator PAHs, PCDD/Fs, PCBs, γ-HCH and HCB for 2005. Trends of contamination from 1990 to 2005 were examined for PCDD/Fs. In addition, media response to possible PCDD/F emission scenarios up to 2020 was evaluated. Estimates of transboundary transport of B[a]P and PCDD/Fs within the EMEP region for 2005 were obtained. For PCBs, γ-HCH and HCB the emphasis was put to the evaluation of intercontinental transport and contamination of remote regions (the Arctic).
- The levels of PCDD/F net deposition flux in Europe in 2005 differ from about 0.1 ng TEQ/m^2/y in northern Europe (Norway, northern parts of Sweden and Finland) to 3 ng TEQ/m^2/y and higher in central and southern Europe (Poland, the Czech Republic, Macedonia, Serbia and Montenegro, Portugal). High values of deposition levels (1 – 3 ng TEQ/m^2) due to high emission densities are calculated for Ukraine and part of Turkey.
- Calculations of pollution levels by PCDD/Fs for a long-time period allow evaluating temporal trends of pollution for European countries. The results, in particular, indicate an increasing role of re-emission in the countries with strong emission decrease. In particular, in 2005 re-emissions in the UK amount to about 10%, and in the Czech Republic to about 20% of the anthropogenic emissions.
- Media response to possible emission scenarios for PCDD/Fs up to 2020 was evaluated. Under CR scenario (CR – Base Line scenario with Current Legislation and Current Ratification of the UNECE POP Protocol) typical reduction of PCDD/F air concentrations from 2005 to 2020 are from 20% to 40%. On the opposite, for FI scenario (FI – Base Line scenario with Current Legislation and Full Implementation of the UNECE POP Protocol), in addition to decrease of air concentration levels in Central Europe essential reduction of contamination levels in eastern and south-eastern parts of Europe takes place. In this case typical reduction of PCDD/F air concentrations in European countries is 40% − 60%.
- The transboundary transport of PCDD/Fs was evaluated taking into account national anthropogenic emission sources of European countries, non-EMEP anthropogenic sources (USA and Canada) and re-emission. Contributions of other European countries to the deposition levels of a particular country are significant for the majority of European countries. Typically they vary from 20% to 80%. The contributions of non-EMEP anthropogenic sources to the pollution of European countries can be noticeable and reach up to 20% for countries located close to EMEP boundaries. Considerable contributions of non-EMEP sources (more than 15%) to depositions take place for countries located near the borders of the EMEP domain: Kazakhstan, Iceland, Norway, Finland and Sweden. The input of re-emission to depositions in European countries is in the range from 30% to 70%.

- Annual mean B[a]P concentrations in the surface atmospheric layer vary from 0.1 to 1 ng/m^3 and more in Central and Southern Europe. High levels of contamination are characteristic for Poland, Ukraine, parts of the Czech Republic and Slovakia (up to 1 ng/m^3 and higher). Spatial distribution of the rest three indicator PAHs (B[b]F, B[k]F, and I_P) in 2005 are similar to that of B[a]P. The levels of air concentrations of B[k]F in Europe are lower than for the rest three indicator compounds.
- The transboundary transport of B[a]P between European countries was evaluated by regional calculations (within the EMEP region). The contribution of the external sources to air concentrations and depositions of B[a]P in particular countries is essential and varies typically from 20 to 80%.
- Estimates of intercontinental transport of three PCB congeners were obtained by hemispheric version of MSCE-POP model using maximum scenario of updated inventory of global PCB emission. According to modelling results major contribution to the pollution of the Arctic is made by emission sources of Europe, Russia, and North America. Pollution of Central Asia countries by selected PCB congeners is mainly determined by emission sources of Africa and Asia and Russia. More volatile PCB congeners have higher contributions of intercontinental transport to the depositions. In particular, contribution of Southeast Asia emission sources to the depositions of PCB-28, PCB-118, and PCB-153 over Americas accounted for 26%, 12%, and 9%, respectively.
- Preliminary estimates of γ-HCH intercontinental transport from European, North American, and Chinese emission sources were carried out. It should be noted that currently available information on γ-HCH emission covers only part of the northern hemisphere and requires further refining. Following the modeling results Chinese emission sources can provide significant contribution to the intercontinental transport and to the pollution of remote regions.
- Modelling of HCB intercontinental transport was performed on the basis of official emission data and available unofficial information. It should be noted that available officially submitted HCB emissions are essentially lower than unofficial data on HCB emissions. Therefore HCB emission within the EMEP region is most likely underestimated and requires further refinement. This can be also confirmed by the underestimation of measured HCB concentrations at EMEP monitoring sites by the hemispheric MSCE-POP model. According to obtained modeling results intercontinental transport of HCB can significantly contribute to the pollution levels of different regions within the northern hemisphere.

Co-operation

- MSC-E continued the work on evaluation of POP intercontinental transport in co-operation with the Task Force on Hemispheric Transport of Air Pollution. In framework of source-receptor experiment of TF HTAP multi-model intercomparison MSC-E has carried out simulations of PCB-153 and α-HCH for 2001 and submitted obtained modelling results for the analysis.
- In 2007 MSC-E participated in the work on evaluation of potential new POPs proposed for the inclusion into the Protocol on POPs. This year modeling data as additional information for the evaluation of short chain chlorinated paraffins (SCCPs) with regard to potential for long-range transboundary atmospheric transport (LRTP) and overall persistence (Pov) have been obtained.
- For chlordecone (a substance proposed to be added to the priority list of the Stockholm Convention) model assessment of long-range transport potential and overall persistence in the environment has been performed.
- Collaborative work of EMEP Centres on evaluation of airborne pollution load to the Baltic Sea for HELCOM was continued. MSC-E contributed to the Joint report of three EMEP Centres for

HELCOM the evaluation of atmospheric depositions of lead, cadmium, mercury, and dioxins and furans for 2004. Besides the indicator reports on emissions of HELCOM countries and depositions to the Baltic Sea of HMs and PCDD/Fs for the period 1990-2004 were updated.

- In 2007 MSC-E in co-operation with national experts is finalizing the work on the intercomparison of POP models. The last Stage III of the intercomparison is devoted to the comparison of model rankings of pollutants with regard to their long-range transport potential and persistence in the environment.
- In co-operation with national experts MSC-E continued the studies of POP pollution levels in Europe on the basis of joined interpretation of modelling results and available measurements.

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Annex A

EMEP work-plan for POPs in 2007

2.2. Atmospheric measurements and modelling

Description/objectives

To support the implementation of protocols to the Convention; provide the measurement and modelling tools necessary for further abatement policies; compile and evaluate information on transboundary air pollution; and implement the EMEP monitoring strategy adopted in 2004. The Task Force on Measurements and Modelling, led by the United Kingdom and co-chaired by WMO, reviews and assesses the scientific and operational activities of EMEP related to monitoring and modelling, evaluates their contribution to the effective implementation and further development of the protocols, and reviews national activities related to measurement, modelling and data validation.

Main activities and time schedule for monitoring:

(b) Review, store and make available the 2006 monitoring data (CCC, MSC-W, MSC-E); assess uncertainties relating to, and the representativeness of, monitoring data on heavy metals and POPs (CCC, MSC-E);

(k) Support the organization of a pilot study using passive and active air samplers to monitor POPs across the EMEP domain in order to provide spatially and temporally resolved air concentration data (CCC, MSC-E, Parties);

(l) Evaluate the POP passive measurements campaign and compare with modelling; evaluate the EMEP monitoring strategy in relation to the outcome of this campaign as well as UNEP's global monitoring strategy; report conclusions to the Task Force (MSC-E, CCC);

Main activities and time schedule for atmospheric modelling in general:

(c) Further develop the MSC-E models and report on progress, taking into account the recommendations of the model review (MSC-E);

(e) Complement EMEP data with data from other international programmes and make a comprehensive comparison of observations with model results (CCC, MSC-E, MSC-W, Parties).

Main activities and time schedule for atmospheric modelling for POPs:

(a) Prepare information on polycyclic aromatic hydrocarbons (PAHs) and toxic congeners of dioxins/furans (PCDD/Fs) for 2005: air concentrations and depositions over Europe; comparison of modelling results (concentration in air and precipitation, deposition fluxes) with monitoring data; country-to-country matrices; estimates of depositions on marginal seas (Mediterranean, Baltic, Black and North Seas); evaluation of media response to a possible emission reduction scenario for PCDD/Fs (MSC-E, CCC);

(b) Further develop the MSCE-POP model in accordance with the recommendations of the model review: refine datasets of physical-chemical properties used in modelling; develop the model parameterization for POP resuspension and volatilization from soils and improve the model description of degradation in the atmosphere and deposition processes and seasonal variations of main processes (MSC-E);

(c) Prepare input data for the model application; use the ECMWF reanalysis for the data preprocessing; prepare mapped emission data for regional modelling based on both official and expert estimates (MSC-E);

(d) Complete stage III of the MSCE-POP model intercomparison study (comparison of different model approaches to ranking a number of reference chemicals with respect to longrange transport potential and overall persistence) and the analysis of agreement and discrepancies between model simulations of previous stages; cooperate with national experts on POP modelling issues (MSC-E, Parties)

(e) Assess the atmospheric behaviour of possible new POPs;

(f) Investigate the possibility of applying inverse modelling for selected POPs on the basis of measurement data, including passive sampling; (MSC-E).

2.4. Hemispheric transport of air pollution

Description/objectives:

Description/objectives: To develop a fuller scientific understanding of the hemispheric transport of air pollution and estimate the hemispheric transport of specific air pollutants, the Task Force on the Hemispheric Transport of Air Pollution, led by the United States and the European Community, coordinates activities, including collaboration with other international bodies, programmes and networks, both within and outside the UNECE region, with related interests.

Main activities and time schedule:

(c) Continue the model intercomparison and evaluation exercise and the development of intercomparison tools and information infrastructure begun at Workshop on Intercontinental Transport Modelling Intercomparison held on 30-31 January 2006 (Task Force; CCC, MSC-E, MSC-W);

Annex B

COUNTRY-TO-COUNTRY DEPOSITION MATRICES FOR 2005

***Table B.1**. Codes of countries*

Country/Region/Sea	Code	Country/Region/Sea	Code
Albania	AL	Latvia	LV
Armenia	AM	Lithuania	LT
Austria	AT	Luxembourg	LU
Azerbaijan	AZ	Malta	MT
Belarus	BY	Monaco	MC
Belgium	BE	Netherlands	NL
Bosnia and Herzegovina	BA	Norway	NO
Bulgaria	BG	Poland	PL
Croatia	HR	Portugal	PT
Cyprus	CY	Republic of Moldova	MD
Czech Republic	CZ	Romania	RO
Denmark	DK	Russian Federation (European part)	RU
Estonia	EE	Serbia and Montenegro	CS
Finland	FI	Slovakia	SK
France	FR	Slovenia	SI
Georgia	GE	Spain	ES
Germany	DE	Sweden	SE
Greece	GR	Switzerland	CH
Hungary	HU	The Former Yugoslav Republic of Macedonia	MK
Iceland	IS	Turkey	TR
Ireland	IE	Ukraine	UA
Italy	IT	United Kingdom	GB
Kazakhstan	KZ		

Table B.2. *Matrix of B[a]P country-to-country depositions in 2005, kg/y*

Receptors ↓ Emitters ⟶

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CS	CY	CZ	DE	DK	EE	
AL	**505.6**	0.02	0.99	0.03	6.05	0.71	19.08	0.99	0.03	100.6	0.08	2.49	6.19	0.40	0.12	**AL**
AM	0.04	**435.6**	0.02	61.41	0.04	0.04	0.15	0.10	0.00	0.13	0.42	0.10	0.25	0.03	0.02	**AM**
AT	1.43	0.02	**733.1**	0.06	8.19	18.87	4.51	5.77	2.55	17.36	0.06	149.9	544.7	5.94	1.79	**AT**
AZ	0.10	68.34	0.08	**918.7**	0.11	0.15	0.49	0.51	0.00	0.39	0.74	0.33	0.95	0.13	0.13	**AZ**
BA	15.09	0.02	9.31	0.03	**1001**	2.91	11.94	2.33	0.12	159.3	0.06	18.10	32.64	1.68	0.45	**BA**
BE	0.06	0.01	0.67	0.02	0.15	**1230**	0.22	1.08	0.14	0.29	0.00	2.15	160.6	3.15	0.63	**BE**
BG	12.87	0.19	5.40	0.32	14.87	3.39	**2118**	7.19	0.10	175.1	0.72	15.57	33.88	2.34	1.12	**BG**
BY	1.67	1.08	6.47	1.73	5.07	10.61	11.13	**3980**	0.16	14.66	0.87	54.48	99.69	16.90	40.27	**BY**
CH	0.23	0.01	10.29	0.01	0.69	6.44	0.30	0.80	**36.51**	0.90	0.01	3.60	105.3	1.10	0.40	**CH**
CS	84.08	0.04	9.73	0.07	139.8	4.09	101.8	3.48	0.14	**2002**	0.11	23.48	44.12	2.47	0.62	**CS**
CY	0.18	0.13	0.04	0.09	0.13	0.03	0.37	0.05	0.00	0.40	**193.6**	0.14	0.31	0.02	0.01	**CY**
CZ	1.17	0.03	92.15	0.09	6.14	21.00	4.99	9.88	1.07	16.97	0.05	**2209**	614.1	12.44	2.75	**CZ**
DE	1.61	0.15	134.3	0.34	4.45	465.1	5.41	33.34	19.91	9.89	0.08	310.1	**14646**	110.8	13.31	**DE**
DK	0.08	0.02	0.81	0.06	0.22	13.62	0.36	3.70	0.06	0.49	0.01	6.05	98.91	**633.4**	2.56	**DK**
EE	0.18	0.15	1.21	0.28	0.71	3.37	0.97	43.94	0.04	1.78	0.08	9.07	32.21	8.64	**1022**	**EE**
ES	0.75	0.04	2.26	0.10	1.54	14.36	1.21	3.08	0.39	1.88	0.05	3.69	54.86	5.63	2.16	**ES**
FI	0.69	1.02	4.69	2.11	2.67	19.74	3.73	91.83	0.22	6.82	0.37	34.16	130.3	43.85	214.4	**FI**
FR	2.14	0.08	12.80	0.19	6.19	248.3	3.27	7.83	12.97	6.91	0.08	22.73	678.2	19.31	5.82	**FR**
GB	0.13	0.05	1.24	0.13	0.33	61.25	0.53	5.74	0.15	0.62	0.03	9.40	124.5	16.57	2.90	**GB**
GE	0.16	70.95	0.14	77.93	0.22	0.22	0.93	1.05	0.00	0.77	1.01	0.71	1.65	0.17	0.14	**GE**
GR	50.64	0.22	2.48	0.29	8.40	2.07	84.16	4.23	0.07	54.71	1.62	7.61	17.61	1.24	0.56	**GR**
HR	8.99	0.02	22.76	0.04	207.3	2.73	8.81	2.45	0.14	89.66	0.05	24.98	35.74	1.53	0.61	**HR**
HU	3.91	0.04	61.47	0.08	27.97	5.40	12.83	5.08	0.24	112.6	0.09	78.37	78.67	3.39	1.15	**HU**
IE	0.03	0.01	0.13	0.04	0.06	4.19	0.15	1.15	0.02	0.13	0.01	1.06	14.01	2.85	0.82	**IE**
IS	0.02	0.01	0.13	0.03	0.07	1.16	0.05	0.59	0.01	0.10	0.00	0.66	4.88	1.89	0.40	**IS**
IT	30.23	0.07	57.40	0.14	66.05	10.38	18.90	6.33	4.37	58.18	0.49	35.49	122.6	4.18	1.58	**IT**
KZ	0.20	1.92	0.46	9.65	0.37	1.65	1.27	12.72	0.02	1.23	0.14	3.71	10.41	1.75	2.79	**KZ**
LT	0.33	0.12	2.64	0.27	1.32	5.25	1.90	196.9	0.07	3.18	0.14	21.70	51.45	11.98	23.02	**LT**
LU	0.01	0.00	0.13	0.00	0.02	11.32	0.02	0.09	0.03	0.04	0.00	0.30	27.76	0.21	0.06	**LU**
LV	0.33	0.18	2.20	0.37	1.29	5.53	1.85	124.8	0.07	3.15	0.14	16.90	53.00	14.14	143.0	**LV**
MC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	**MC**
MD	0.55	0.08	0.55	0.15	0.96	0.60	5.28	7.28	0.01	3.63	0.28	2.94	5.54	0.66	0.65	**MD**
MK	52.09	0.02	1.05	0.02	4.60	0.68	58.99	0.79	0.02	104.5	0.05	2.98	6.46	0.45	0.13	**MK**
NL	0.05	0.01	0.63	0.02	0.13	367	0.21	1.53	0.08	0.24	0.00	3.22	302.0	5.25	0.78	**NL**
NO	0.47	0.24	3.02	0.61	1.54	34.41	1.85	17.71	0.20	2.93	0.13	15.15	148.8	92.57	10.53	**NO**
PL	3.76	0.28	41.26	0.70	14.79	50.95	16.98	289.5	0.99	37.17	0.41	976.5	801	89.29	24.30	**PL**
PT	0.08	0.01	0.21	0.01	0.15	1.91	0.14	0.40	0.04	0.20	0.01	0.31	5.73	0.82	0.28	**PT**
RO	15.43	0.36	16.35	0.65	39.52	9.01	123.7	23.69	0.29	245.9	1.20	56.06	97.73	6.81	3.40	**RO**
RU	8.31	48.21	20.69	152.1	16.61	56.76	45.31	1108	0.72	48.63	5.94	149	430.6	101.9	544.4	**RU**
SE	1.07	0.55	5.37	1.43	3.77	59.90	5.06	57.17	0.30	8.19	0.26	41.52	324.9	280.5	54.83	**SE**
SI	1.05	0.01	57.16	0.02	10.28	1.34	2.34	1.29	0.11	12.15	0.02	13.33	22.83	0.68	0.42	**SI**
SK	2.05	0.04	28.38	0.08	9.25	4.97	6.74	7.00	0.19	23.37	0.08	219.9	71.23	4.25	1.57	**SK**
TR	7.14	87.83	3.44	17.59	7.04	3.25	47.57	12.31	0.10	27.31	73.96	12.85	28.51	2.42	1.83	**TR**
UA	8.29	4.93	16.18	7.35	19.44	17.15	51.90	353.1	0.37	56.97	4.94	106.2	166.4	19.71	21.24	**UA**
	AL	**AM**	**AT**	**AZ**	**BA**	**BE**	**BG**	**BY**	**CH**	**CS**	**CY**	**CZ**	**DE**	**DK**	**EE**	

Table B.2*. Matrix of B[a]P country-to-country depositions in 2005, kg/y (continued)*

R e c e p t o r s ↓ E m i t t e r s ⟶

	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KZ	LT	LU	LV	MC	
AL	3.79	0.10	1.31	0.34	0.09	38.14	2.48	5.30	0.21	0.00	79.9	0.03	0.25	0.06	0.60	0.0	**AL**
AM	0.11	0.01	0.03	0.02	27.41	0.24	0.03	0.11	0.01	0.00	0.39	0.16	0.03	0.00	0.07	0.0	**AM**
AT	13.74	0.77	13.84	5.25	0.10	1.54	17.54	95.13	2.27	0.04	112.6	0.09	2.90	2.37	8.62	0.0	**AT**
AZ	0.47	0.06	0.11	0.10	57.22	0.65	0.08	0.36	0.05	0.00	1.10	2.83	0.12	0.01	0.43	0.0	**AZ**
BA	6.46	0.30	2.91	1.10	0.08	5.34	112.5	58.38	0.58	0.01	134	0.05	1.01	0.27	2.38	0.0	**BA**
BE	17.71	0.42	67.82	13.46	0.04	0.09	0.15	0.45	3.02	0.04	3.21	0.03	0.85	25.97	2.61	0.0	**BE**
BG	6.12	0.70	2.55	1.43	0.99	90.67	8.35	34.09	0.71	0.01	50.17	0.46	1.88	0.27	4.85	0.0	**BG**
BY	15.38	13.56	5.49	5.16	3.04	4.33	4.09	31.67	2.23	0.04	18.05	2.08	214.7	0.68	313.6	0.0	**BY**
CH	11.38	0.27	36.67	2.55	0.03	0.27	0.97	1.25	1.47	0.01	93.54	0.01	0.54	0.85	1.90	0.0	**CH**
CS	7.40	0.43	3.44	1.54	0.17	26.39	43.48	100.9	0.80	0.01	125.1	0.10	1.26	0.37	3.04	0.0	**CS**
CY	0.13	0.01	0.05	0.02	0.10	1.01	0.07	0.21	0.01	0.00	1.52	0.01	0.01	0.00	0.03	0.0	**CY**
CZ	15.69	1.18	13.31	5.92	0.13	1.51	8.50	87.49	2.26	0.04	28.55	0.13	4.64	2.20	12.77	0.0	**CZ**
DE	124.3	7.00	229.7	61.21	0.64	2.52	4.44	25.83	19.53	0.32	77.64	0.44	19.31	80.35	57.34	0.0	**DE**
DK	9.85	1.41	4.61	7.09	0.07	0.22	0.20	1.12	2.44	0.04	1.96	0.07	3.04	0.53	10.46	0.0	**DK**
EE	4.37	31.23	1.83	2.05	0.44	0.39	0.64	3.93	0.97	0.02	3.40	0.45	42.43	0.23	490.7	0.0	**EE**
ES	**11317**	1.44	61.75	11.45	0.18	1.48	1.74	1.95	9.64	0.12	50.39	0.08	2.16	1.38	8.08	0.0	**ES**
FI	26.90	**1790**	11.23	12.10	2.78	1.70	2.37	14.84	6.75	0.15	15.18	2.80	61.69	1.17	317.8	0.0	**FI**
FR	862.1	3.83	**2692**	65.84	0.39	2.75	7.76	9.00	25.08	0.23	341.2	0.20	6.15	63.48	22.24	0.0	**FR**
GB	129.4	2.00	38.01	**1073**	0.11	0.36	0.35	1.35	184.4	0.41	4.85	0.07	3.43	1.76	10.90	0.0	**GB**
GE	0.50	0.07	0.15	0.14	**941**	1.13	0.16	0.79	0.08	0.00	1.89	0.45	0.23	0.01	0.60	0.0	**GE**
GR	7.67	0.40	2.93	1.02	0.93	**1245**	4.33	13.62	0.55	0.01	74.05	0.29	0.97	0.16	2.43	0.0	**GR**
HR	6.84	0.30	2.77	0.91	0.07	3.38	**576**	119.3	0.43	0.01	182.3	0.06	1.24	0.27	3.21	0.0	**HR**
HU	7.78	0.60	4.01	1.77	0.13	3.46	76.55	**1976**	0.76	0.01	63.41	0.11	2.42	0.54	5.73	0.0	**HU**
IE	56.54	0.60	6.92	57.59	0.03	0.13	0.05	0.20	**1221**	0.19	0.76	0.02	0.66	0.18	2.64	0.0	**IE**
IS	13.31	0.69	1.24	2.93	0.02	0.03	0.07	0.28	3.02	**9.05**	1.17	0.02	0.34	0.05	1.15	0.0	**IS**
IT	61.02	0.85	30.51	4.52	0.30	35.89	69.48	57.30	2.85	0.05	**9062**	0.19	2.86	1.12	7.88	0.0	**IT**
KZ	3.11	1.50	0.89	0.93	3.92	0.72	0.30	2.28	0.47	0.005	2.39	**541.8**	3.15	0.09	9.92	0.0	**KZ**
LT	6.21	7.50	2.49	2.54	0.39	0.90	1.27	8.62	1.08	0.02	6.40	0.40	**1164**	0.32	478.7	0.0	**LT**
LU	1.74	0.03	11.14	0.48	0.00	0.01	0.02	0.06	0.15	0.002	0.50	0.00	0.07	**44.63**	0.22	0.0	**LU**
LV	6.81	15.45	2.75	3.13	0.58	0.78	1.16	7.12	1.47	0.03	6.21	0.58	238.7	0.35	**3926**	0.0	**LV**
MC	0.003	0	0.01	0.00	0.00	0.00	0.002	0.001	0.0	0.00	0.14	0.00	0.00	0.00	0.00	**0.0**	**MC**
MD	1.04	0.40	0.37	0.30	0.37	2.10	0.59	3.69	0.14	0.002	3.96	0.16	1.28	0.04	2.80	0.0	**MD**
MK	1.92	0.10	0.75	0.29	0.08	60.61	2.06	6.37	0.16	0.003	27.38	0.02	0.22	0.06	0.56	0.0	**MK**
NL	16.59	0.45	23.40	14.30	0.04	0.09	0.13	0.48	3.21	0.05	2.37	0.03	0.99	2.11	3.12	0.0	**NL**
NO	43.27	23.37	16.80	43.22	0.66	1.23	1.26	5.90	22.87	0.51	13.33	0.69	9.27	1.52	34.59	0.0	**NO**
PL	50.25	11.54	26.78	18.93	1.16	7.16	15.69	136.1	7.35	0.14	67.70	1.05	102.1	3.85	144.5	0.0	**PL**
PT	564.1	0.18	4.41	1.45	0.02	0.16	0.14	0.17	1.31	0.02	4.60	0.01	0.26	0.15	1.00	0.0	**PT**
RO	14.49	2.05	6.24	3.85	1.38	33.53	23.87	194.4	1.82	0.03	100.4	0.70	6.38	0.75	15.76	0.0	**RO**
RU	85.23	359.8	30.40	37.40	192.6	24.80	11.99	81.27	18.84	0.46	86.88	272.2	315.5	3.29	1282	0.0	**RU**
SE	52.67	157.5	24.67	35.87	1.73	2.76	3.00	15.60	17.91	0.32	25.40	1.77	36.08	2.46	163.3	0.0	**SE**
SI	4.07	0.15	1.46	0.46	0.03	0.75	73.77	34.80	0.22	0.00	138.8	0.03	0.69	0.14	2.08	0.0	**SI**
SK	6.93	0.76	3.52	1.88	0.12	2.36	10.42	216	0.80	0.01	32.59	0.12	3.33	0.45	7.95	0.0	**SK**
TR	10.43	1.03	3.84	1.99	36.94	104.2	4.60	18.21	1.10	0.01	67.40	1.97	2.97	0.22	7.62	0.0	**TR**
UA	26.69	10.76	10.33	8.07	18.97	29.04	15.21	153.6	3.62	0.06	78.25	6.86	45.26	1.23	97.41	0.0	**UA**
	ES	**FI**	**FR**	**GB**	**GE**	**GR**	**HR**	**HU**	**IE**	**IS**	**IT**	**KZ**	**LT**	**LU**	**LV**	**MC**	

Table B.2. *Matrix of B[a]P country-to-country depositions in 2004, kg/y (continued)*

Receptors ↓ Emitters ⟶

	MD	MK	NL	NO	PL	PT	RO	RU	SE	SI	SK	TR	UA	ReEmis	Total	
AL	0.34	35.61	0.60	0.17	8.98	0.37	11.67	0.48	0.24	0.94	2.38	9.87	22.83	105.1	976	**AL**
AM	0.04	0.02	0.04	0.01	0.58	0.01	0.63	0.44	0.02	0.02	0.08	56.47	4.64	90.0	680	**AM**
AT	0.50	0.81	14.75	2.28	139.6	1.56	17.25	1.69	2.11	101.3	46.62	3.40	32.20	261	2396	**AT**
AZ	0.11	0.06	0.15	0.03	2.00	0.06	2.08	6.57	0.08	0.06	0.28	42.88	20.68	173.1	1303	**AZ**
BA	0.50	3.58	2.54	0.63	50.30	0.75	37.86	0.90	0.82	12.40	19.27	5.69	31.84	276	2023	**BA**
BE	0.04	0.03	111.2	1.33	11.76	2.21	0.77	0.58	1.21	0.19	0.64	0.56	4.69	255.4	1926	**BE**
BG	7.62	36.31	3.23	0.80	64.90	0.72	466.6	5.87	1.46	4.60	16.10	104.9	325.5	475.9	4109	**BG**
BY	6.69	1.13	11.33	4.37	940.7	2.61	71.37	77.81	18.61	3.57	42.45	40.86	1228	1303	8632	**BY**
CH	0.06	0.07	3.37	0.54	12.89	1.00	1.24	0.28	0.61	1.72	0.85	0.71	4.25	40.6	387	**CH**
CS	1.54	49.69	3.64	0.86	71.10	0.86	158.5	1.63	1.26	9.26	27.07	11.64	71.82	476.6	3616	**CS**
CY	0.04	0.09	0.03	0.01	0.55	0.01	0.80	0.06	0.01	0.04	0.12	27.02	1.80	25.9	255	**CY**
CZ	0.65	0.74	21.50	3.00	765.0	1.79	24.80	2.51	4.16	11.43	174.9	2.92	48.19	629.4	4867	**CZ**
DE	1.27	0.91	574	18.33	665.6	15.13	24.08	10.84	24.81	6.62	29.71	9.58	121.9	2977.6	20946	**DE**
DK	0.13	0.04	19.44	7.51	34.83	1.26	1.80	2.11	10.04	0.24	1.38	1.29	17.43	213.9	1115	**DK**
EE	0.44	0.11	4.10	2.26	120.7	0.69	6.96	26.22	15.61	0.64	4.99	3.96	62.77	336.8	2294	**EE**
ES	0.19	0.26	9.99	2.18	22.08	457.1	3.39	1.85	2.83	2.48	1.41	4.05	19.07	2827.5	14915	**ES**
FI	1.54	0.43	21.44	23.20	388	4.00	24.73	110.4	221.3	2.45	18.50	18.04	248.2	422.1	4328	**FI**
FR	0.43	0.71	81.01	7.12	106.7	48.08	9.79	4.59	9.14	10.53	7.60	7.78	47.51	1397.1	6868	**FR**
GB	0.17	0.07	55.10	7.16	56.48	16.66	2.32	2.29	6.08	0.41	2.07	1.90	16.78	617.3	2459	**GB**
GE	0.32	0.10	0.22	0.05	4.34	0.06	5.25	11.41	0.11	0.11	0.63	123.9	52.74	304.6	1607	**GE**
GR	2.28	57.08	1.85	0.51	31.35	0.61	65.62	3.58	0.81	2.13	7.15	177.3	163.7	292.6	2397	**GR**
HR	0.44	2.13	2.39	0.57	60.48	0.87	26.28	0.99	0.76	122.7	25.34	3.88	29.05	308.9	1888	**HR**
HU	1.03	2.27	5.02	1.00	191.3	1.01	137.0	1.83	1.75	45.29	315	4.65	95.71	520.9	3858	**HU**
IE	0.04	0.02	4.92	1.58	8.55	8.82	0.55	0.63	1.41	0.06	0.29	0.62	5.09	759.2	2164	**IE**
IS	0.01	0.01	1.19	2.02	5.19	2.64	0.24	0.55	1.22	0.09	0.34	0.19	1.92	6.62	66	**IS**
IT	1.16	6.83	7.64	1.91	99.68	4.92	40.88	2.69	2.03	97.27	24.71	33.64	80.43	1497	11655	**IT**
KZ	1.09	0.12	1.69	0.55	32.37	0.50	11.11	102.9	1.67	0.25	2.68	12.42	314.4	209.5	1311	**KZ**
LT	0.88	0.21	5.88	2.50	421.5	1.04	12.44	21.82	12.76	1.33	11.65	6.60	132.3	490.9	3123	**LT**
LU	0.00	0.00	1.60	0.06	1.29	0.20	0.08	0.05	0.10	0.03	0.08	0.05	0.42	21.45	124	**LU**
LV	0.80	0.20	6.74	3.37	243.3	1.12	12.20	27.62	19.65	1.15	9.20	7.27	120.2	832.9	5864	**LV**
MC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0	**MC**
MD	**174.5**	0.42	0.61	0.22	29.77	0.12	194.78	3.26	0.74	0.39	3.11	15.42	314.8	108.7	893	**MD**
MK	0.32	**240**	0.60	0.17	10.47	0.20	12.50	0.42	0.26	0.90	2.91	5.86	19.66	83.09	711	**MK**
NL	0.06	0.03	**851**	1.99	14.25	2.00	0.84	0.71	1.45	0.16	0.71	0.56	6.24	288.3	1917	**NL**
NO	0.58	0.24	39.56	**703.7**	96.09	5.92	9.77	15.62	78.98	1.24	5.25	7.85	77.32	258.1	1849	**NO**
PL	6.10	2.27	54.56	13.53	**18123**	6.52	113.1	33.49	44.39	17.39	401.0	27.01	620.4	3374.6	25779	**PL**
PT	0.02	0.03	1.46	0.23	1.86	**2977**	0.41	0.25	0.36	0.19	0.12	0.52	2.52	727.15	4300	**PT**
RO	62.10	11.96	8.72	2.20	264.3	1.75	**5279**	11.19	4.81	12.63	76.81	88.89	799.4	1021.3	8691	**RO**
RU	23.00	5.19	64.47	42.76	1697	13.97	273.5	**9380**	172.7	10.41	99.86	439.0	7070	4020	28852	**RU**
SE	1.80	0.61	73.08	118.2	405.9	7.60	28.62	46.47	**2280**	2.78	17.31	20.40	250.1	448.9	5088	**SE**
SI	0.17	0.47	1.10	0.26	28.94	0.42	7.33	0.54	0.35	**554.9**	10.70	1.37	11.09	139.2	1137	**SI**
SK	0.80	1.16	4.87	1.04	633.7	0.84	49.95	2.05	2.41	10.53	**1218**	3.38	79.65	328.1	3003	**SK**
TR	7.46	4.72	3.30	0.90	64.96	0.82	169.8	18.04	1.89	2.87	11.48	**11531**	544.3	1964.3	14921	**TR**
UA	93.11	5.52	17.10	5.62	1418	3.71	529.2	197.1	19.07	10.93	152.0	298.9	**34343**	6591	45044	**UA**
	MD	**MK**	**NL**	**NO**	**PL**	**PT**	**RO**	**RU**	**SE**	**SI**	**SK**	**TR**	**UA**	**ReEmis**	**Total**	

***Table B.3**. Matrix of PCDD country-to-country depositions in 2005, g TEQ/y*

R e c e p t o r s ↓ E m i t t e r s ⟶

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CS	CY	CZ	DE	DK	EE	
AL	**18.47**	0.004	0.04	0.01	0.25	0.02	0.93	0.01	0.01	3.73	0.001	0.11	0.03	0.01	0.00	**AL**
AM	0.01	**20.45**	0.003	2.80	0.01	0.002	0.04	0.00	0.00	0.02	0.01	0.01	0.002	0.00	0.00	**AM**
AT	0.06	0.002	**21.69**	0.01	0.22	0.32	0.19	0.03	0.42	0.49	0.001	5.34	1.13	0.05	0.002	**AT**
AZ	0.02	2.77	0.01	**45.1**	0.01	0.01	0.11	0.01	0.002	0.04	0.01	0.03	0.01	0.00	0.00	**AZ**
BA	0.43	0.00	0.30	0.01	**29.34**	0.05	0.48	0.01	0.03	5.66	0.001	0.72	0.11	0.02	0.001	**BA**
BE	0.004	0.00	0.02	0.001	0.01	**29.5**	0.01	0.003	0.02	0.01	0.00	0.07	0.84	0.03	0.001	**BE**
BG	0.47	0.03	0.17	0.04	0.39	0.06	**138.6**	0.05	0.03	6.80	0.004	0.62	0.12	0.03	0.002	**BG**
BY	0.04	0.04	0.11	0.07	0.09	0.11	0.42	**24.67**	0.02	0.31	0.004	1.09	0.20	0.19	0.05	**BY**
CH	0.02	0.001	0.34	0.001	0.04	0.15	0.05	0.00	**7.75**	0.06	0.00	0.18	0.31	0.01	0.00	**CH**
CS	2.58	0.01	0.31	0.02	4.04	0.07	3.07	0.02	0.03	**87.9**	0.001	0.99	0.13	0.03	0.001	**CS**
CY	0.01	0.01	0.003	0.01	0.01	0.001	0.05	0.001	0.001	0.02	**1.01**	0.01	0.002	0.001	0.00	**CY**
CZ	0.03	0.00	2.13	0.01	0.12	0.29	0.14	0.04	0.12	0.37	0.00	**87.52**	1.35	0.10	0.002	**CZ**
DE	0.06	0.01	2.99	0.02	0.12	6.50	0.26	0.11	2.38	0.29	0.001	11.88	**49.59**	1.17	0.01	**DE**
DK	0.003	0.001	0.02	0.003	0.01	0.18	0.02	0.01	0.01	0.01	0.00	0.20	0.23	**6.34**	0.004	**DK**
EE	0.005	0.004	0.02	0.01	0.01	0.03	0.04	0.12	0.004	0.04	0.00	0.15	0.05	0.10	**1.26**	**EE**
ES	0.07	0.003	0.10	0.01	0.10	0.32	0.19	0.01	0.08	0.16	0.001	0.21	0.22	0.08	0.003	**ES**
FI	0.02	0.02	0.07	0.05	0.05	0.19	0.14	0.24	0.02	0.15	0.002	0.55	0.22	0.36	0.2	**FI**
FR	0.20	0.01	0.40	0.01	0.29	6.35	0.44	0.04	2.00	0.48	0.002	1.01	3.39	0.25	0.01	**FR**
GB	0.01	0.004	0.04	0.01	0.02	1.19	0.05	0.02	0.03	0.04	0.00	0.25	0.46	0.22	0.003	**GB**
GE	0.02	3.10	0.01	4.31	0.02	0.01	0.19	0.01	0.004	0.07	0.01	0.05	0.01	0.00	0.00	**GE**
GR	2.11	0.03	0.11	0.04	0.37	0.05	12.32	0.03	0.03	2.48	0.01	0.36	0.09	0.02	0.001	**GR**
HR	0.30	0.003	0.73	0.005	5.68	0.06	0.34	0.01	0.04	3.25	0.001	1.07	0.13	0.02	0.001	**HR**
HU	0.09	0.005	1.67	0.01	0.74	0.09	0.40	0.04	0.04	3.92	0.001	3.05	0.22	0.04	0.002	**HU**
IE	0.002	0.001	0.004	0.002	0.004	0.06	0.01	0.00	0.00	0.01	0.00	0.03	0.04	0.02	0.001	**IE**
IS	0.001	0.001	0.004	0.002	0.002	0.03	0.01	0.01	0.003	0.004	0.00	0.03	0.02	0.04	0.001	**IS**
IT	1.39	0.01	1.88	0.02	2.08	0.28	1.37	0.04	1.02	2.38	0.005	1.69	0.48	0.06	0.002	**IT**
KZ	0.04	0.25	0.03	1.21	0.04	0.04	0.34	0.09	0.01	0.15	0.004	0.17	0.05	0.03	0.01	**KZ**
LT	0.01	0.00	0.04	0.01	0.02	0.05	0.07	0.75	0.01	0.07	0.001	0.42	0.11	0.17	0.03	**LT**
LU	0.00	0.00	0.00	0.00	0.001	0.27	0.002	0.00	0.005	0.002	0.00	0.01	0.15	0.00	0.00	**LU**
LV	0.01	0.01	0.03	0.01	0.02	0.05	0.07	0.42	0.01	0.06	0.001	0.29	0.09	0.18	0.20	**LV**
MC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**MC**
MD	0.02	0.01	0.02	0.01	0.03	0.01	0.29	0.05	0.003	0.12	0.001	0.11	0.02	0.01	0.001	**MD**
MK	1.84	0.003	0.04	0.01	0.16	0.01	3.19	0.01	0.01	4.47	0.001	0.13	0.03	0.01	0.00	**MK**
NL	0.003	0.00	0.02	0.00	0.00	6.31	0.01	0.00	0.01	0.01	0.00	0.11	1.59	0.06	0.001	**NL**
NO	0.02	0.01	0.06	0.03	0.03	0.40	0.11	0.06	0.03	0.08	0.001	0.39	0.32	0.73	0.01	**NO**
PL	0.08	0.02	0.80	0.04	0.24	0.53	0.48	1.14	0.11	0.75	0.002	27.22	1.84	1.06	0.03	**PL**
PT	0.01	0.00	0.01	0.00	0.01	0.04	0.02	0.00	0.01	0.01	0.00	0.02	0.02	0.01	0.00	**PT**
RO	0.39	0.04	0.42	0.07	1.02	0.14	6.54	0.14	0.05	9.16	0.01	2.04	0.28	0.08	0.01	**RO**
RU	0.44	2.54	0.47	9.09	0.53	0.72	3.52	4.77	0.13	1.78	0.06	3.26	0.98	1.06	0.78	**RU**
SE	0.03	0.02	0.08	0.05	0.06	0.51	0.20	0.15	0.03	0.16	0.00	0.81	0.57	3.52	0.06	**SE**
SI	0.03	0.00	1.35	0.001	0.21	0.03	0.08	0.01	0.02	0.29	0.00	0.44	0.06	0.01	0.00	**SI**
SK	0.04	0.00	0.75	0.01	0.18	0.07	0.19	0.04	0.03	0.60	0.00	6.67	0.17	0.05	0.002	**SK**
TR	0.57	4.89	0.21	1.35	0.44	0.11	9.41	0.12	0.06	1.66	0.58	0.81	0.18	0.05	0.004	**TR**
UA	0.24	0.26	0.38	0.41	0.45	0.24	2.82	2.14	0.06	1.69	0.02	2.88	0.42	0.24	0.03	**UA**
	AL	**AM**	**AT**	**AZ**	**BA**	**BE**	**BG**	**BY**	**CH**	**CS**	**CY**	**CZ**	**DE**	**DK**	**EE**	

Table B.3*. Matrix of PCDD country-to-country depositions in 2005, g TEQ/y (continued)*

R e c e p t o r s ↓ E m i t t e r s ⟶

	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KZ	LT	LU	LV	
AL	0.06	0.002	0.10	0.04	0.01	1.50	0.24	0.14	0.004	0.00	1.59	0.00	0.001	0.00	0.002	**AL**
AM	0.01	0.00	0.01	0.01	1.05	0.05	0.01	0.01	0.001	0.00	0.04	0.03	0.00	0.00	0.00	**AM**
AT	0.15	0.01	0.73	0.41	0.01	0.10	0.87	1.07	0.03	0.002	2.77	0.003	0.01	0.01	0.02	**AT**
AZ	0.01	0.00	0.02	0.02	2.35	0.11	0.02	0.02	0.002	0.00	0.09	0.40	0.001	0.00	0.002	**AZ**
BA	0.09	0.01	0.20	0.11	0.01	0.28	7.79	1.20	0.01	0.001	2.27	0.003	0.01	0.001	0.01	**BA**
BE	0.11	0.00	4.14	0.89	0.001	0.01	0.01	0.01	0.03	0.001	0.08	0.00	0.003	0.14	0.005	**BE**
BG	0.11	0.01	0.19	0.15	0.07	3.46	0.50	0.76	0.01	0.001	1.10	0.03	0.01	0.001	0.01	**BG**
BY	0.08	0.14	0.19	0.36	0.09	0.17	0.15	0.41	0.02	0.003	0.32	0.04	0.95	0.00	0.69	**BY**
CH	0.15	0.003	1.80	0.23	0.002	0.05	0.10	0.04	0.02	0.001	2.89	0.00	0.00	0.01	0.004	**CH**
CS	0.12	0.01	0.23	0.14	0.02	0.91	3.08	2.29	0.01	0.001	2.31	0.01	0.01	0.002	0.01	**CS**
CY	0.005	0.00	0.01	0.004	0.01	0.18	0.01	0.01	0.00	0.000	0.06	0.001	0.00	0.00	0.00	**CY**
CZ	0.11	0.02	0.51	0.41	0.01	0.05	0.35	1.39	0.02	0.002	0.57	0.003	0.02	0.01	0.02	**CZ**
DE	0.69	0.09	10.26	3.87	0.02	0.14	0.24	0.42	0.19	0.01	1.63	0.01	0.07	0.32	0.13	**DE**
DK	0.05	0.03	0.20	0.70	0.002	0.01	0.01	0.02	0.03	0.003	0.04	0.001	0.02	0.001	0.03	**DK**
EE	0.02	0.26	0.05	0.14	0.01	0.02	0.02	0.04	0.01	0.002	0.05	0.01	0.12	0.00	0.83	**EE**
ES	**87.09**	0.02	3.93	1.38	0.01	0.20	0.21	0.07	0.18	0.01	1.63	0.003	0.01	0.01	0.02	**ES**
FI	0.12	**13.86**	0.31	0.78	0.05	0.08	0.08	0.15	0.07	0.01	0.26	0.03	0.16	0.003	0.46	**FI**
FR	8.92	0.05	**144.7**	6.46	0.02	0.45	0.71	0.25	0.40	0.02	7.23	0.01	0.03	0.50	0.06	**FR**
GB	0.72	0.03	2.04	**112.4**	0.01	0.04	0.04	0.03	2.02	0.03	0.18	0.00	0.01	0.01	0.02	**GB**
GE	0.02	0.00	0.03	0.03	**36.40**	0.16	0.03	0.03	0.003	0.00	0.14	0.08	0.002	0.00	0.003	**GE**
GR	0.17	0.01	0.29	0.14	0.06	**56.94**	0.42	0.37	0.01	0.001	2.34	0.02	0.01	0.001	0.01	**GR**
HR	0.09	0.01	0.22	0.10	0.01	0.20	**42.40**	1.92	0.01	0.001	3.35	0.00	0.01	0.002	0.01	**HR**
HU	0.08	0.01	0.22	0.16	0.01	0.13	4.62	**53.68**	0.01	0.001	1.14	0.00	0.01	0.003	0.02	**HU**
IE	0.22	0.01	0.23	2.43	0.001	0.01	0.01	0.01	**14.50**	0.01	0.03	0.00	0.002	0.001	0.004	**IE**
IS	0.07	0.01	0.06	0.26	0.002	0.005	0.004	0.004	0.04	**0.34**	0.02	0.001	0.003	0.00	0.004	**IS**
IT	0.85	0.02	2.86	0.54	0.03	1.78	5.39	1.16	0.05	0.004	**151.5**	0.01	0.01	0.01	0.02	**IT**
KZ	0.07	0.03	0.11	0.15	0.35	0.16	0.06	0.10	0.01	0.001	0.21	**20.18**	0.02	0.00	0.03	**KZ**
LT	0.03	0.11	0.09	0.19	0.01	0.03	0.04	0.09	0.01	0.002	0.10	0.01	**5.47**	0.00	1.10	**LT**
LU	0.01	0.00	1.41	0.04	0.00	0.001	0.002	0.001	0.002	0.00	0.01	0.00	0.00	**0.37**	0.001	**LU**
LV	0.03	0.19	0.08	0.21	0.01	0.03	0.03	0.07	0.01	0.002	0.09	0.01	0.99	0.00	**8.83**	**LV**
MC	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**MC**
MD	0.01	0.01	0.03	0.03	0.02	0.07	0.04	0.09	0.002	0.00	0.10	0.01	0.01	0.00	0.01	**MD**
MK	0.04	0.00	0.07	0.03	0.01	2.26	0.16	0.16	0.003	0.00	0.63	0.003	0.001	0.00	0.002	**MK**
NL	0.09	0.01	1.20	1.14	0.00	0.01	0.01	0.01	0.04	0.002	0.06	0.00	0.004	0.01	0.01	**NL**
NO	0.24	0.23	0.57	2.72	0.02	0.07	0.06	0.08	0.22	0.04	0.24	0.01	0.03	0.004	0.07	**NO**
PL	0.26	0.18	0.85	1.14	0.04	0.21	0.59	2.26	0.07	0.01	1.02	0.02	0.45	0.01	0.32	**PL**
PT	2.64	0.00	0.25	0.20	0.001	0.02	0.01	0.01	0.03	0.00	0.11	0.00	0.00	0.001	0.00	**PT**
RO	0.18	0.04	0.35	0.33	0.11	0.94	1.27	3.66	0.03	0.00	1.76	0.04	0.03	0.003	0.04	**RO**
RU	0.76	2.26	1.44	3.05	7.88	2.04	0.75	1.34	0.25	0.05	2.78	9.53	1.03	0.01	2.13	**RU**
SE	0.24	1.61	0.67	2.31	0.04	0.11	0.09	0.17	0.18	0.03	0.35	0.02	0.12	0.01	0.34	**SE**
SI	0.03	0.00	0.10	0.04	0.00	0.04	4.01	0.36	0.00	0.00	2.56	0.001	0.00	0.001	0.003	**SI**
SK	0.05	0.01	0.14	0.14	0.01	0.07	0.50	6.86	0.01	0.00	0.50	0.004	0.01	0.002	0.02	**SK**
TR	0.37	0.03	0.59	0.36	2.72	7.54	0.59	0.64	0.03	0.00	3.15	0.22	0.02	0.003	0.03	**TR**
UA	0.25	0.14	0.51	0.68	0.77	1.10	0.73	2.76	0.05	0.01	1.55	0.28	0.20	0.005	0.22	**UA**
	ES	**FI**	**FR**	**GB**	**GE**	**GR**	**HR**	**HU**	**IE**	**IS**	**IT**	**KZ**	**LT**	**LU**	**LV**	

Table B.3. *Matrix of PCDD country-to-country depositions in 2005, g TEQ/y (continued)*

Receptors ↓ Emitters ⟶

	MC	MD	MK	NL	NO	PL	PT	RO	RU	SE	SI	SK	TR	UA	Re Emis	Non EMEP	Total	
AL	0.005	0.004	8.55	0.01	0.00	0.18	0.07	0.15	0.05	0.004	0.01	0.09	0.50	0.52	28.2	1.8	67.4	**AL**
AM	0.00	0.001	0.03	0.00	0.00	0.02	0.01	0.02	0.07	0.001	0.001	0.01	3.35	0.18	18.6	1.6	48.4	**AM**
AT	0.02	0.01	0.18	0.15	0.03	2.05	0.22	0.17	0.08	0.03	0.71	1.69	0.24	0.81	62.4	5.2	110.1	**AT**
AZ	0.001	0.003	0.06	0.004	0.004	0.06	0.02	0.05	0.75	0.003	0.002	0.02	2.68	0.60	44.2	6.9	106.6	**AZ**
BA	0.01	0.01	0.73	0.03	0.01	0.90	0.12	0.39	0.07	0.01	0.10	0.62	0.35	0.86	61.6	3.5	118.5	**BA**
BE	0.001	0.00	0.01	1.12	0.02	0.12	0.17	0.01	0.02	0.01	0.002	0.01	0.03	0.05	46.5	1.8	85.7	**BE**
BG	0.01	0.08	9.13	0.04	0.02	1.03	0.16	5.16	0.50	0.02	0.03	0.53	6.41	6.59	156.0	5.9	345.4	**BG**
BY	0.00	0.04	0.19	0.08	0.09	9.88	0.21	0.43	3.54	0.22	0.02	0.66	1.39	20.89	46.1	8.8	123.6	**BY**
CH	0.02	0.00	0.04	0.05	0.01	0.20	0.17	0.02	0.02	0.01	0.02	0.03	0.09	0.12	27.8	3.2	46.0	**CH**
CS	0.01	0.02	11.50	0.04	0.02	1.35	0.17	1.96	0.15	0.02	0.07	1.04	0.76	2.02	122.0	5.2	7.5	**CS**
CY	0.00	0.001	0.04	0.001	0.001	0.01	0.01	0.01	0.01	0.00	0.001	0.01	1.90	0.07	3.7	0.4	238.2	**CY**
CZ	0.01	0.01	0.12	0.19	0.04	10.83	0.18	0.19	0.10	0.05	0.06	2.88	0.16	1.02	122.6	4.0	459.8	**CZ**
DE	0.02	0.01	0.20	4.73	0.27	8.72	1.19	0.19	0.38	0.33	0.05	0.50	0.51	1.55	327.5	20.2	23.0	**DE**
DK	0.00	0.001	0.01	0.20	0.13	0.58	0.13	0.01	0.08	0.31	0.001	0.03	0.06	0.18	11.1	2.0	378.3	**DK**
EE	0.00	0.002	0.02	0.03	0.05	0.91	0.05	0.04	1.20	0.21	0.002	0.05	0.14	0.65	8.4	1.7	16.9	**EE**
ES	0.03	0.003	0.17	0.16	0.07	0.44	39.33	0.06	0.10	0.04	0.03	0.06	0.35	0.41	207.6	33.1	67.2	**ES**
FI	0.003	0.01	0.09	0.14	0.53	2.67	0.30	0.14	3.75	2.16	0.01	0.19	0.62	2.01	22.0	13.9	708.8	**FI**
FR	1.10	0.01	0.45	1.23	0.16	1.63	4.95	0.18	0.23	0.13	0.10	0.24	0.70	1.07	475.7	36.2	245.3	**FR**
GB	0.003	0.001	0.04	0.82	0.22	0.60	1.71	0.03	0.10	0.10	0.01	0.04	0.15	0.24	107.2	14.1	115.9	**GB**
GE	0.001	0.01	0.10	0.005	0.01	0.11	0.03	0.11	1.32	0.00	0.00	0.03	6.54	1.56	57.0	4.3	228.9	**GE**
GR	0.01	0.03	16.57	0.03	0.02	0.60	0.19	0.82	0.38	0.01	0.03	0.27	10.60	3.80	109.8	6.9	141.4	**GR**
HR	0.01	0.01	0.47	0.03	0.01	1.14	0.12	0.31	0.06	0.01	0.98	0.81	0.28	0.83	73.1	3.3	194.2	**HR**
HU	0.01	0.01	0.37	0.05	0.02	3.49	0.12	1.65	0.11	0.03	0.30	17.56	0.30	3.99	91.9	3.8	46.0	**HU**
IE	0.00	0.00	0.01	0.05	0.04	0.07	0.66	0.01	0.02	0.01	0.00	0.01	0.04	0.04	21.9	5.5	6.9	**IE**
IS	0.00	0.00	0.00	0.02	0.14	0.07	0.27	0.003	0.04	0.03	0.00	0.005	0.02	0.05	2.8	2.5	417.6	**IS**
IT	0.49	0.02	2.09	0.12	0.05	1.94	0.79	0.52	0.22	0.04	0.84	0.83	1.77	2.23	210.5	18.3	149.6	**IT**
KZ	0.002	0.02	0.18	0.03	0.03	0.57	0.12	0.22	11.74	0.04	0.01	0.11	1.79	5.86	50.7	54.3	33.3	**KZ**
LT	0.001	0.005	0.04	0.04	0.05	4.39	0.09	0.07	1.15	0.18	0.01	0.14	0.22	1.68	13.4	2.8	8.2	**LT**
LU	0.00	0.00	0.002	0.02	0.001	0.01	0.02	0.001	0.002	0.001	0.00	0.002	0.004	0.01	5.6	0.2	32.7	**LU**
LV	0.001	0.004	0.04	0.04	0.06	2.11	0.08	0.07	1.11	0.26	0.004	0.10	0.25	1.34	12.3	2.9	30.3	**LV**
MC	**0.005**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	137.7	**MC**
MD	0.001	**2.18**	0.09	0.01	0.01	0.48	0.02	1.99	0.20	0.01	0.003	0.11	0.62	9.10	13.1	1.2	44.3	**MD**
MK	0.003	0.00	**70.55**	0.01	0.01	0.19	0.05	0.20	0.05	0.00	0.01	0.11	0.45	0.55	50.7	1.5	59.0	**MK**
NL	0.001	0.00	0.01	**9.12**	0.03	0.17	0.15	0.01	0.02	0.02	0.001	0.01	0.03	0.07	22.1	1.8	642.6	**NL**
NO	0.003	0.004	0.06	0.35	**12.40**	1.05	0.55	0.08	0.55	0.74	0.01	0.09	0.32	0.82	21.1	13.9	464.7	**NO**
PL	0.01	0.03	0.31	0.37	0.22	**264.5**	0.52	0.67	1.54	0.56	0.09	6.19	0.84	13.66	296.6	14.7	287.9	**PL**
PT	0.002	0.003	0.01	0.02	0.01	0.04	**275.7**	0.01	0.01	0.01	0.002	0.01	0.04	0.04	178.2	7.2	1684	**PT**
RO	0.01	0.67	2.16	0.09	0.05	4.11	0.29	**59.60**	0.79	0.06	0.08	2.62	3.74	21.84	151.5	11.1	132.3	**RO**
RU	0.02	0.24	1.85	0.55	1.31	16.21	1.70	2.61	**598.1**	1.96	0.08	1.78	25.71	111.5	654.5	201	39.2	**RU**
SE	0.00	0.01	0.11	0.43	2.61	3.87	0.60	0.16	1.26	**21.92**	0.01	0.21	0.65	2.02	60.7	19.9	127	**SE**
SI	0.01	0.002	0.08	0.01	0.00	0.41	0.04	0.07	0.02	0.01	**4.10**	0.25	0.09	0.26	22.8	1.3	1183	**SI**
SK	0.00	0.01	0.16	0.04	0.02	9.27	0.09	0.43	0.10	0.03	0.07	**33.79**	0.18	2.93	65.4	2.6	254.8	**SK**
TR	0.02	0.14	2.48	0.07	0.06	1.60	0.46	2.55	3.68	0.04	0.05	0.57	**627.2**	19.07	535.1	33.7	0.0	**TR**
UA	0.01	1.26	1.15	0.16	0.14	18.12	0.49	5.38	13.59	0.24	0.07	4.25	11.44	**649.2**	432.6	23.5	1263	**UA**
	MC	**MD**	**MK**	**NL**	**NO**	**PL**	**PT**	**RO**	**RU**	**SE**	**SI**	**SK**	**TR**	**UA**	**Re Emis**	**Non EMEP**	**Total**	

Annex C

MINUTES of the Joint MSC-West and MSC-East technical meeting (1-2 February 2007)

The meeting was attended by Anna Benedictow, Jan Eiof Jonson, Leonor Tarrasón and Svetlana Tsyro from MSC-West and by Sergey Dutchak, Alexey Gusev, Ilia Ilyin, Oleg Travnikov and Marina Varygina from MSC-East.

The aim of the meeting was the discussion and harmonization of EMEP Centres activities in the field of the development of hemispheric/global modelling, preprocessing of meteorological data, model description of dust suspension and preparation of emission data for model runs.

Another important topic for the meeting was consideration of a possible assistance of the EMEP Centres to EECCA countries in raising the capacity of air quality management within the institutions in these countries and in implementing selected LRTAP Convention protocols.

These minutes of the meeting include:

1) Short summary of the discussions
2) Annex CI: Agenda of the meeting
3) Annex CII: Proposal for the development of a common EMEP global modeling system
4) Annex CIII: Proposal for transboundary pollution calculations for EECCA countries

The proposals in Annex CII and Annex CIII are to be presented at the forthcoming EMEP Bureau meeting on 26-28 March for consideration and evaluation by the EMEP Bureau members.

Short summary of the discussions

Hemispheric/global modelling

The meeting participants considered in depth possibilities for further streamlining the work at both modelling Centres with regard to hemispheric/global modeling. MSC-E and MSC-W discussed experience in approaches to hemispheric/global modeling currently used by the Centres.

It was recognized that specially for ozone, mercury, and some POPs, there is a clear need to consider their transport at the global scale rather than on hemispheric scale. Application of hemispheric modelling approach leads to the uncertainties in the description of pollution levels near the equator due to necessity of definition of boundary conditions. This is particularly important for the Southeast Asia which growing economic development and increase of emission levels in recent years makes it an important source of pollution for other regions of the globe. For long-lived components, like mercury, the inter-hemispheric exchange of pollution becomes relevant and even for ozone, convection in the Tropics becomes relevant process to take into account for an accurate description of the pollution levels in the free troposphere. For POPs which require the description of pollutant transport within seawater it is also of importance to include southern Atlantic in the model domain. Furthermore, the vertical extension of a global model needs also to be increased in order to take into account troposphere-stratosphere exchange.

With the growing importance of intercontinental pollution transport, the meeting agreed that the development of hemispheric scale models in EMEP is not satisfactory and recommended the extension of the modeling domain to cover global scale.

MSC-W and MSC-E discussed possible ways of streamlining of hemispheric/global model development. It was recognized that there could be three different options of the development of common hemispheric/global modelling system. One of them implies the joint development of such a single modelling system from the beginning. This option could the most fully fit EMEP needs but it is likely very time- and resource consuming. Additional drawback is that this system as a new one will require thorough validation. The second possible option is the adaptation of a hemispheric/global model already developed outside the EMEP. This is possibly the easiest way that, however, also contains some negative aspects. First, one can hardly expect that an external model will completely fit the needs of EMEP modelling or will not require significant modifications. Second, updates and development of such a model could be connected with undesirable dependence on the “third party”. Additionally, such model should be well recognized by the community, validated, and efficient enough to permit operative computations of transboundary fluxes of acidifying pollutants, photooxidants, HMs, and POPs. The third option is gradual unification of the existing MSC-E and MSC-W hemispheric/global approaches starting from unification of the model geometry, meteorological drivers and input information. It was agreed to recommend this option as most appropriate and realistic, as it does not neglect existing EMEP modelling systems.

Following this discussion, a work plan was defined to allow for the gradual unification of MSC-E and MSC-W models and elaboration of the common modular system for modelling of different pollutants on global level. The summarized draft work-plan of elaboration of common unified modelling system for global scale is given in Annex CII. MSC-E and MSC-W have agreed to implement some of these practical steps in 2008 and reflect this activity in their work-plans for 2008.

Computation of transboundary pollution of the EECCA countries

In order to support EECCA countries with information required for air quality management in these countries and implementation of the selected LRTAP Convention protocols MSC-E and MSC-W considered possibility to include these countries into EMEP routine calculations of pollution levels and transboundary fluxes.

A long-term perspective solution of this task implies application of the hemispheric/global model with fine enough spatial resolution or possibility of nesting. An interim solution could include combination of the available EMEP regional and hemispheric models. For this aim the current EMEP 50x50 km grid should be extended eastward to cover EECCA countries and the hemispheric model is to be used for calculation of boundary conditions for this region. As an interim solution, the regional EMEP model could be applied for routine calculations of transboundary pollution on this extended area. For the future, an in-depth reconsideration of the EMEP grid domain, projection and resolution is required. A draft of the suggested interim extensions of the EMEP grid is presented in Annex CIII. MSC-E and MSC-W have agreed to implement calculations of transboundary fluxes in the interim extended EMEP grid in their routine calculations starting from 2008.

Dust suspension

MSC-W and MSC-E discussed modeling approaches to assessing wind suspension of dust from natural and agricultural surfaces applied by the Centres. The two centers presently use very similar parametrisation approaches for modeling of the dust suspension, especially after the last developments at MSC-E. Large uncertainties remain still on the requirements for information on soil types and their morphology and moisture. Additional efforts are also needed to compile observational data to validate the model estimates.

It was agreed to cooperate in order to improve the input information to the wind driven dust suspension modeling. It was agreed to start compiling a common input data for land use, extending it afterwards to include soil types and morphology and if possible also information on soil chemical composition. Efforts would also be addressed to compile available measurements for the validation purposes. This work should be carried out at global scale.

Taking into account the developing status of contemporary dust mobilization models and significant uncertainty of major input parameters it was recognized that final selection of the unified parameterization requires common efforts by MSC-E and MSC_W, with coordinated sensitivity studies and evaluation against measurements. A proposal for such research effort is to be included already in the work plan for EMEP in 2008 and supports the development of the unified global model as identified in Annex CII.

Preprocessing of meteorological data for regional modelling

MSC-E and MSC-W also discussed current activities and future plans on preparation of meteorological data for the regional-scale modeling. Both MSC-E and MSC-W gave overview of meteorological drivers used to prepare meteorological information for transport models. Both Centres use similar approaches for generation of meteorological data, but while MSC-E uses primarily MM5 data, MSC-W uses primarily HIRLAM data.

MSC-W shared its experience in adapting and testing different meteorological drivers (HIRLAM, ALADIN, WRF) and summarized their advantages and drawbacks. Plans for further MSC-W activities in preparation of meteorological data were presented including improvement of the operational set of meteorological input data, moving towards finer spatial resolution and developing meteorological data for national-scale applications.

MSC-E discussed possible approaches to quality control and validation of data produced by meteorological drivers as an input for transport models. It was agreed to share experience and harmonize approaches of MSC-E and MSC-W to quality control of meteorological data for the purposes of air pollution modelling.

MSC-E also presented ideas on evaluation of the effects of meteorological variability and climate change on modelled pollution levels. Their possible approaches to treat the meteorological variability in model calculations (e.g. assessment of future scenarios) included averaging of modeled pollution levels over long time period (decades); selecting of one or a few years based either on similarity of pollution levels in these years to the long-term average or on the meteorological statistics (atmospheric circulation indices, similarity of meteorological fields to climatic means etc.); adoption of a single meteorological year based on political principles (e.g. formulated in CLRTAP Protocols, EU directives etc). The Centers did not agree on a common position. Different approaches are valid and require further evaluation and discussion. Such discussion is especially relevant also for scenario analysis within EMEP for 2020 and beyond and the question on how EMEP should account for meteorological variability and climate change in the future.

Emission data

MSC-W presented an overview of the needs on emission related activities within EMEP, their status and need for changes. In particular, MSC-E and MSC-W discussed the need for emission data as input to atmospheric transport modeling. Both Centres agreed that the activities dedicated to the gap filling and the elaboration and review of gridded sector data for modeling need to be strengthened and coordinated, especially as we intend to extend the domain of the EMEP transboundary calculations and in future years, also increase the resolution of the model results.

Currently, MSC-E is dependent on gridded emission data from expert estimates. MSC-W has improved their methodology in the preparation of gridded emissions from ancillary information, but it is still far from satisfactory. Gridded sector official data reported by countries is still so sparse that further efforts are necessary in the elaboration of input emissions for modelling.

The extension of the modeling activities to global scale imposes additional requirements on the preparation of emission data. It is important to recognize the need for consistent, complete and accurate data in global scale to support the development of the EMEP global model. In some cases, this goes beyond the competence area of EMEP and experts estimates would have to be used instead. The meeting agreed to invite the EMEP Bureau to identify and share responsibilities with respect to expert estimates of emissions in relation to the Bureaus evaluation of a new organization of emission work under EMEP.

Additionally, the work planned at MSC-W on nested models, down to finer resolution scales imposes also new requirements on emission data. To what extent such requirements should be extended also to the official reported data is a matter for discussion first by the EMEP Bureau, and eventually also by the EMEP Steering Body.

Annex CI. Agenda of Joint MSC-W/MSC-E meeting

The aim of the meeting is harmonization of the MSC-W and MSC-E activities in the field of global/hemispheric modeling, meteorology, dust suspension, and emissions

Thursday, 1 February

9.00 Hemispheric/global modeling

- Approaches to hemispheric/global modeling (concepts of the hemispheric/global transport model considered in MSC-W and MSC-E)
- Unification of input data (meteorological data, preprocessing, land-use, LAI, soil properties etc.)
- Unification of hemispheric/global model parameters from the point of view of output results (coverage, spatial resolution, nesting etc.)

(Alexey Gusev, Jan Eiof Jonson)

11.00 Coffee break

11.15 Continuation of hemispheric/global modeling topic.

Discussion of approaches for the evaluation of source-receptor relationships for EECCA countries

(*Leonor Tarrason, Ilia Ilyin*)

13.00 **Lunch**

14.00 Preparation of a draft common discussion paper on hemispheric/global issues that should be considered at the next EMEP SB Bureau meeting in March 2007

15.45 Coffee break

16.00 Dust suspension

- Approaches to parameterization of wind suspension in air quality models (possibility of harmonization of dust mobilization schemes)
- Unification of input data on (soil size distribution, clay content etc.)

(*Oleg Travnikov, Svetlana Tsyro*)

18.00 Adjourn

Friday, 2 February

9.00 Meteorology

- Preprocessing of meteorological data for regional modeling (pre-processor, data assimilation, technical questions about the use of ECMWF data) in both Centres
- Validation procedure and quality control of the output of meteorological data (meteorology criteria)
- Effects of meteorological variability on assessment of pollution levels. How to harmonize these effects when evaluating effectiveness of long-term emission reduction measures and future pollution scenarios
- Effects on climate change on pollution transport and depositions

(*Leonor Tarrason, Anna Benedictow, Ilia Ilyin*)

10.30 Coffee break

10.45 Continuation of the discussion on meteorological issues

12.45 **Lunch**

13.40 Emissions

- Further development of the emission database (two options proposed by the meeting of the Core Bureau of the EMEP Steering Body)
- Emission data preparation for model runs, as a work-element of item “Modelling” of EMEP work-plan for 2007
- Emission compilation at finer spatial resolution then the present 50x50km.

(*Leonor Tarrason, Oleg Travnikov*)

14.40 The end of the meeting and departure.

Annex CII. PROPOSAL "Draft work-plan of agreed activities on streamlining the development of common global modeling system within EMEP"

This appendix responds to the invitation of the EMEP core Bureau from November 2006 for the EMEP chemical modelling centers to discuss the possibilities for further streamlining the work at MSC-E and MSC-W with respect to hemispheric/global modelling.

MSC-E and MSC-W welcome the recommendation from the EMEP Bureau to consider the development of a common global modelling framework that includes traditional main pollutants, particulate matter, heavy metals and POPs.

The main reason to develop a global modelling system is that many of the pollutants considered within EMEP undergo significant intercontinental transport. The increased importance of intercontinental transport and the existence of significant pollution sources in areas susceptible for inter-hemispheric transport, advise the extension of hemispheric approaches to use of global scale models instead.

After considering different alternatives for the development of such global system, the Centres recommend to streamline the existing parallel hemispheric model developments both at MSC-E and MSC-W towards a common global development. Synergies with other (global) modelling groups should be used under way, but a main focus for the next 3-5 years would be to strengthen the cooperation between the two EMEP chemical transport modelling centers.

A stepwise approach, involving the present capabilities at both centers, is suggested in the following tasks and is summarized in Table C1:

1. Unification of geographical coverage and parameters of the model domains including type of projection, spatial resolution, type of the vertical coordinate, number of vertical layers etc.

2. Unification of the input data (land-use, leaf area index, soil properties), spatial distribution of common anthropogenic emission sources, climatological data (sea surface temperature, snow cover, etc.)

3. Unification of the meteorological drivers and driving meteorological input (e.g. ECMWF meteorological analysis data).

4. Harmonization and development of physical processes modules including atmospheric advection, eddy diffusion, convection, dry and wet deposition, dust suspension, troposphere-stratosphere exchange, etc. Application of common physical and chemical modules as far as possible.

5. Unification of modeling system code with possibility of plugging different pollutant specific modules (Unification of input/output routines, identification of subroutines which needs to be rewritten, integration of modular subroutines, paralellisation and support of different platforms).

The work involved in this harmonization is time and resource demanding but can be completed in a period of 5 years, without jeopardizing the operationality of the EMEP project and securing routine results from the EMEP centers during this period. To trace progress in this task, annual joint deliverables from MSC-W and MSC-E have been identified in Table C1.

Task 1 on the unification of the physical domain of the model can be completed already in 2007. For 2008, work should be addressed both to Task 2 and Task 3 on the unification of input data and meteorological drivers.

In 2008, we expect to be able to identify an agreed input dataset for land use, soil properties, emission data, and climatological properties. These tasks have been assigned between MSC-E and MSC-W as expressed in Table C1.

Work for the unification of meteorological drivers needs to begin as soon as possible, in order to ensure an informed decision in 2009. The requirements for the selected meteorological drivers are as follow: a) the system should be capable to provide necessary set of parameters for the global scale, b) should be flexible enough to permit usage of different input data and c) should generate meteorological information with different spatial resolution (2.5˚x2.5˚, 1˚x1˚, etc.). Along with that additional features like data assimilation, nesting capabilities, availability of source code and support, possibility of selection of different parameterizations of physical processes are also considered important. Above all, the meteorological data should be easily accessible for both Centers. It is proposed that MSC-E and MSC-W will investigate possibilities of four different candidate meteorological drivers. The drivers to be implemented and tested by MSC-E are GEM from Environment Canada and PUM from the UK Met Office. The drivers to be tested by MSC-W are the IFS at ECMWF and the hemispheric WRF from US EPA. Experience on the use of these drivers is to be compiled for two years and then inform a common decision on which system should be used by the two modelling centres.

It is proposed to initiate the harmonization of physical and chemical modules and numerical techniques through a common development of an improved parametrisation of dust suspension. The work is to be initiated in 2008 with the compilation of information on soil properties and the compilation of observational data for model validation. The work is to be finalized in 2009, with a common report on an improved and validated common methodology for modelling soil emissions, tested both for HM and PM.

Further harmonization of physical processes modules and unification of common modelling system code, should proceed from 2009. MSC-E and MSC-W are willing to continue this work and coordinate their work plans up to 2012 when the common global modelling system should be fully tested and implemented.

Table C1. *Proposed work plan for the development of a common EMEP global model*

Activity	Deliverable	Period
Unification of input data ***Land-use*** – MSC-W will compile the global 0.1˚ x 0.1˚ land use from MM5 consistent as much as possible with the EMEP land-use – MSC-E will identify independent land-use sources and compare these sets if appropriate	Agreed land-use dataset	2008
Soil properties – MSC-E will start compile the global data on soil properties – MSC-W and MSC-E will start to compile soil chemical composition data for European region for validation purposes, if possible, for calcium, HMs, silicates, iron, and aluminum	Agreed soil properties dataset	2008
Other input data – Leaf area index (LAI) – Climatological data (sea surface temperature, snow cover etc.) – Spatial distribution of emission sources and population	Agreed datasets on LAI, climatological data, spatial distribution of emissions, population	2008
Unification of the meteorological driver – Common evaluation of meteorological drivers and processed meteorological data for modelling by both Centres – MSC-E will implement GEM and PUM meteorological weather prediction models – MSC-W will implement ECMWF IFS and WRF meteorological weather prediction models	Joint report on the comparison of meteorological drivers; decision for unification	2009
Harmonization of physical and chemical modules and numerical techniques – Parametrisation of dust suspension (sensitivity and validation) – Atmospheric transport (advection, diffusion, convection) – Dry and wet deposition – Troposphere-stratosphere exchange – Transpolar transport – Mass conservation filters	Joint report on improved and verified soil resuspension Agreed procedures to include parameterizations of common physical processes; agreed numerical techniques	2009
Unification of common modelling system code – Unification of input/output routines and formats – Identification of subroutines which needs to be rewritten – Integration of modular subroutines – Parallelization and support of different platforms	Common global modelling system	2010 - 2012

Annex C III. PROPOSAL
Extension of the EMEP grid to include EECCA countries

The extension of the geographical scope of EMEP in order to include Eastern Europe, Caucasus and Central Asian countries has become an important priority within the Convention. At the Steering Body session in 2006, representatives from Central Asian countries that are Parties to the CLRTAP raised the question as to when the operational EMEP results on transboundary fluxes could be presented also for Central Asian countries.

This appendix considers the requirements on the extension of the EMEP grid in order to include EECCA countries in the routine EMEP model calculations. The goal is that EECCA countries should receive information on transboundary fluxes with the same level of accuracy as other EMEP countries. A two-step approach is proposed here.

Step 1: Extension of the existing EMEP grid to the East

A first step solution could include combination of the available EMEP regional and hemispheric models. For this aim the current EMEP 50x50 km^2 grid should be extended eastward to cover EECCA countries and the hemispheric model is to be used for calculation of boundary conditions for this region. As an interim solution, the regional EMEP model could be applied for routine calculations of transboundary pollution on the extended area as tentatively indicated in Fig. C1. This solution has the advantage that it can be easily implemented. MSC-E and MSC-W would be willing to implement calculations of transboundary fluxes in the interim extended EMEP grid in their routine calculations starting from 2008. The main disadvantage is that important sources in Asia, India and the Middle East are outside the modelling domain, and only considered through boundary conditions to the hemispheric models.

Step 2: Future change of the EMEP grid projection to LONG-LAT

In the long-term, source-receptor analysis for EECCA countries should involve global simulations providing the boundary conditions to the EMEP regional domain. The development of the global model advocates for a change of projection of the EMEP grid. Instead of using the traditional polar stereographic projection, adequate for studies of transport to northern areas and the Arctic, it is proposed to change to geographical coordinates that support better global scale applications. For the future, by 2012, MSC-W proposes to change the projection of the EMEP grid to a longitude-latitude grid, with the regional domain covering a similar domain as in Step 1. A tentative extension and projection of the new EMEP domain is presented in Fig. C.2. It is at the moment an open question whether the resolution of the new EMEP calculations is still 50 x 50km^2 or if it should be more refined. MSC-Ws preference would be a finer resolution, down to 10 x 10km^2, but this is indeed a matter for future discussions.

The extension of the EMEP domain has consequences for the requirements on the compilation of official emissions. It has also consequences for the definition of the geographical scope of EMEP and the compliance with Protocols. An analysis of such consequences is beyond the purpose of this note. The EMEP Bureau is invited to consider the proposed changes in the EMEP domain, projection and resolution and forward a recommendation to the Steering Body on how to proceed further with the proposed changes in the EMEP grid.

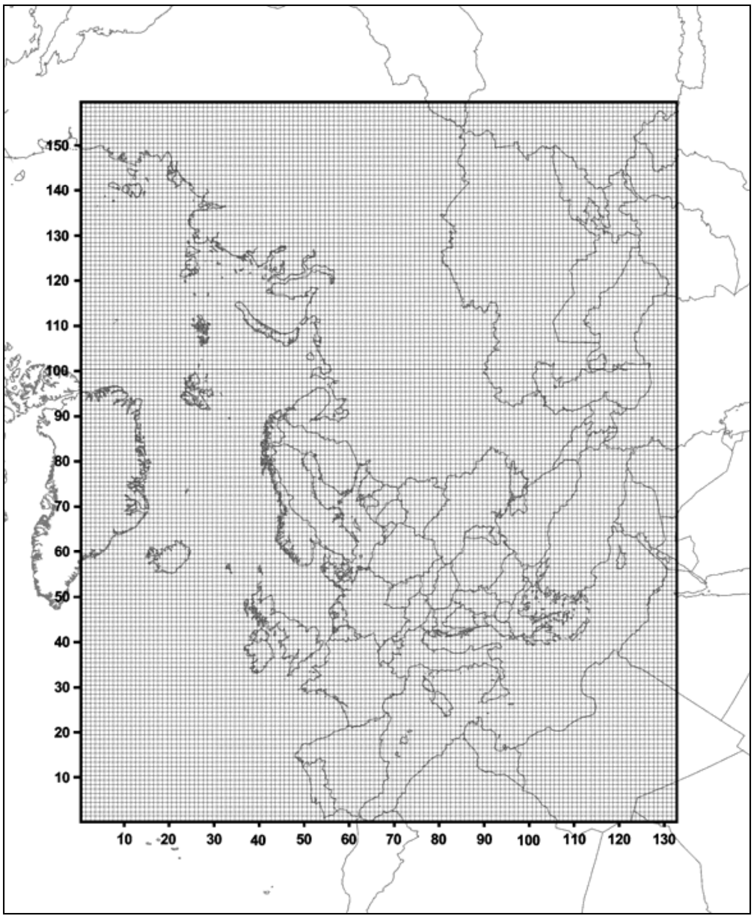

Fig. C1. *Extended EMEP 50×50 km grid (132×159 gridcells) suggested to include EECCA countries. (Step 1, operational from 2008)*

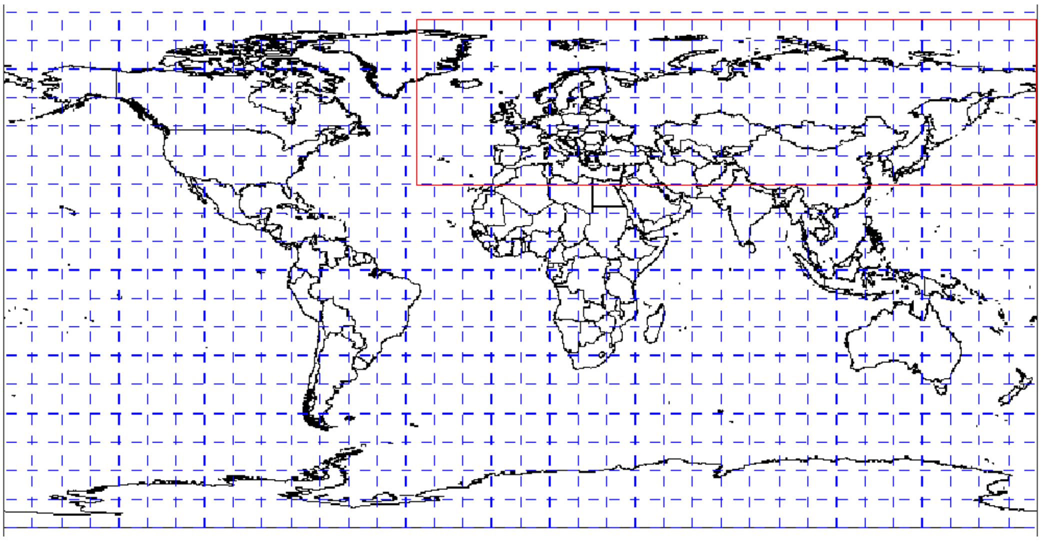

Fig. C2. *Tentative future EMEP grid in geographical LONG-LAT coordinates by 2012. The proposal in red is for the EMEP domain for routine calculations (extending from 40W, 180E - 25N, 90N). Both Centres agree that this is only a tentative proposal and needs to be further discussed*